














# SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOL. 121

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"EVERY MAN IS A VALUABLE MEMBER OF SOCIETY WHO, BY HIS OBSERVATIONS, RESEARCHES,  
AND EXPERIMENTS, PROCURES KNOWLEDGE FOR MEN"—JAMES SMITHSON

(PUBLICATION 4220)

CITY OF WASHINGTON  
PUBLISHED BY THE SMITHSONIAN INSTITUTION  
1955

The Lord Baltimore Press  
BALTIMORE, MD., U. S. A.





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LEONARD CARMICHAEL,  
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SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 121, NUMBER 1

# GEOLOGY OF THE SAN JON SITE, EASTERN NEW MEXICO

(WITH 5 PLATES)

BY

SHELDON JUDSON

University of Wisconsin



(PUBLICATION 4098)

CITY OF WASHINGTON  
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AERIAL PHOTOGRAPH OF THE SAN JON SITE. NORTH TO RIGHT.

(Soil Conservation Service photograph.)



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# GEOLOGY OF THE SAN JON SITE, EASTERN NEW MEXICO

By SHELDON JUDSON

*University of Wisconsin*

WITH 5 PLATES

## INTRODUCTION

### GENERAL STATEMENT

The study of early man in North America has made rapid strides since an unquestioned association between man and extinct animals was discovered near the small town of Folsom, N. Mex., a generation ago (Figgins, 1927; Cook, 1927). Much remains to be learned, however. There is still a wide gap, both in time and degree of cultural attainment, between the hunting Sandia-Folsom men and their contemporaries, with their finely chipped implements, and the much later pottery-making Pueblo Indians. This gap, first emphasized by Roberts (1940), begins to close as new finds come to light (Kelley, Campbell, and Lehmer, 1940; Sayles and Antevs, 1941; Bryan and Toulouse, 1943; Bryan and McCann, 1943; Haury, 1943). Unfortunately these finds are widely scattered and usually consist of a few stone implements which tell little as to the cultural attainments of the men who made them. Furthermore, these discoveries were made in soft, unconsolidated deposits whose dating by the geologic method is still incomplete. Consequently, the intermediate cultures have a status nebulous archeologically and vague chronologically.

The San Jon site seemed to present a reliable guidepost along this otherwise poorly marked road. Preliminary reconnaissance produced stone artifacts, obviously not a part of any late pottery-making culture. These were associated with the bones of bison in stratified beds lying at the headwaters of streams having obviously terraced valleys. Furthermore, the geographic location of the site held great promise, situated as it is between the relatively well-known areas bordering the southern Rocky Mountains in Colorado and New Mexico, and the great areas of still unexplained but reputedly ancient stone cultures of central and western Texas.

The geology of the site is so singular as to quicken the interest of the most hardened investigator. Nature has apparently gone out of her way to produce a fascinating and, at first glance, indecipherable puzzle. The site is located within a small depression in the Southern High Plains. This depression has been breached, drained, and dissected to depths of 100 feet, producing a geologist's delight, a soil conservationist's nightmare. In the exposed, stratified deposits lay the bones and artifacts which drew the archeologist to the site. At first glance, magnificently exposed and varied deposits augured well for the geologist. They held hope of representing a sequence of events which would add to our present highly inadequate knowledge of the late Pleistocene<sup>1</sup> history of the Southern High Plains. The incompleteness of that knowledge on the one hand and the great distance of the site from the glaciated areas of the southern Rocky Mountains on the other discounted the possibility of a direct tie to the glacial chronology. Nevertheless, the presence of beds clearly deposited under conditions more moist than now exist suggested a tentative correlation with the climatic fluctuations of late Pleistocene time.

The hopes engendered by the preliminary reconnaissance have been only imperfectly realized. Archeological investigation by the Smithsonian Institution was confined to the summer of 1941. From this preliminary and necessarily incomplete investigation Roberts (1942) obtained a sequence of faunas, some of them extinct, and associated cultures. Unfortunately, these cultures are represented by too few artifacts to be too helpful in an exact dating.

The geological work, originally planned to extend through at least three field seasons, was interrupted by World War II and subsequently reduced in scope. The results, although they do not completely fulfill the initial hopes, are by no means inconsiderable. Conclusions have been reached on the following problems: (1) The character, order, and origin of the beds at the site; (2) the correlation of this sequence along the northern edge of the Southern High Plains; (3) the origin of the "depression of the High Plains" in this locality; (4) the nature and origin of the so-called "cap rock" of the High Plains in this general vicinity; (5) the correlation of the sedimentary sequence at the site and nearby points on the High Plains with successive

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<sup>1</sup> Throughout this report the term "Pleistocene" is used in the sense suggested by Flint (1947, p. 209). In such a sense it includes all time that has elapsed since the end of the Pliocene. The terms "Recent" and "Postglacial" are abandoned as exact time designations and when used have only a local or informal connotation.



periods of erosion and alluviation in local streams of the Canadian Valley; (6) the relation of the sequence so established to climatic changes in the Southwest during late Pleistocene time; and (7) the relative and in some cases exact ages of the several cultural horizons within the sequence.

### HISTORY OF INVESTIGATION

Keith Martin, a local ranchman, first discovered the site and reported his find to the Laboratory of Anthropology at Santa Fe and to the Department of Anthropology at the University of New Mexico. Dr. Frank C. Hibben, of the University of New Mexico, with the assistance of several University students, conducted a preliminary survey of the site in the spring of 1940. Animal bones and some artifacts were found. It was soon apparent, however, that the thorough investigation demanded by the site could not be reconciled with previous and extensive archeologic commitments elsewhere assumed by the University. Therefore, after a visit to the site in August 1940 by Dr. Frank H. H. Roberts, Jr., in the company of Dr. Hibben, the University of New Mexico offered to turn over its interest in the site to the Smithsonian. The offer was accepted, and Roberts directed an archeologic investigation of the site and immediate vicinity from June 20 to September 6, 1941. Archeologic work was stopped by the war. Unfortunately, Dr. Roberts was unable to resume the investigation after the cessation of hostilities because of the additional administrative burdens imposed upon him as Director of the River Basin Surveys conducted under the administration of the Smithsonian Institution in cooperation with the National Park Service, the Corps of Engineers, and the Bureau of Reclamation.

The late Dr. Kirk Bryan, Harvard University, accompanied Hibben and Roberts on their visit to the site in 1940. During the following winter, after it had been decided to conduct extensive archeologic investigations at San Jon, arrangements were made to provide for a concurrent geologic study. Dr. Bryan and the writer made a general reconnaissance of the area during the period July 6 to 16, 1941. The writer remained on the ground until September 6, carrying forward the detailed geologic investigation. Although the war interrupted the continuance of the geologic field work, the results obtained during 1941 were checked in the field by Dr. Bryan, Dr. Franklin T. McCann, and the writer in the period from August 27 to September 11, 1943. The writer returned to the problem after the war, spending the period from June 30 to September 1, 1947, in the completion of field work.

Dr. Bryan again conferred in the field with the writer from August 10 to 15, 1947.

#### ACKNOWLEDGMENTS

The writer is under obligation to the officials of the Smithsonian Institution who authorized the project and provided funds for the field studies of 1941 and 1947. Dr. Roberts, by his continued interest and support, has been a predominating influence in this and earlier investigations of the geology of early man. The writer is particularly indebted to him for the care and skill with which he discriminated between the several geologic horizons exposed in the San Jon excavations, for his advice on problems of correlation, and for his personal interest in the progress of the geologic study. In 1941 the hospitality of the archeological camp offered optimum conditions for work. The members of the archeological party and Mrs. Roberts contributed much in making the camp a home for the geologist.

Bryan and the writer were accompanied on the brief and hurried field trip of 1942 by Dr. Franklin T. McCann. Herbert W. Dick, of the Colorado Museum of Natural History and a member of the 1941 archeological party, spent a week on needed archeologic investigation during the 1947 season and devoted considerable time and effort in the office processing the material excavated.

Many local residents contributed to the geologic work and without their aid the field problems would have been many times multiplied. Particular thanks are due to Wayne H. Miles, of the Canadian River Soil Conservation District, Tucumcari; H. W. Mutch, formerly resident engineer of the Arch Hurley Conservancy District; Halbert N. Knapp, former chief, and D. H. McLeod, of the Southwest Quay County Soil Conservation District; and Royal A. Prentice, Tucumcari. The writer expresses thanks for information and courtesies received from M. Tom Horne, Clovis, formerly postmaster at San Jon; Mr. and Mrs. James Wilson, San Jon; Mrs. Helen Anderson, San Jon; Mr. and Mrs. Frank Wilson, Wheatland; Guy Fife, Tucumcari; D. R. Burnham, U. S. Experiment Station, Tucumcari; Mr. and Mrs. Luis C. de Baca, Newkirk; Foley Griggs, Norton; and to the many other New Mexicans who added to the success and enjoyment of the field work.

The writer's wife, Anne Perrin Judson, served as field assistant during the 1947 field season and provided technical and editorial assistance in the preparation of this report.

The late Prof. Kirk Bryan, Department of Geology, Harvard University, supervised this study in field and office from its formal

inception in 1941. His many kindnesses, both professional and personal, cannot be recounted.

## PHYSICAL SETTING OF THE SAN JON SITE

### LOCATION OF THE SITE

The San Jon site is located approximately 10 miles south of the town of San Jon,<sup>2</sup> N. Mex., from which it takes its name (see fig. 1). The town is a local trading center of slightly over 400 inhabitants. It lies on the Chicago, Rock Island & Pacific Railway and U. S. Highway 66. A paved road, State Highway 39, leads south from the town 44 miles to Clovis, N. Mex., and passes within three-quarters of a mile of the site.

The town of San Jon lies at an elevation of 4,025 feet on a gently rolling plain carved by the Canadian River and its tributaries. The plain is part of a broad valley separating two great tablelands, the Central High Plains to the north and the Southern High Plains, or Llano Estacado, to the south. The town is situated in the small valley of the San Juan<sup>3</sup> Arroyo,<sup>4</sup> which flows east toward the town of Endee<sup>5</sup> before turning northeast and eventually entering the Canadian River across the State boundary in Texas. A broad ridge, 200 to 300 feet high, intervenes between the San Juan Valley and

<sup>2</sup> The word *sanjon* is an old Spanish spelling of *zanjon*, a ditch. According to local tradition there was once a pool of water in the adjacent grassy flat. Such pools were usually called *charcos* by the Spanish, but one of long and narrow form might easily be termed a ditch. Round-ups of the early cattle days centered around the now-vanished *sanjon*, which gave the modern town its name. The present spelling is an obvious error.

<sup>3</sup> The name "San Juan" for this arroyo appears on Soil Conservation Service maps and is doubtless a still further corruption of *sanjon*.

<sup>4</sup> The Spanish arriving in the New World found that some of the smaller drainageways carried live water but that the majority were grassy-bottomed draws, marked here and there by *charcos*, or stagnant pools of water. Lacking a precise descriptive term for these drainages the Spanish applied the word *arroyo*, which in their native land referred, and still does, to a small stream of running water. It is obvious that such application of *arroyo* was not entirely correct and did not accurately describe the ephemeral streams of the area at the time of Spanish settlement. By the end of the last century and the beginning of the present these same arroyos had changed their regimes and had become steep-sided, sandy-bottomed, intermittent gullies so that their present aspect is still further removed from the original meaning of *arroyo* than it was during Spanish days. Despite its etymological inappropriateness the term *arroyo* is universally retained throughout the Southwest to designate a wet-weather stream and its vertically walled channel.

<sup>5</sup> Endee is obviously a phonetic rendition of an old cattle brand "ND."

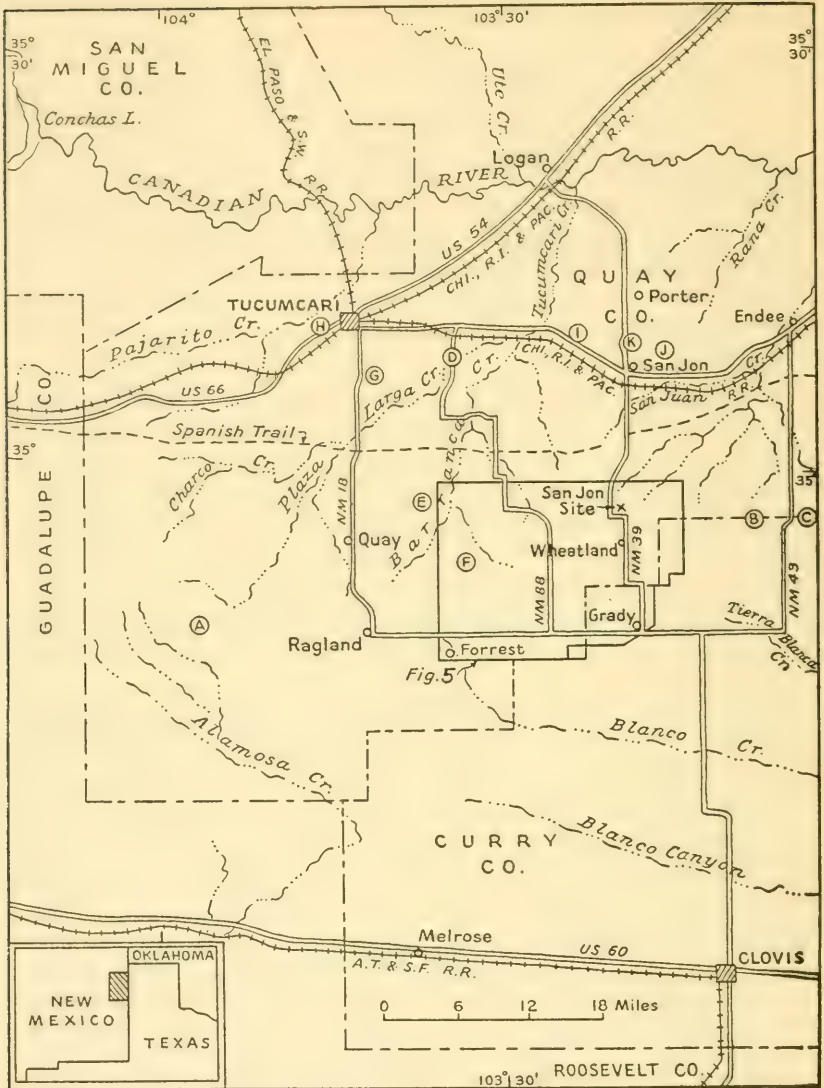


FIG. 1.—Index map of San Jon site and environs. Letters refer to localities mentioned in text.

the Canadian River to the north. South of the town the plain rises gently over a distance of 9 miles until it butts abruptly against a bold escarpment some 700 feet high forming the northern boundary of the Southern High Plains (pl. 2, fig.1). The differences in the topography, the vegetation, and the economy of the inhabitants of the High Plains and the valley are as marked as the escarpment itself. Almost on the brink of this escarpment the site occupies a position at once picturesque and strategic to the two areas, the relatively low valley plains to the north and the higher Staked Plains to the south.

### CLIMATE

This section of eastern New Mexico has a continental, semiarid climate characterized by dry winters, mid- and late-summer rainfall maxima, a marked annual variation of precipitation, a high percentage of clear, sunny days, high summer temperatures, moderately low winter temperatures, and high evaporation. Rainfall is apt to be torrential, falling too quickly to be absorbed by the soil, and thus lost by rapid run-off.

The climate is remarkably similar over a wide area, a situation directly related to the lack of local topographic control. The modern climate is directly dependent upon the great distance of the area from large water bodies capable of supplying adequate moisture, the southerly latitude, and the general uniformity of the land surface.

Summary figures of precipitation, temperature, and evaporation for selected stations within a 40-mile radius of the site are shown in table 1. Figure 2 illustrates that precipitation follows the annual march of temperatures.

### VEGETATION

Even as the climate of this section of New Mexico is transitional between desert and subhumid or humid climates, so is the vegetation transitional in character between desert and true grassland. The greater part of the area falls within the Upper Sonoran Life Zone, although a narrow reentrant exhibiting Lower Sonoran elements enters the area from Texas and extends westward up the Canadian River and along Pajarito Creek (Bailey, 1913).

In general, that part of eastern New Mexico here considered possesses a vegetative unity. There are no regionally significant changes in the distribution of plant life. Despite this unity, however, there are variations in plant geography. These are not explicable in terms

of major climatic changes but rather in terms of local differences in elevation, bed-rock geology, surface deposits of eolian material and alluvium, changes in the declivity of slopes and the position of these slopes, relative availability of water, and the recent history of land use.

Of great importance to the present study is the relation of the vegetative cover to the variations of rainfall. During years of plentiful precipitation the grasses and perennial flowers flourish in profusion and abundance. A high percentage of the ground surface is covered by plants and the top soil is well anchored by their root systems.

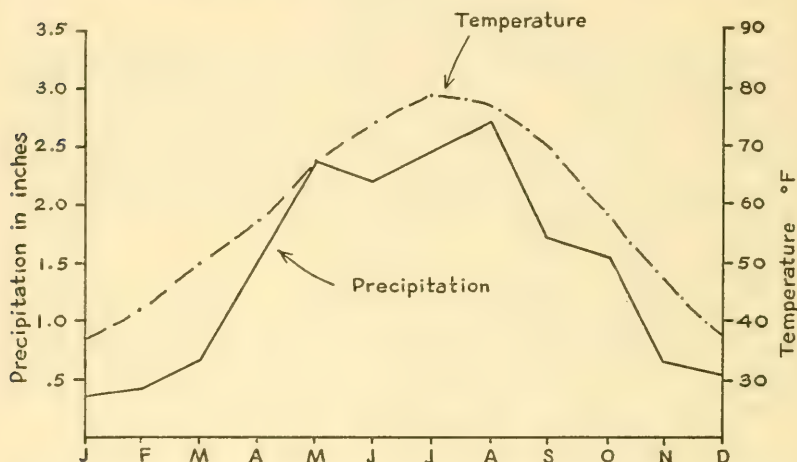


FIG. 2.—Graph showing average monthly precipitation and temperatures recorded from stations at San Jon, Tucumcari, Logan, and Clovis.

Gullyng, sheet wash, and deflation are arrested by this protective mat of plants. Erosion is at a minimum. During a dry year, or a succession of dry years, deficiency of moisture reduces the percentage of plant cover. Bare patches between individual plants or small groups of plants increase in area. The plants become increasingly less effective in protecting the ground surface from erosion by wind and water. It is during such periods that gullyng is initiated. At the same time sand sources are bared to the incessant winds and wind erosion commences. Concurrently with deflation of source areas of sand an already weakened vegetation in other areas is smothered beneath a blanket of wind-moved material. Thus does the intimate relation between rainfall and vegetation contribute to successive periods of stability and instability of the surficial deposits.

TABLE I.—Climatological data summarized from selected stations in Quay and Curry Counties, eastern New Mexico

Station	Yrs.	Precipitation in inches												Total	Percent Apr.-Oct.
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.		
San Jon	..... 39	0.29	0.32	0.55	1.26	2.24	2.13	2.36	2.82	1.39	1.56	0.61	0.58	16.11	85
Tucumcari	... 41	0.30	0.46	0.71	1.40	2.39	1.97	2.31	2.72	1.55	1.40	0.74	0.63	16.58	83
Porter	..... 21	0.22	0.45	0.82	1.07	2.58	2.12	2.15	2.80	1.37	2.18	0.87	0.70	17.33	82
Logan	..... 39	0.28	0.47	0.66	1.51	2.25	2.14	2.56	2.29	1.62	1.39	0.65	0.54	16.36	84
Quay	..... 22	0.28	0.41	0.66	0.80	2.33	1.59	1.91	2.48	1.48	1.71	0.73	0.66	15.04	81
Ragland	..... 10	0.52	0.51	0.66	1.24	3.33	2.60	2.12	2.71	2.87	1.68	0.54	0.88	19.66	84
Melrose	..... 38	0.35	0.38	0.77	1.34	2.03	2.02	2.27	2.81	1.96	1.46	0.62	0.65	16.66	83
Clovis	..... 35	0.35	0.41	0.69	1.39	2.47	2.72	2.44	2.94	2.36	1.83	0.51	0.60	18.71	85

## Temperature in degrees Fahrenheit

Station	Yrs.	Temperature in degrees Fahrenheit												Total	Mean
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.		
San Jon	..... 38	37.4	41.4	48.0	56.6	65.1	74.5	78.5	76.9	70.6	59.3	46.2	37.2	57.6	
Tucumcari	... 41	37.1	41.2	48.5	56.8	65.3	75.2	78.6	77.5	70.8	59.2	46.8	38.1	58.0	
Logan	..... 36	36.7	40.0	56.0	56.0	64.7	74.4	78.8	76.8	70.3	57.8	45.4	36.3	57.5	
Clovis	..... 34	37.0	41.6	47.1	57.0	66.0	75.1	79.0	77.3	69.9	59.0	47.0	38.1	57.8	

## Evaporation in inches

Station	Yrs.	Evaporation in inches						Total
		Apr.	May	June	July	Aug.	Sept.	
Tucumcari	... 36	7.073	9.309	10.697	10.839	9.554	7.242	55.314

## GENERAL GEOLOGY

### PHYSIOGRAPHIC DIVISIONS OF EASTERN NEW MEXICO

Eastern New Mexico lies largely in the Great Plains Province (Fenneman, 1931). The San Jon site is located in the High Plains section, a major subdivision of the Great Plains Province, which is itself divisible into three units stretching from South Dakota to Texas and here referred to as the Northern, Central, and Southern High Plains.

The San Jon site lies along the northern escarpment of the Southern High Plains or Llano Estacado (Staked Plains). This plain has a regional slope to the southeast. To the north the Southern High Plains are separated from the Central High Plains by a series of buttes and mesas, outliers of the Plain, and by the broad but lower Valley Plains of the Canadian River into which the Canadian River has incised the present canyon. Figure 3 shows the major physiographic features of the area.

### ROCKS OF THE AREA

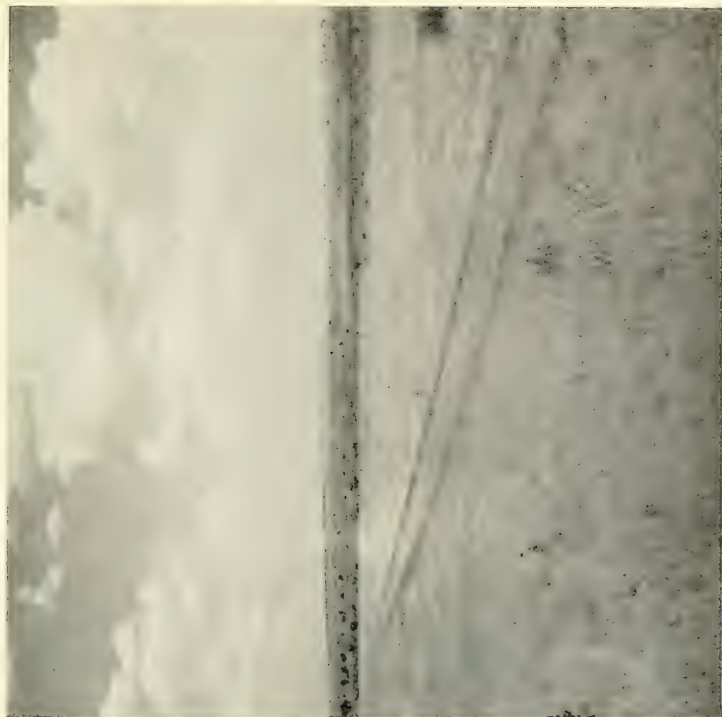
The general geology of the area is recorded in a geologic column involving pre-Cambrian, Upper Paleozoic, Mesozoic, and Cenozoic rocks. Beginning with the Paleozoic these rocks are exclusively sedimentary and flat-lying. The character, thickness, and position of these rocks determine in large measure the main topographic features and are critical in all minor features. The Pleistocene and, to some extent, the Pliocene deposits are discussed in detail in this report. For a detailed consideration of older rocks the reader is referred to Darton (1922), Bates (1946), and Dobrovolsky and Summerson (1946).

## GEOLOGY OF THE SAN JON SITE

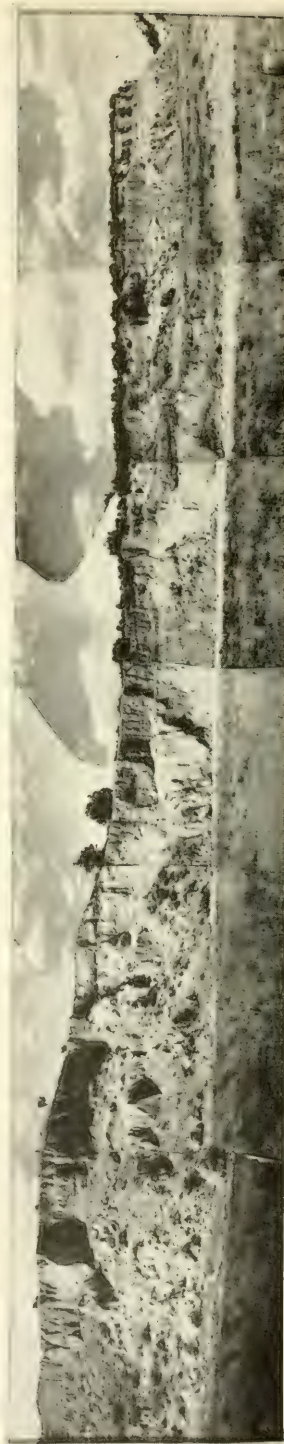
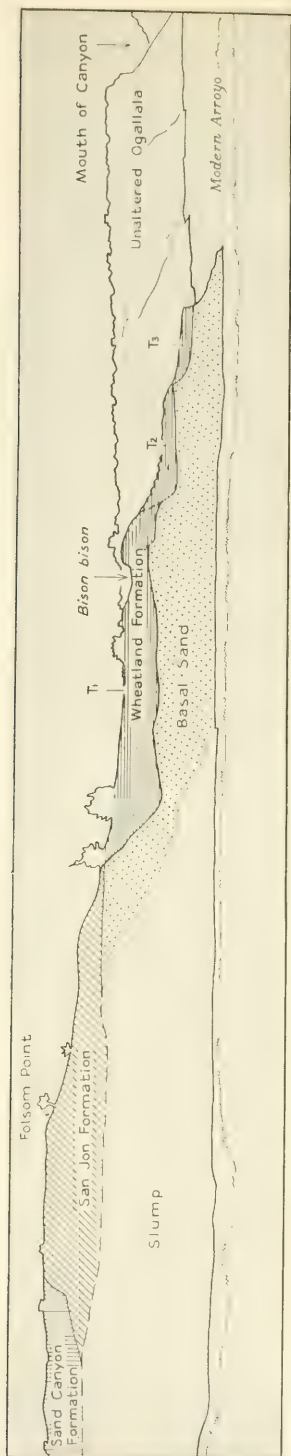
### GENERAL STATEMENT

Viewed from the surface of the High Plains the San Jon site lies in a broad, shallow depression over a mile in diameter. The gentle slopes of this depression are scarcely perceptible at first glance, particularly if one comes upon it from the north over the rugged relief of the "breaks" below the escarpment (pl. 2, fig. 2). The rim of depression is almost featureless, although a broad, low hill east of the site rises slightly above the general level of the plains. To the south and west lie plowed fields. The site and the slopes immediately ad-





Figs. 1 (left) : View looking east along the northern escarpment of the Southern High Plains from the vicinity of the San Jon site.  
Fig. 2 : (right) : View looking east across the depression containing the San Jon site.



Photographic panorama and landscape sketch showing relation of late Pleistocene formations to the Basal Sand at the San Jon site. T<sub>1</sub>, etc., indicates terraces of Wheatland age. For location see figure 4.

joining it are in grassy pasture land and the edge of the escarpment is fringed with piñon, juniper, and low-growing bushes.

In the center of this shallow bowl a crow's-foot pattern of arroyos 50 to 100 feet in depth has been fashioned (frontispiece and fig. 4). The three major toes of the pattern point south, southwest, and west.



FIG. 3.—Physiographic map of a portion of eastern New Mexico.

These converge to form a single drainage, Sand Canyon Arroyo, which flows northeast through a deep narrow canyon. This canyon pierces the escarpment and the arroyo descends to the Valley Plains of the Canadian and hence via the San Juan Arroyo to the Canadian River. The dissected portion of the depression is almost completely contained within an area one-half mile in diameter. Considered in a broad way this depression is one of several depressions lying in a groove in the High Plains as discussed below.

## ORIGIN OF THE SAN JON DEPRESSION

The dissected depression which contains the San Jon site is one of several depressions lying in a broad, shallow groove in the High Plains as shown in figure 5. Figure 5 shows also that there are other grooves in the Plains to the south and that these also contain depressions of varying size. These depressions, which range from a few feet across to well over a mile in diameter and from a few inches to over 50 feet in depth, are characteristic of much of the High Plains surface.

It was necessary to determine the age and origin of these depressions because the artifact-bearing beds of the San Jon site are involved in one of these depressions which has been breached by the retreating scarp of the High Plains.








A study of the depressions, breached and unbreached, shows that in this section of the High Plains the depressions are the result of alternate periods of leaching and wind deflation (Judson, 1950). During wet periods of the Pleistocene the calcareous cement of the Pliocene Ogallala formation which covers the High Plains was locally destroyed by downward-percolating ground water. During succeeding dry periods these locally leached areas suffered wind deflation. In many places sand hills resulting from this deflation are found to the east of the depressions (fig. 5). Figure 6 suggests the relation of form and process to the periods of aridity and moisture and indicates some of the variations in form which might be expected.


As noted above, the depressions are located along broad, shallow troughs. These troughs involve, in a way which is as yet imperfectly understood, the "cap rock" of the Plains, that limestone crust at the top of the Ogallala formation or above it. Certainly, however, the depressions are not due to true collapse into the underground although some collapse depressions are known from the area (fig. 1, A; Judson, 1950).


The initiation and expansion of the depressions form a feature of the Pleistocene but cannot be confined to any specific horizon of the Pleistocene. It is entirely reasonable that depressions have been forming on the Plains since the end of the Pliocene. Some have ceased to grow and have become so choked that there may be little recognizable surface expression. Were the surficial cover stripped from the Plains, the resulting surface would be literally pock-marked with the open scars of modern depressions and the healed or partially


MAP  
OF THE  
**SAN JON SITE**  
EASTERN NEW MEXICO

EXPLANATION


-  Pleistocene (Undifferentiated)
-  "Pliocene Cap Rock"
-  Ogallala Formation Pliocene (Unleached)
-  Purgatoire Formation Lower Cretaceous
-  Chinle Formation Triassic
-  Contact of Leached and Unleached Ogallala
-  Dashed line indicates inferred contact


 Location of Geologic Sections

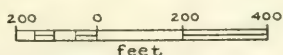
 AREA I Location of Areas of Archeologic Excavations

 Location of Photographs

 Fence line

 Intermittent stream

 Extent of Gully



Topographic Control From Survey by ROBERT H. MERRILL, 1941

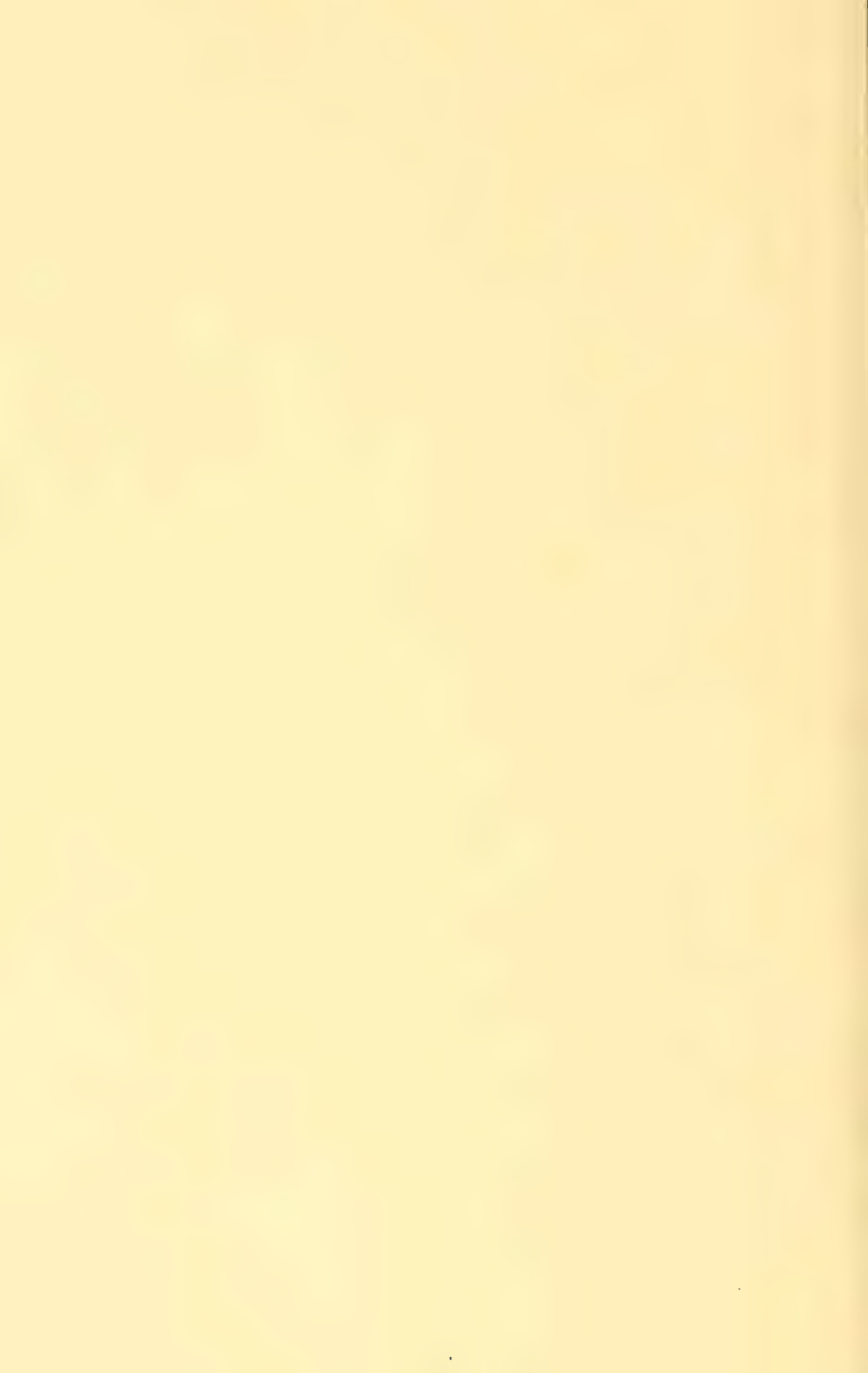


Text L.



Miles

in the vicinity of



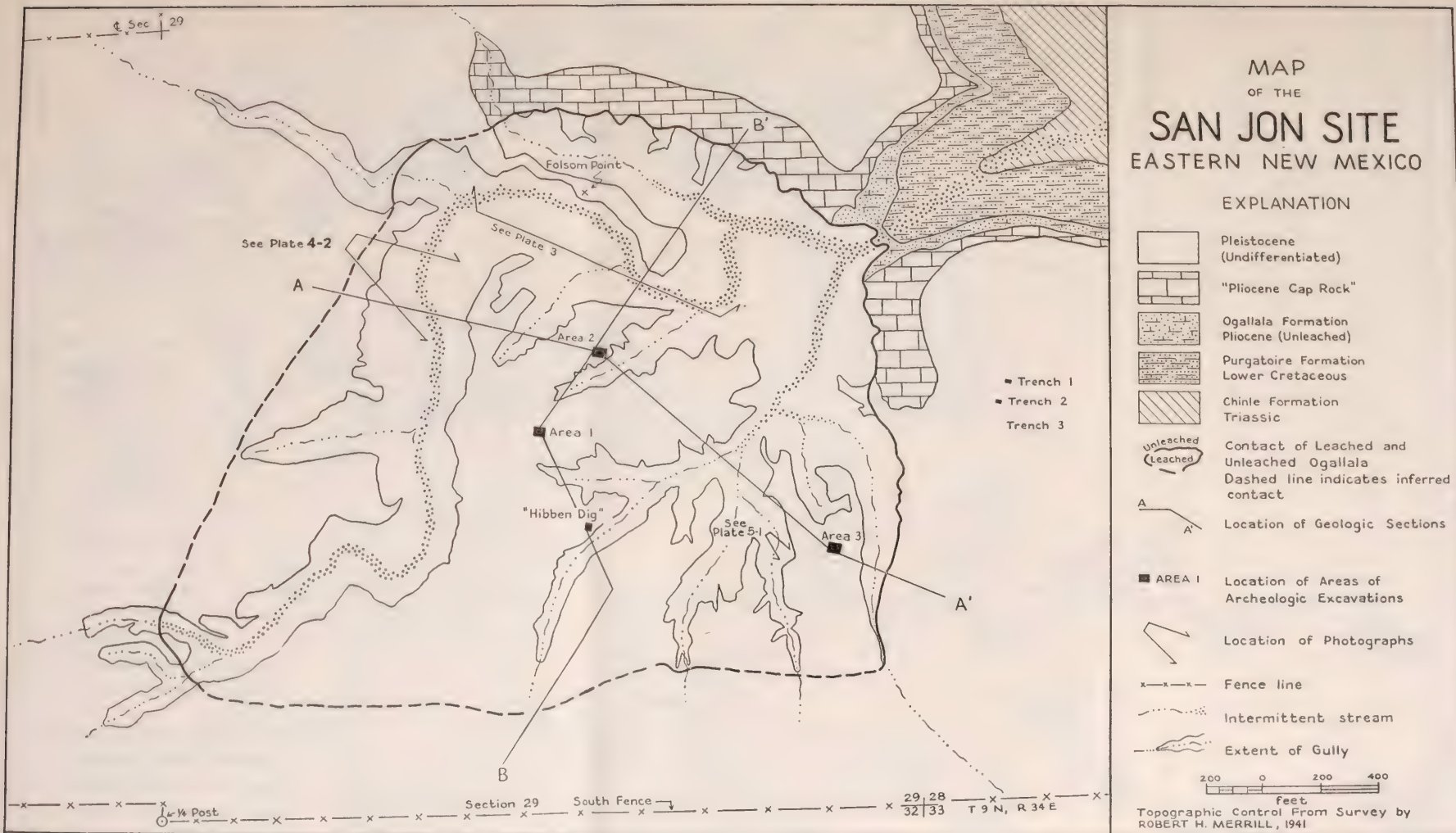
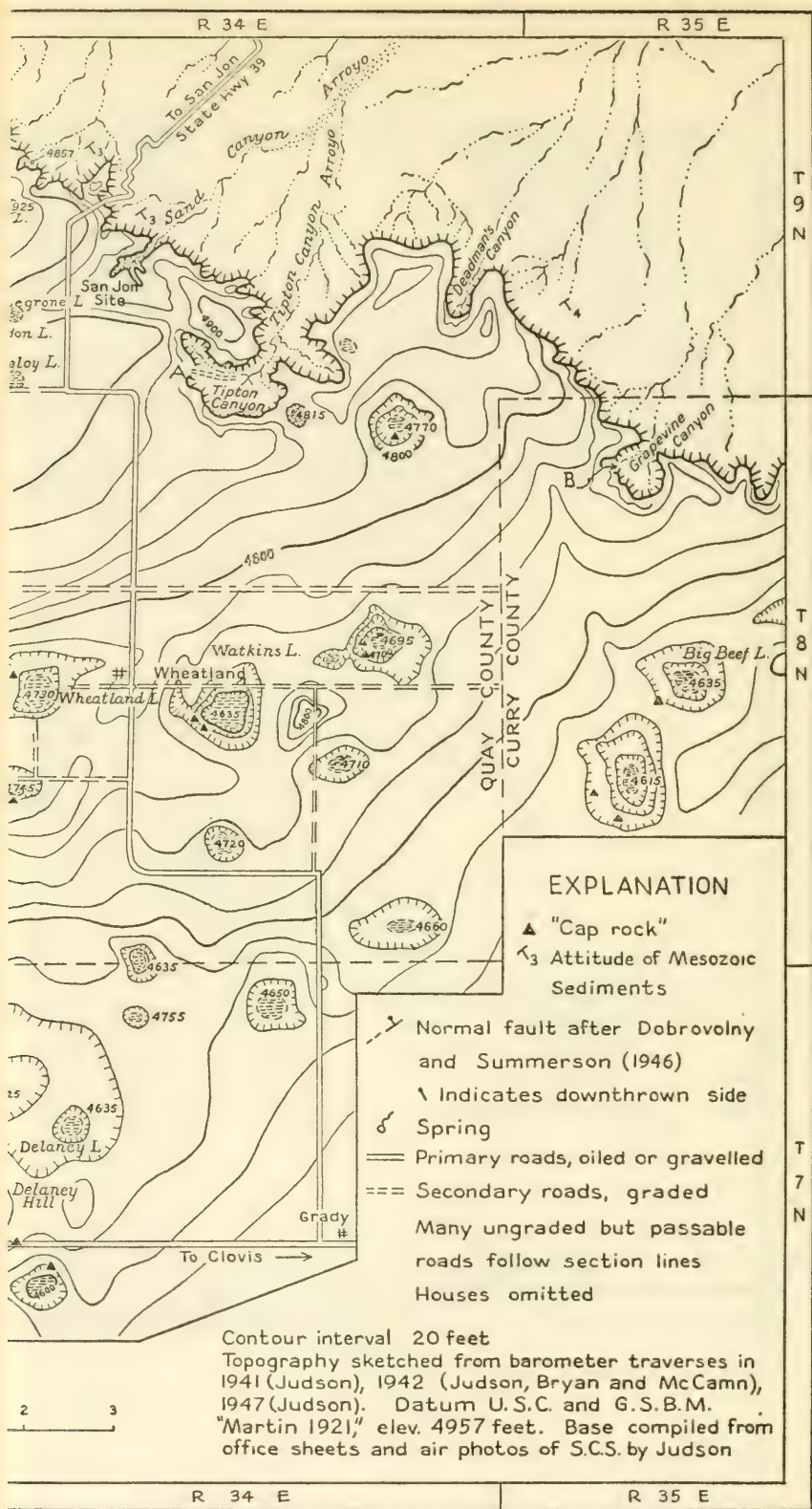


FIG. 4.—Map of the San Jon site showing location of geologic sections, photographs, and archeological excavations.



f the San Jon site.



healed scars of "extinct" depressions. The depression is characteristic not only of the Plains of the present but also of the past back to the beginning of the Pleistocene.

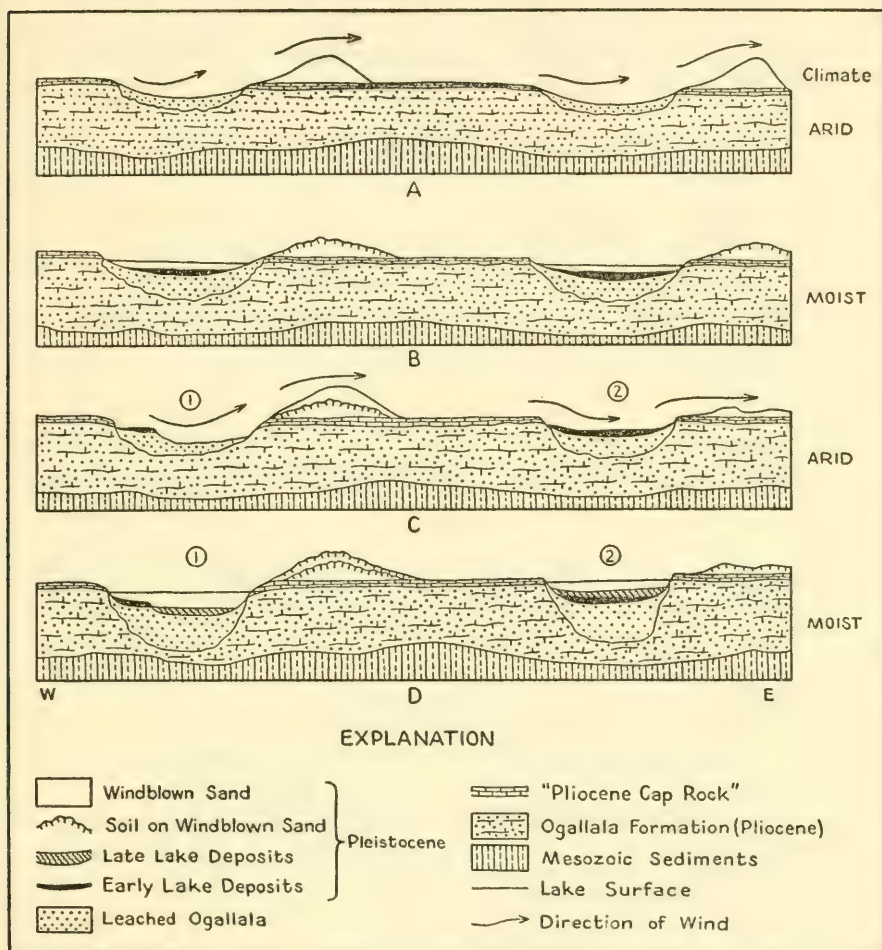


FIG. 6.—Schematic diagram to illustrate the relation of process and form to climate in the development of depressions.

#### DEPOSITS OF THE SAN JON SITE

The deep arroyos of the site expose a series of beds of pond and alluvial origin. They lie within and upon the rocks which form the support of the High Plains. It is obvious that the narrow canyon has been cut back into the depression which it now drains. The top of



FIG. 5.—Map of the Southern High Plains in the vicinity of the San Jon site.



the escarpment is formed by Pliocene beds composed largely of white to buff calcareous sandstone with a limy plate, the "cap rock," at the top. The Pliocene can be traced almost completely around the site in a somewhat asymmetrical loop as indicated in figure 4. Within this loop and overlapping it, particularly to the south, rest the beds involved in the archeological excavations. They are summarized as follows and discussed in more detail later on.

## SUMMARY OF THE BEDS EXPOSED AT THE SAN JON SITE

	Feet
Modern deposits of the arroyos.....	0 to 10
Periodically moved by flood.	
——disconformity——	
Wheatland formation .....	5 to 15
<i>Low Terrace</i> . Base 1 to 5 feet above grade of arroyos. Fine gravel, sand and silt.	
——disconformity——	
<i>Intermediate Terrace</i> .....	5 to 15
Base 8 to 10 feet above grade of arroyos. Materials as above.	
——disconformity——	
<i>High Terrace</i> .....	10 to 15
Base 20 to 25 feet above grade of arroyos. Materials as above. Contains bones of <i>Bison bison</i> . No artifacts found.	
——disconformity——	
Sand Canyon formation.....	0 to 50
Reddish to reddish-brown alluvium. Alternating beds of sand and clayey-humic material. Contains numerous iron-manganese nodules averaging $\frac{1}{4}$ inch in diameter. Lime occurs as tubules and as films particularly along joints in the clayey horizons. Occurs in broad channels cut into underlying formations 40 to 50 feet above grade of modern arroyos. Contains artifacts ("Collateral" Yuma and Clear Fork (?)), bones of <i>Bison bison</i> , and the planorbid <i>Helisoma tenue sinuosum</i> (Bonnet), a modern mollusk common in the area.	
——disconformity——	
San Jon formation.....	0 to 50
<i>Zone 3</i> .....	0 to 45
Dark blue-gray clay grading laterally into greenish clay and into reddish compact sandy alluvium toward the borders of the basin. Contains nodules and plates of iron-manganese oxide and concretions and plates of calcite. Lime plates occur on laminations and on strong vertical jointing. Bones of extinct bison and artifacts are found in top of the blue clay as in the planorbid <i>Helisoma tenue sinuosum</i> (Bonnet).	

<i>Zone 2</i> .....	0 to 1.5
Discontinuous lenses of fine gray-white volcanic ash.	
<i>Zone 1</i> .....	0 to 3
Crust of iron-manganese oxides, 0 to 3 feet thick overlain by bleached white sand with clay lenses 0 to 4 feet thick; grades toward periphery of basin into reddish laminated clay 5 to 8 feet thick with green clay seams in joints. This in turn grades into reddish alluvium. Proboscidian and bison bones in the clay facies.	

——disconformity——

Basal Sand (decalcified Ogallala) .....	40 to 50
Upper zone, 5 to 10 feet thick, has vertical, columnar jointing. Calcareous concretions and iron-manganese flecks and clay-filled cracks. Lower zone, 35 to 40 feet thick, is a brown to buff sand without laminations. It contains vertical joints. Near the base it has calcareous concretions. In most places it is separated from the unchanged Ogallala formation by vertical contacts.	

——angular unconformity (hidden)——

Lower Cretaceous shale and sandstone.

Cross sections of these beds along general east-west and north-south lines and more detailed sections in the areas of actual archeologic excavation are presented in figures 7 and 8, respectively.<sup>6</sup> The photographic panorama and accompanying outline sketch in plate 3 illustrate the complexity of the deposits and their relations to one another,

#### BASAL SAND

The Basal Sand rests unconformably on the Purgatoire formation of Lower Cretaceous age. The nature of the contact, nowhere exposed at the site, is inferred from the position of the Purgatoire in the canyon draining the depression in which the site is located. Here the top of the Cretaceous has an elevation of approximately 4,700 feet and is overlain by a cemented and resistant bed 8 feet thick composed of boulders, cobbles, and gravel forming the base of the Ogallala formation. This basal Pliocene conglomerate forms the lip of a falls some 15 feet in height. The upper limit of the Cretaceous

<sup>6</sup> Geologic sections offer the most effective method of illustrating the geologic sequence. Areal mapping of the deposits proved unsatisfactory because of the difficulty in delimiting the deposits in plan and because of the large percentage of outcrops confined to vertical or near-vertical cliffs. The original sections were made in the field on a horizontal scale of 1 inch to 100 feet and a vertical scale of 1 inch to 20 feet. Basic topographic control was obtained from a 1941 survey by Robert H. Merrill. Secondary control was developed with a hand level and used primarily for the location of contacts.

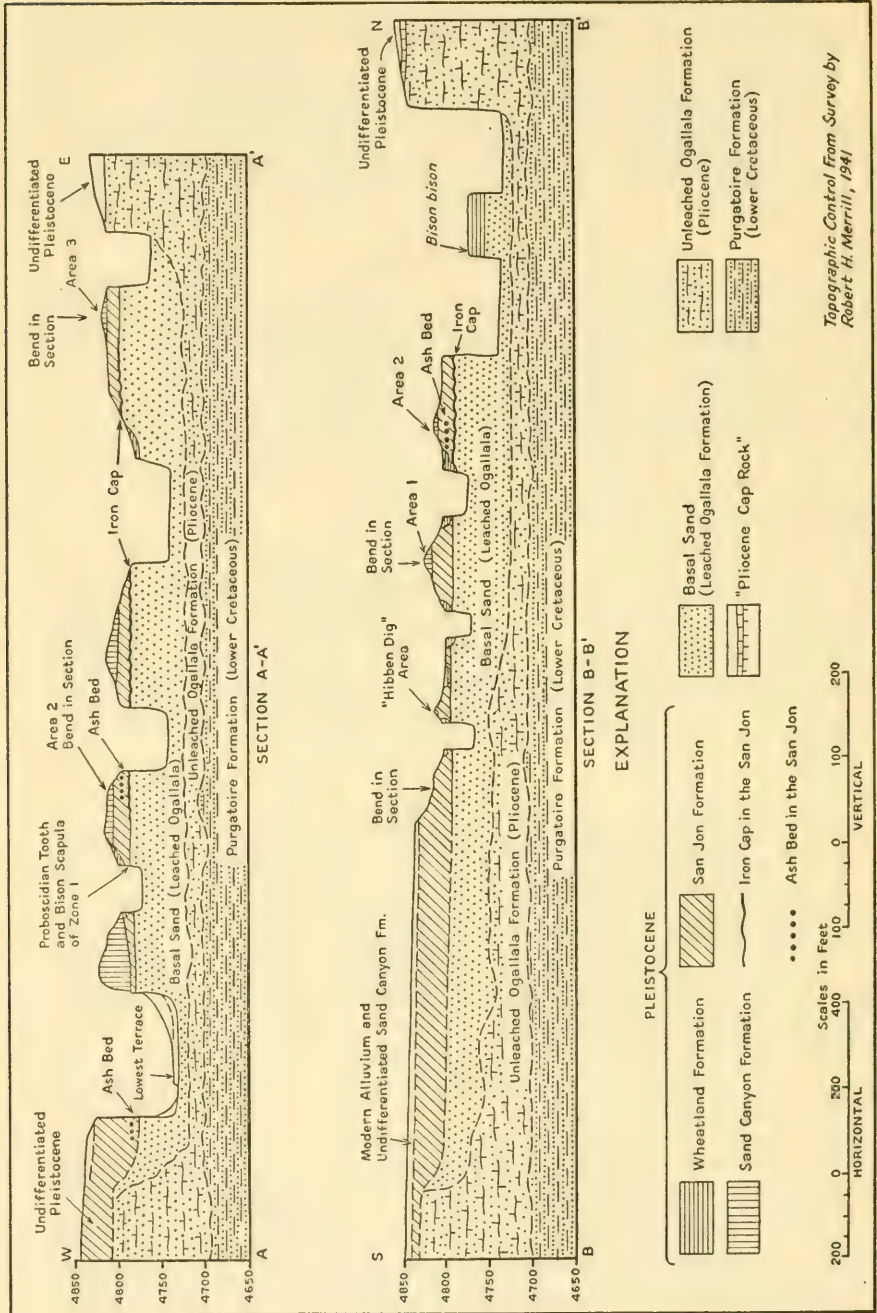


Fig. 7.—General geologic sections of the San Jon site. For locations see figure 4.

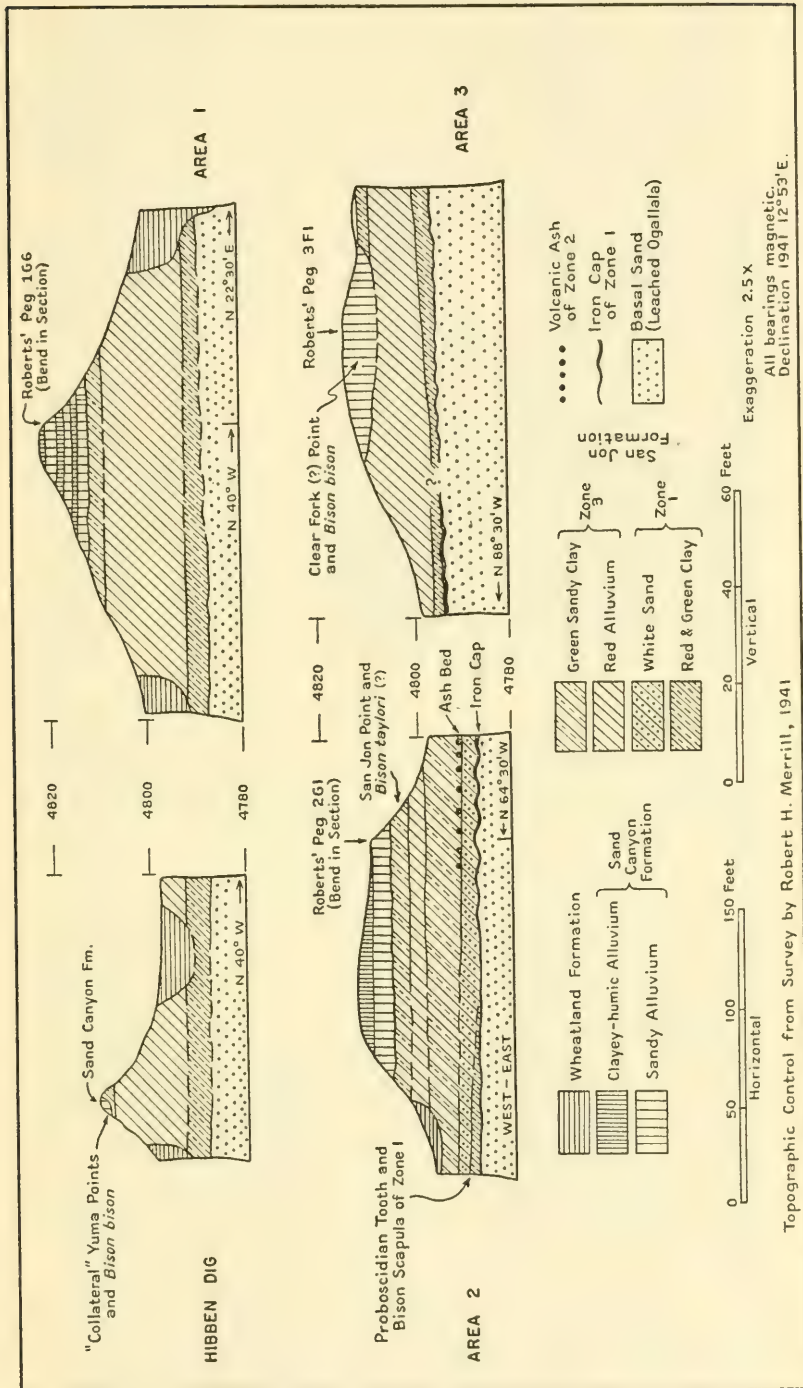


FIG. 8.—Geologic sections of areas of archeologic excavation at the San Jon site. For locations see figures 4 and 7.

in the profiles of figure 7 is shown as an irregular but essentially horizontal plane projected into the basin from the top of the Cretaceous in this falls. Patches of the basal Ogallala conglomerate similar to that at the falls may very well be present between the Basal Sand and the Cretaceous within the basin, but this possibility is not indicated in the sections.

The Basal Sand is contained within near-vertical walls of the calcareous Ogallala formation. Its friable nature and relatively even grade size suggests an eolian origin. However, a careful examination of the deposit both at the San Jon site and at other breached depressions along the northern escarpment of the Llano Estacado has shown that it is decalcified Ogallala formation (Judson, 1950). Plate 4, figure 1, shows the relation of this residuum, the Basal Sand, to as yet unaltered Ogallala formation. It was the partial deflation of this Basal Sand that created the original depression in which were laid down the deposits at the San Jon site.

The upper part of the Basal Sand is of most immediate interest. It is whitish and free of the diffused iron oxide that gives the brown color to the rest of the sand. There is a strong vertical jointing. Calcareous concretions and iron-manganese flecks occur. There are also clay-filled cracks which cut across and are obviously later than jointing and concretions. Below this zone there are bands of limonite stain. All the phenomena represent changes brought about in the Basal Sand by action begun at its upper and eroded surface. They are connected with, and the result of, processes that produced the overlying beds.

#### SAN JON FORMATION <sup>7</sup>

The San Jon formation rests on the nearly horizontal but slightly irregular top of the Basal Sand. Its thickness is controlled by the basin in which it was deposited and by the extent of subsequent erosion. The deepest part of the depositional basin was to the north nearer to the head of the present canyon than to the southern edge of the basin. At the end of San Jon time the thickest part of the deposit in the depression was at the lowest part of the basin. Later erosion, however, has reduced the original thickness, and it is probable that a complete and uneroded section is not encountered except in the southern portion of the basin. At places near the center of the basin where the original thickness is best preserved the formation is over

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<sup>7</sup> The name "San Jon formation" is here proposed to include those strata hereinafter described. It derives its name from the San Jon site and exposures there developed are considered to represent the type exposures.



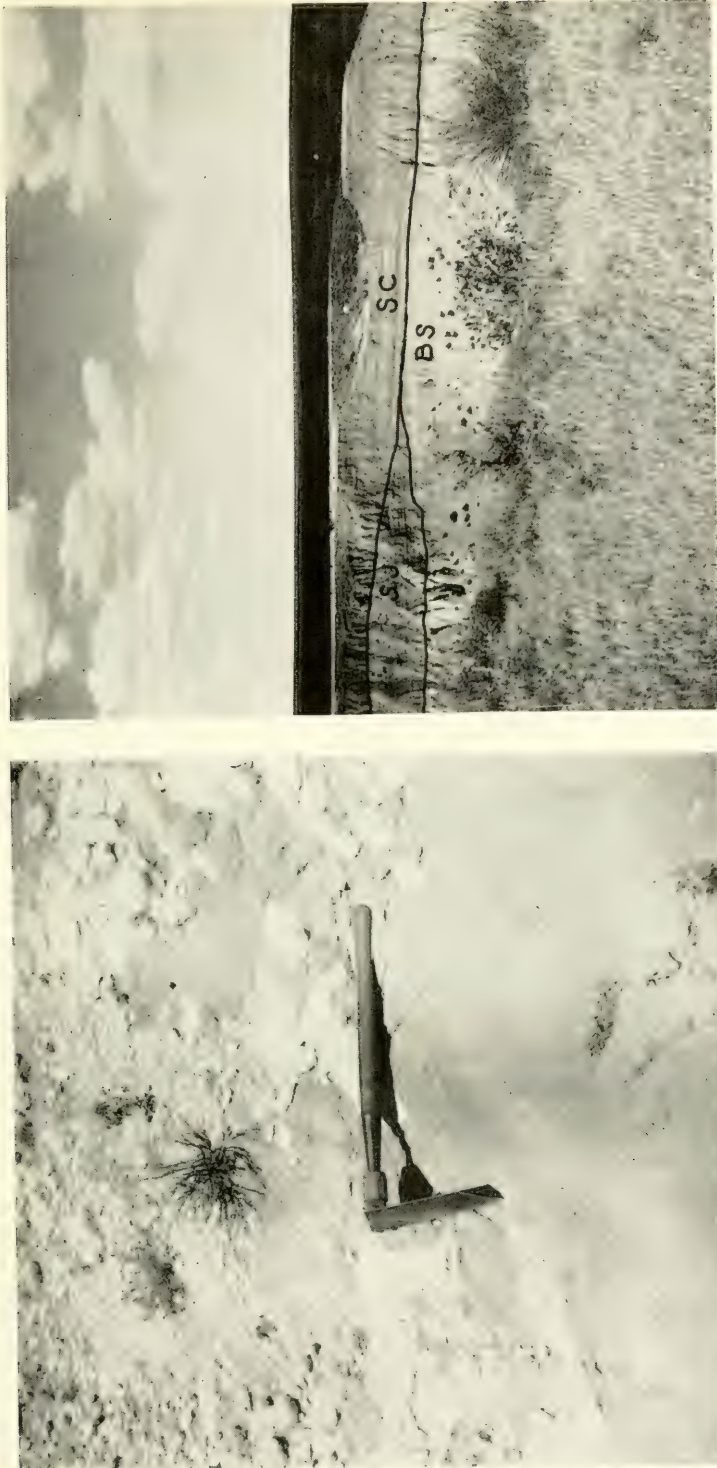


Fig. 1 (left): Leached (gray) and unleached (white) Ogallala formation at Tipton Canyon. Fig. 2 (right): Sand Canyon formation (SC) filling broad channel in the San Jon formation (Sj) at the San Jon site. BS indicates Basal Sand. For location see figure 4.

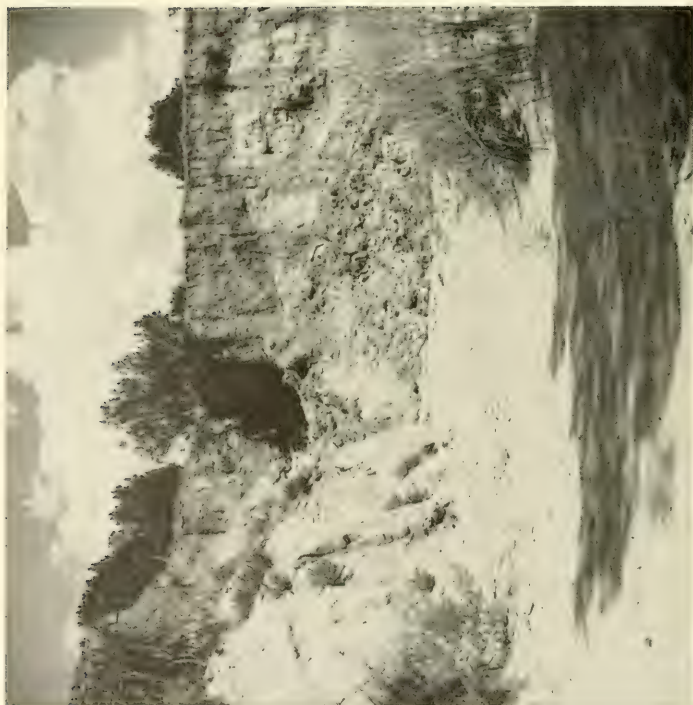
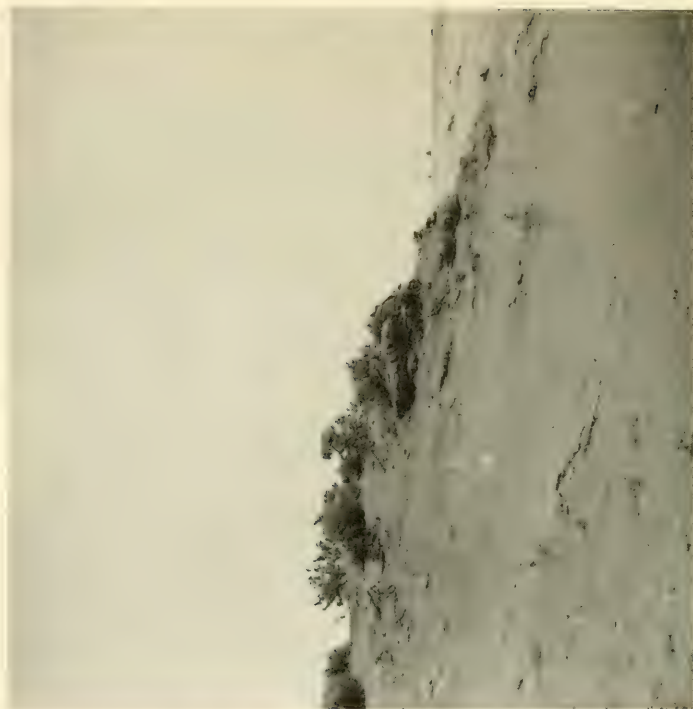


Fig. 1. (left) : Highest terrace deposits of the Wheatland formation filling channel cut in Basal Sand at the San Jon site. For location see figure 4. Fig. 2 (right) : Small cliff formed by soil developed at top of old wind-blown sand and covered by modern-blown sand. (K, fig. 1.)

40 feet thick. The equivalent reddish alluvium to the south may be somewhat thicker. Although exposures do not exist because the modern arroyos do not cut to the extreme southern edges of the basin, the San Jon formation presumably thins to nothing in this direction.

Near the center of the depression the first deposit of zone 1 is a layer of limonite and manganese oxide. It varies from a paper-thin film to a crust of botryoidal, crystalline iron-manganese oxide 2 to 6 inches thick but in a few places reaches 3 feet in thickness. Over it lies a bleached gray-white sand with layers of red and green clay at the top. This zone is in places 4 feet thick but elsewhere is missing. Laterally to the south the crust and the bleached sand grade into, and are replaced by, 5 to 8 feet of reddish laminated clay and silt. This zone is stained to a greenish tint by green clay films which occupy strong vertical joints in the clay, and near the center of the basin penetrate downward from the top of the clay into the Basal Sand. Fragments of proboscidian teeth and a bison scapula have been taken from the top of these laminated clays at a locality in the first gulch west of area 2. (See profile A-A', fig. 7, and profile of area 2, fig. 8.) Toward the south these laminated clays grade in turn into a compact reddish alluvium with clay zones.

Near and at the top of the clay are discontinuous bodies of fine gray-white tuff which constitute zone 2 of the San Jon formation. Where present this tuff zone is a distinctive horizon. It is composed of minute fragments ranging in size from 0.005 mm. to 0.15 mm. in diameter. There is no apparent uniformity in the shape of the individual shards. Some are the angular fragments of shattered vesicle walls; others are lathlike in shape, and still others are vesicular. Approximately 95 percent or more of the tuff is made up of a glass having an index of about 1.500. Small phenocrysts and some isolated crystal fragments of orthoclase and, to a lesser extent, of sodic feldspar and quartz constitute the balance of the ash. Some finely disseminated calcite and some iron staining has been introduced after the deposition of the tuff. Other bodies of tuff are known in the region and are mentioned in subsequent pages.

Swineford and Frye (1946) distinguish between the Pliocene and Pleistocene volcanic-ash beds of western Kansas on stratigraphic position as well as on the optical and physical properties of the individual shards. The bulk of the Pleistocene ash deposits described by them is assigned to the Pearlette ash, which occurs in discontinuous beds from western Texas to Iowa in deposits of late Kansan and Yarmouthian age (Frye, Swineford, and Leonard, 1948). Although the

ash at the San Jon site exhibits petrographic similarities to the Pearl-ette ash its stratigraphic position indicates it to be late Pleistocene in age. The nature of the phenocrysts within the San Jon ash may eventually serve to distinguish it petrographically from the mid-Pleistocene Pearllette ash.

The limonite crust appears to have been deposited in an open body of water in which its botryoidal top could freely form. The laminated clay is also a deposit of standing water. It is presumable, therefore, that zone 1 of the San Jon formation was deposited in a fairly deep pond. The clay settled out on the southerly portion of the bottom of this pond, whereas the central portion was relatively free of silt and here chemical precipitation of limonite took place.

Limonite is commonly deposited in waters that are slightly acid in reaction by the intervention of the iron bacteria, nonspecific bacteria, and other microorganisms (Starkey, 1945). The acid reaction arises by reason of decaying vegetation and most of such deposits are in lakes or swamps in cool temperate climates. The mere presence of a permanent pond in this region in a watershed as small as that involved implies a climate somewhat cooler and moister than that of the present. Toward the close of deposition of the red-green clays this water body dried up, presumably more than once, and the deep cracks were formed. Clay was washed into the cracks. The cracks extend into the Basal Sand previously described and near the center of the basin the Basal Sand is lime-bearing and has a vertical columnar structure. These phenomena seem to be related to the presence of the pond and to its subsequent drying toward the end of deposition of zone 2. As this was presumably a slow process it is inferred that the pond formed and reformed.

The discontinuous small bodies of tuff came in at this time. This fine volcanic ash was derived from an ash shower of a distant volcano. Within the basin its thickness ranges from paper thinness to 1.5 feet. Elsewhere in the region bodies of tuff of similar character and presumably due to the same ash fall reach 4 to 12 feet in thickness. If at the time of the ash shower the tuff at the site was thicker and more continuous than now, it has been eroded and carried away by the wind during the periodic drying-up of the pond.

Above the volcanic-ash horizon and near the center of the basin, zone 3 is a hard, compact, columnar-jointed, blue clay which passes laterally into a sandy, greenish clay. Both the blue and green clays grade upward and laterally into a reddish sand, which is also silty, compact, and vertically jointed, containing here and there clayey beds. Southward from the center of the basin red and green clays or reddish

alluvium make up both zones 1 and 3 and are indistinguishable unless separated by lenses of the tuff which constitutes zone 2.

Rounded iron-manganese nodules averaging one-quarter of an inch in diameter are common throughout zone 3 and in the clayey and silty portions of zone 1. They are hard, pitted pellets where exposed to the air but slightly softer on fresh exposure. Calcite concretions and plates are also characteristic of the same horizons. The plates occupy vertical joints and horizontal bedding planes. Within the clay and alluvium and lying between the bedding planes and in the joint system are roughly round concretions ranging from one-eighth to one-half inch in diameter. In places the calcite penetrates cracks and breaks in the iron-manganese pellets and plates. Thus the calcite is obviously later in time than the iron manganese. Both the calcite plates and concretions are hard and when broken with the hammer exhibit a fibrous structure. The large amount of calcite and its hardness is a distinguishing feature of the San Jon formation. Shells of *Helisoma tenue sinuosum* (Bonnet) are common.

The San Jon formation was laid down in a pond that became increasingly smaller until it had dried completely, except in its central portion where the blue clays were probably always wet during the period of deposition. The iron-manganese oxides were presumably precipitated when the pond was relatively deep. The calcite was deposited at a later date.

#### SAND CANYON FORMATION <sup>8</sup>

The Sand Canyon formation overlies the San Jon formation unconformably. It lies in broad and, in most places, flat-bottomed channels, which lead northward to the canyon (pl. 3; pl. 4, fig. 2). Much of the deposit has been removed by the cutting of the existing arroyos which tended to follow these old channelways. Presumably there once existed a broad area of the formation just south of the head of the canyon, but all this material has been removed by erosion.

The thickness varies from a thin cover over the San Jon formation to 20 to 30 feet in the axes of the channels. At one locality the formation is 50 feet thick. On the south near the heads of the gullies the Sand Canyon overlaps the alluvial beds of the San Jon in an indistinguishably thin sheet.

<sup>8</sup> The name "Sand Canyon formation" is proposed for those deposits hereinafter described. It derives its name from Sand Canyon, a local designation for the dissected depression containing the San Jon site. Exposures there developed are considered to represent the type exposures.

The Sand Canyon consists of a reddish-brown alluvium with beds and laminae of sand, humic and silty clay ranging from paper thinness to 2 or 3 feet in thickness. The clayey layers have a strong vertical jointing such as develops in grassy places along streamways today.

Iron-manganese nodules are common, but calcium carbonate exists only in small tubules and along the joints in the formation. There is much less lime than in the San Jon formation, a distinguishing criterion. It is possible that the iron-manganese nodules are secondarily derived from the underlying San Jon formation.

Bones of *Bison bison*, the modern species, and associated "Collateral" Yuma-type projectile points have been found near the base of the formation.<sup>9</sup> A Clear Fork (?) point, also in association with modern bison, was found at a slightly higher level in the same formation. The shells of *Helisoma tenue sinuosum* (Bonnet) are found throughout the formation.

#### WHEATLAND FORMATION<sup>10</sup>

The present aspect of the arroyos and gullies of the site suggest rapid and extraordinary erosion beyond the gloomiest dreams of the soil conservationist. Inspection demonstrates, however, that these gullies, reaching in places 100 feet in depth, have developed over a considerable period of time and with successive stages of reversal of erosion and effective alluviation.

These stages are shown by terrace remnants which occur as scraps or fragments hanging on the walls of the gullies or on the points between gullies (pl. 3; pl. 5, fig. 1). The terrace sediments comprise the Wheatland formation. Each of these terrace remnants consists of a fine basal gravel, mostly of fragments of concretions from the Ogallala sandstone, and of sand. The sand and gravel layer is 1 to 3 feet

<sup>9</sup> Roberts (1942) originally suggested that these points showed affinities to the Eden Valley Yuma. In a personal communication, however, dated March 16, 1948, he writes: "Since writing my report [Roberts, 1942] and seeing Howard's later article in *American Antiquity* [Howard, 1943] I am doubtful as to whether this type should be called Eden Valley Yuma. It unquestionably belongs in the category formerly called Collateral, but possibly should be considered as Scottsbluff rather than Eden." The points are hereafter referred to in this report as "Collateral" Yuma.

<sup>10</sup> The name "Wheatland formation" is here proposed to include those strata at the San Jon site hereinafter described and the exposures at the site are considered as type exposures. The name is derived from the town of Wheatland  $4\frac{1}{2}$  miles south of the site. (Figs. 1, 5.)

thick and overlies an irregular surface cut in the older formations. In places, a rubble of clay fragments takes the place of the basal gravel, and 5 to 15 feet of gray sand and silty sand which at the top is a dark, grass-covered soil, overlies the basal gravel and represents aggradation of the stream channels.

The highest terrace has a base 20 to 25 feet above the grade of the streams at points nearest the head of the canyon. The base rises rapidly and near the heads of the gullies is 60 to 70 feet above the grade of the arroyos. In these southerly localities this terrace occupies considerable areas.

The two lower terraces have bases at 8 to 10 feet and 1 to 5 feet above present grades. When fully developed they were confined to narrow areas along the gullies.

Each terrace records a downcutting of streams through the Sand Canyon and older formations with a stabilization of grades and a later slight alluviation. This episode was repeated three times before the present stream grades were established. At places in the highest terrace, bones of *Bison bison* have been excavated. These bones give no critical evidence as to the time interval separating this terrace deposit from the present. The dates of the episodes of erosion and sedimentation involved in the three terraces fall within the interval spanned by the Wheatland formation and estimated in a subsequent section.

#### RELATION OF CULTURAL AND FAUNAL MATERIAL TO THE DEPOSITS

Extensive archeologic excavations at the San Jon site by Roberts during the summer of 1941 (Roberts, 1942) and test trenches by Hibben in 1940 have produced a sequence of cultural material associated with the bones of animals, some of them now extinct. Although the amount and variation of the material are disappointingly small, enough information has been gained to demonstrate four distinct cultural horizons. These horizons can be tied to the deposits of the site as diagrammatically suggested in figure 9. The stratigraphic position of the material is in accord with the conclusion of the archeologist that it includes four different time horizons separated by intervals of varying duration.

The oldest cultural horizon is represented by a single point, called by Roberts (1942, p. 8 and fig. 2a) the San Jon point. It was found in area 2 in association with the heavily mineralized bones of an extinct bison, probably *Bison taylori* (Roberts, 1942, p. 8 and ftn. 2). The point and the bone were embedded in a clayey-silt bed near the

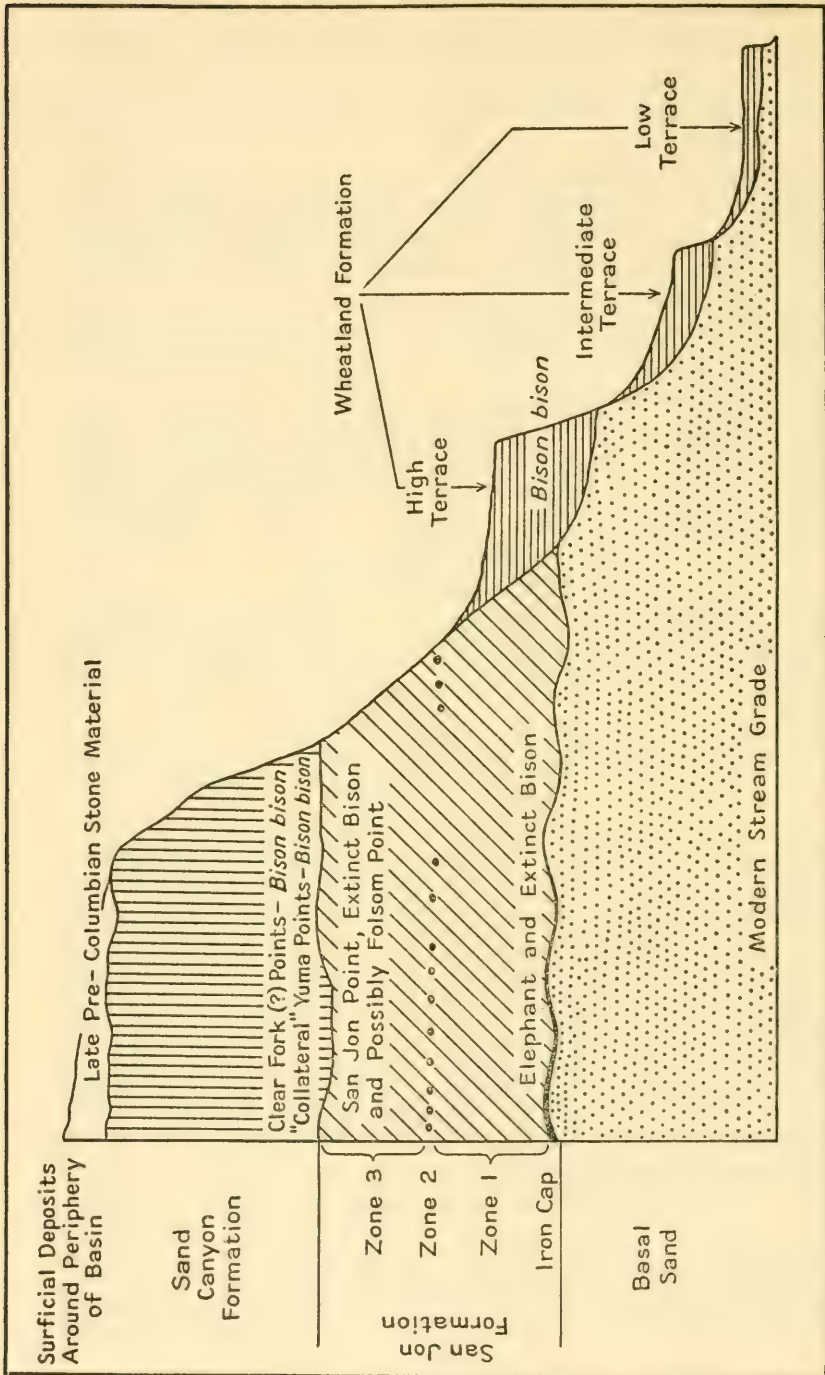


FIG. 9.—Diagrammatic sketch to show relation of cultural and faunal material to late Pleistocene deposits at the San Jon site.



top of zone 3 of the San Jon formation (figs. 8 and 9). The upright position of articulated leg bones within the deposit suggests that the animals died after miring in a shallow pond. The almost complete absence of all but leg bones further suggests that the bulk of the carcasses were removed by scavenging animals or by man (Roberts, 1942, p. 8). A true Folsom point was found on the surface along a ridge 500 feet to the north as indicated in figure 4 and plate 3. Although this point was not found in situ it appeared to be raveling out of clays belonging to the same horizon as that containing the San Jon point. The horizon also contained fragments of bone similar in amount of mineralization to that associated with the San Jon point.

The second horizon recognized contains the "Collateral" Yuma points in association with the slightly fossilized bones of *Bison bison* excavated in the Hibben dig area. These points have been obtained by both Roberts and Hibben and are also included among the points collected by Keith Martin, discoverer of the site, and turned over to the Museum of Anthropology at Santa Fe. The points and bones occur in the base of the Sand Canyon formation. The amount of time involved between the end of San Jon time and the beginning of Sand Canyon time was of considerable extent and will be considered later at some length.

The third horizon also occurs within the Sand Canyon formation but at a slightly higher stratigraphic position than do the Yuma points. It is represented by a point bearing some similarities to the Clear Fork types of west Texas (Roberts, 1942, p. 10). The bones of *Bison bison* were found with the point, but they were slightly less mineralized than were those found with the Yuma points.

Shallow trenches along the eastern slopes of the depression produced stone material obviously of a comparatively late culture, probably slightly pre-Spanish in age. The artifacts were found just below the grass roots within surficial deposits equivalent in age to some phase of terrace formation within the site itself during Wheatland time.

No artifact material has been removed from the Wheatland formation represented by the terrace deposits although the bones of modern bison have been found within the highest terrace as previously noted.

### CONCLUSIONS

The sequence of beds at the San Jon site presents problems that require further discussion and amplification. Nevertheless simple inferences can be made from the material thus far presented.

1. A depression, to be the future location of the San Jon site, was formed in the Ogallala formation by alternate leaching and deflation. This depression was formed during some portion of Pleistocene time as climate alternated between moist and arid or semiarid. This depression was bottomed by the Basal Sand.

2. In this depression of the Plains underlain by the Basal Sand a pond existed and gradually became shallower and less constant as the San Jon formation was deposited. A volcanic-ash shower occurred while this deposit was being laid down. During the latter part of this period the people who made the San Jon points, and possibly also a true Folsom people, occupied the area. Proboscideans were present during the early stages of deposition, and extinct bison watered here during human occupation of the late stages of depositions.

3. Following the deposition of this formation the depression was breached and was dissected by broad channels.

4. In these channels the Sand Canyon formation was deposited partly as alluvium and partly in temporary evanescent ponds along the streamways. During this period the people who made the "Collateral" Yuma and the Clear Fork (?) points occupied the area. By this time the modern bison had replaced the large bison and the elephant was probably extinct.

5. Erosion then began on the present drainage lines and the existing deep arroyos were cut in stages represented by three terraces, the sediments of which are termed the Wheatland formation. During these time intervals the area was occupied, but the sequence of cultures is as yet indefinite.

6. The human occupation at the San Jon site is correlated with a series of events which are reflected in the local deposits and erosional intervals.

7. The human occupation is also closely related to one of the depressions of the Plains. Before discussing the geographic extent of the events recorded at the site it is fitting to consider the role of the depressions and human occupancy of the Plains.

#### DEPRESSIONS AND OCCUPANCE OF THE PLAINS

The history of human occupancy of the Plains has been dominated in large part by the depressions. This dominance is less apparent today than it was 50 years ago or when aboriginal peoples roamed the Plains. It is still important, nevertheless, for here man has found water not only in the lakes but also in shallow wells, which tap soft water at economical depths. Most of the pasture land of today surrounds these depressions.

The Indians, recent and ancient, were of necessity more sensitive to their environment than are modern men. When on the Plains they depended almost entirely on these shallow lakes for water. Moreover, the game on which they lived watered here, and a mired buffalo or elephant was easy prey for a hungry Indian. The more prominent of the sand hills east of the lakes provided still another attraction for the migrant hunters of the past. These hills offered them not only a commanding camp site from which they could see for great distances in all directions, but they were also well drained. On all the higher hills examined by the writer, evidence of Indian occupation is present. The depressions drew the Indians to them not only during the moist periods of the past but even during the dry periods, although presumably the population of the Plains was smaller than during the periods of more effective rainfall.

Unfortunately, our knowledge of cultural successions on the Plains is as yet incomplete. As that knowledge expands, however, it should key to, and be explained in large part by, the depressions of the Plains and the variations in climate from dry to moist. The San Jon site contributes a few facts to this picture. The people who made the San Jon point, and probably the Folsom point, hunted around the small lake which once occupied the now-dissected depression. The mere presence of the lake suggests a climate moister than the present. Whether these peoples camped around this lake is not known. Certainly the lake's strategic position with respect to the Valley Plains of the Canadian to the north and the High Plains to the south, along with water and game, would provide a logical setting for a camp site. If one or more camp sites once existed they were either destroyed by erosion or lie buried under more recent deposits. One would expect that primitive hunters would not camp directly on the lake margin but on higher, better-drained ground to the east and south of the lake where a commanding view of the surrounding country could be obtained. If this be true then the camp sites have been either destroyed by erosion or mantled by subsequent eolian deposits.

Following the occupation by the San Jon-Folsom people, a period of erosion occurred during which the depression was breached, the lake drained, and the basin partially dissected. As will be discussed later, this stage is thought to coincide with a dry period. Whatever the climate, we have no cultural record from this interval, perhaps because people were absent from the area, but more probably because no deposits representing this interval have been found.

The next record of human occupation is that of the people who made the "Collateral" Yuma points, closely followed by people using

points having affinities to the Clear Fork complex of Texas. The conditions of burial indicate that these people enjoyed a climate moister than the preceding dry period and probably moister than that of the present. The camp sites of these peoples are also unknown. No longer was there a lake to attract man but small pools or *charcos* must have existed along the drainageways. If the Yuma and Clear Fork (?) peoples maintained camp sites here they are now destroyed or as yet undiscovered.

The more recent history of the San Jon site is recorded by remnants of three terraces. These periods of alluviation were interrupted by progressive downward cutting of the streams until the modern drainage was established. What relation human occupancy of the site bears to these periods of alluviation and erosion is not clearly understood. Roberts (1942, pp. 10-12) reports the presence of a comparatively late culture from shallow sites around the peripheries of the basin. What relation the physical events at the site bear to this culture is unknown.

#### SUMMARY

The Pleistocene deposits of the San Jon site lie within a depression now breached and partially dissected. As shown by an examination of this site and of other breached depressions along the northern escarpment and confirmed by studies of undrained depressions on the Plains, these depressions were formed by the deflation of locally leached areas of the Ogallala formation. Deflation has been in progress intermittently since the beginning of the Pleistocene. The depressions were excavated in warm, dry periods, and deposition occurred in cool, wet periods. The depressions have been important geographic factors in the utilization of the Plains by aboriginal peoples. Furthermore, they contain deposits which duplicate in part the events recorded from the San Jon site. This duplication is important for it permits the assertion that the deposits at the San Jon site do not represent locally restricted and unique events, but rather events which have some geographic extension on the adjacent High Plains. This extension of the San Jon sequence to the adjacent Plains is considered below.

### PLEISTOCENE STRATIGRAPHY IN THE VICINITY OF THE SAN JON SITE

#### GENERAL STATEMENT

In addition to the deposits at the San Jon site the writer has studied in some detail the Pleistocene stratigraphy of the surrounding area. This area, although ill-defined, extends in a general way from the

Texas–New Mexico line on the east to a line approximately 5 miles west of Tucumcari and from the Canadian River on the north to Grady on the south. The northern escarpment of the Llano Estacado divides the area into two irregular portions, a section of the Southern High Plains to the south, hereafter referred to as the Plains, and a large segment of the Valley Plains of the Canadian River to the north, termed the Valley in subsequent pages.

The various phases of the late Pleistocene stratigraphy, lacustrine, alluvial eolian, and erosional, are listed chronologically in table 2, a condensed presentation of late Pleistocene geologic history. The deposits described from the San Jon site have their counterparts throughout the area and are identified in the field on the basis of lithology, fossil and artifact content, and stratigraphic position. Furthermore, the disconformities recorded at the site are represented elsewhere not only by erosion but by wind activity and the accumulation of eolian deposits. Certain other events, such as the deposition of freshwater limestone, the formation of the “cover” of the Plains, and the planation of pediments in the Valley, antedate the oldest Pleistocene deposit of the San Jon site. However, the position of these older events within the late Pleistocene is poorly defined. Therefore the most complete part of the record begins with San Jon time and continues to the present. This is the period spanned by the so-called “Alluvial Chronology” (Bryan, 1941), a sequence of events and time intervals now established in many parts of the Southwest and thus of utmost importance to this discussion. The recognizable fragments of this sequence, now exposed at various localities on the Plains and in the Valley are described in the pages immediately following. From the description and discussion of this sequence, summarized in table 2, it will be evident that there has been an alternation of deposition in ponds and streams, with erosion of channels, deflation of depressions, and accumulations of eolian deposits. A detailed consideration of the implications of the “Alluvial Chronology” is given in a later section.

## CHARACTERISTICS OF LATE PLEISTOCENE FORMATIONS

### SAN JON FORMATION

The lacustrine phase of the San Jon formation is predominately clayey in texture and may be blue, red, green, or brown. The fluvial deposits are sandy to silty alluvium, red to brown. The deposits of both phases are extremely compact and in most instances impossible to crumble between the fingers. They are characterized by a well-developed joint system along which have been deposited alluvial clay. Lime carbonate forms nodules independent of the joint system and

TABLE 2.—Correlation of the various phases of late Pleistocene stratigraphy in eastern New Mexico

AGE	LACUSTRINE & ALLUVIAL PHASE OF THE PLAINS	ALLUVIAL PHASE OF THE VALLEY	EOLIAN PHASE	EROSION PHASE
1900 TO DATE	DEPOSITION IN MODERN EPHEMERAL PONDS	_____	MODERN DUNES	CHANNEL CUTTING ON MANY STREAMS
WHEATLAND 1400 A.D. ± - 1900	LOOSE SEDIMENTS IN PONDS, ON SLOPES OF DEPRESSIONS AND IN CHANNELS IN SHORT STREAMS NEAR ESCARPMENT.	LOOSE ALLUVIUM OF WHEATLAND FORMATION IN CHANNELS.	DEVELOPMENT OF SOIL ZONE	_____
1300 ± - 1400 ± A.D.	_____	_____	FORMATION OF DUNES	DEFILATION OF DEPRESSIONS. EROSION AND CHANNELING OF SAND CANYON (B) FORMATION
SAND CANYON (B) IN PART POST I.A.D.	COMPACT, SOMEWHAT LIMY SEDIMENTS OF SAND CANYON FORMATION DEPOSITED AS ABOVE. AT SAN JON SITE CLEAR FORK ? AND "COLLATERAL" YUMA POINTS WITH MODERN BISON NEAR BASE.	COMPACT, SOMEWHAT LIMY ALLUVIUM OF SAND CANYON (B) FORMATION	DEVELOPMENT OF SOIL ZONE	_____
DATE ?	_____	_____	SOME WIND ACTIVITY	SOME EROSION AND CHANNELING OF SAND CANYON (A) FORMATION
SAND CANYON (A) 3500 - 2000 B.C. ± TO ?	_____	COMPACT, SOMEWHAT LIMY ALLUVIUM OF SAND CANYON (A) FORMATION	DEVELOPMENT OF SOIL ZONE	_____
MEGATHERMAL PHASE 5400 ± - 2000 ± B.C.	_____	_____	FORMATION OF DUNES	DEFILATION OF DEPRESSIONS. EXTENSIVE EROSION AND CHANNELING OF SAN JON FORMATION. BREACHING OF SAN JON SITE AND OTHER DEPRESSIONS
SAN JON PRIOR TO 5400 ± B.C.	COMPACT, LIMY SEDIMENTS OF SAN JON FORMATION DEPOSITED AS ABOVE AT SAN JON SITE CONTAINS SAN JON POINT, PROBABLY FOLSOM POINT, MAMMOTH AND EXTINCT BISON.	VERY COMPACT LIMY ALLUVIUM OF SAN JON FORMATION. CONTAINS MAMMOTH HORSE AND SLOTH.	DEVELOPMENT OF SOIL ZONE PLAINVIEW POINTS IN THIS SOIL ?	_____
UNDIFFERENTIATED LATE PLEISTOCENE PRE - SAN JON IN AGE	LACUSTRINE DEPOSITS, LARGELY LIMESTONE UNDIFFERENTIATED	_____	FORMATION OF PART OF "COVER" OF THE PLAINS.	DISSECTION OF LOW PEDIMENT AND ESTABLISHMENT OF MODERN BEDROCK GRADE
				CUTTING OF LOW PEDIMENT
				DISSECTION OF HIGH PEDIMENT
				CUTTING OF HIGH PEDIMENT

= ALLUVIAL CHRONOLOGY =

up to 1 inch in diameter. In some exposures, particularly of the lacustrine phase, pellets of iron-manganese oxide about one-quarter of an inch in diameter are characteristic. Volcanic ash is present at several localities, and mammoth, horse, and giant bison are found in some exposures. Mollusca are common but not diagnostic. Nonpottery cultures are related to the upper part of the formation. The formation may form a terrace within depressions and along streams.

#### SAND CANYON FORMATION

Good exposures of the lacustrine phase of the Sand Canyon have not been seen. The fluvial phase, however, is a red to brown sandy or silty alluvium containing distinct humic zones of darker tone. In the Valley a set of two humic zones tends to be characteristic. The formation is jointed but not to the same degree as is the San Jon formation. Although calcium carbonate has collected along the joint planes and filled root tubules and worm burrows, it does not form concretions independent of these structures. No extinct animals are known from the formation, and *Bison bison* is characteristic of this and the later Wheatland formation. No pottery has been found in the Sand Canyon but is to be expected from its upper part. Mollusca are again undiagnostic. Along streams it may form a terrace intermediate between terraces of the San Jon and Wheatland formations.

#### WHEATLAND FORMATION

Exposures of lacustrine deposits of Wheatland age are not known. The fluvial phase consists of a gray, sandy, friable, unjointed alluvium very low in calcium carbonate. It contains *Bison bison* and traces of pottery cultures. Mollusca are present but undiagnostic. It occupies channels cut in the older formations and at favorable localities is preserved as a low terrace a few feet above the modern stream.

#### SUMMARY OF LATE PLEISTOCENE STRATIGRAPHY OF THE PLAINS

Exposures of Pleistocene beds, although rare within the undrained depressions, are present in fortuitous artificial cuts. Beds of this age are, however, more completely exposed in the breached and dissected depressions along the escarpment.

The following sections and figures summarize the late Pleistocene stratigraphy of selected localities in the vicinity of the San Jon site:

## TIPTON CANYON

Immediately southeast of the San Jon site along an abandoned wagon trail into Tipton Canyon (A, fig. 5) the following section is present:

	Feet
<i>San Jon formation</i> .—Sandy to clayey, reddish, compact alluvium. Calcium-carbonate and iron-manganese nodules. Midway in section thinly laminated volcanic ash 4-6 feet thick, petrographically similar to volcanic ash at San Jon site.....	50
——disconformity——	
<i>Leached Ogallala formation</i> .—Grades laterally into unaltered lime cemented Ogallala formation. Lower contact obscured.....	15

## GRAPEVINE CANYON

Grapevine Canyon is located about 6 miles southeast of the San Jon site (B, fig. 5). In a gulch on the western side of the Canyon the following section is present:

	Feet
<i>Wheatland formation</i> .—Gray, friable, stream deposits in channels cut into Sand Canyon formation. Little calcium carbonate. Contains <i>Bison bison</i> .....	0-5
' ——disconformity——	
<i>Sand Canyon formation</i> .—Reddish alluvium occupying channels cut in San Jon formation. Crumbled with difficulty between fingers. Calcium carbonate along joint planes and in root tubules. Scattered charcoal and fragments of charred bone in upper few inches.....	0-10
——disconformity——	
<i>San Jon formation</i> .—Well-compacted clay sand, silt, and gravel predominately lacustrine. Calcium carbonate locally in concentrations 1 foot thick. One of these contains volcanic ash similar to that of San Jon site. Pellets of iron and manganese oxides $\frac{1}{4}$ inch in diameter.....	0-40
——disconformity——	
<i>Pleistocene "cap rock"</i> .—Fragments of Pliocene "cap rock" recemented by the calcium carbonate.....	2
——disconformity——	
<i>Leached Ogallala formation</i> .—Buff unconsolidated sand derived by leaching of Ogallala sandstone in place. Lower contact not seen.....ca.	100
——angular unconformity——	
<i>Purgatoire formation</i> .—(Cretaceous).	



DEADMAN'S CANYON

At head of Deadman's Canyon which is located between Tipton and Grapevine Canyons (fig. 5) lies a small breached depression. The section is given below and illustrated in figure 10.

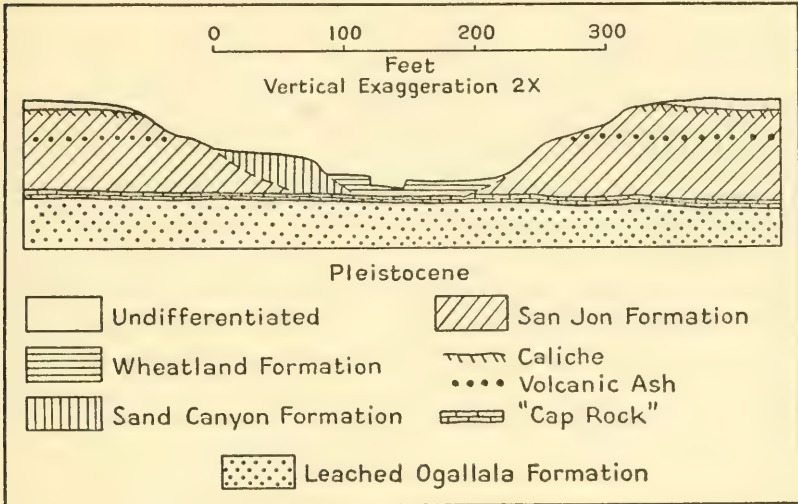


FIG. 10.—Section showing relation of late Pleistocene formations to the Pleistocene "cap rock" and leached Ogallala formation at Deadman's Canyon.

- |  |             |
|--|-------------|
| <i>Wheatland formation.</i> —Low terrace 3-5 feet above modern grade. Gray friable alluvium, little lime carbonate. Lies in channels cut in Sand Canyon formation .....  | Feet<br>0-5 |
| ——disconformity——  |             |
| <i>Sand Canyon formation.</i> —Terrace 8-12 feet above modern grade. Reddish alluvium, some lime carbonate. Lies in channels within San Jon formation .....  | 0-12        |
| ——disconformity——  |             |
| <i>San Jon formation.</i> —Terrace 25-28 feet above modern grade. Basal 15 feet red, jointed, compact, stream-laid alluvium with many lime-carbonate nodules up to ½ inch in diameter. Iron-manganese oxides stain joint planes. Upper 10-12 feet somewhat sandier with caliche zone of over 1 foot at top. Lower and upper zones separated by 5-6 inches of volcanic ash similar to that of San Jon site..... | 0-28        |
| ——disconformity——  |             |
| <i>Pleistocene "cap rock."</i> —Rubble of fragments from Pliocene; rubble overlain by 1 foot of gray platy limestone as much as 25 feet below general level of "Pliocene cap rock".....  | 3           |
| ——disconformity——  |             |

<i>Leached Ogallala formation</i> .....	40
——angular unconformity——	
<i>Purgatoire formation</i> .—(Cretaceous).	

#### PUERTO CANYON

Within the reentrant marked C in figure 5 a well-developed Pleistocene "cap rock" crops out from 20 to nearly 50 feet below the general level of the "Pliocene cap rock." At lowest point it is a gray, platy limestone 3 feet thick which grades downward into a massive caliche which in turn overlies 10 feet of unstratified gravels composed chiefly of rounded fragments of "Pliocene cap rock" with a few silicious pebbles from the Ogallala which have wind-fashioned surfaces. This Pleistocene "cap rock" was deposited in a depression now breached. It predates the terrace deposits in Puerto Canyon at the headwaters of Barranca Arroyo described below and shown in figure 11.

<i>Wheatland formation</i> .—Deposits of gray friable alluvium, low in calcium-carbonate accumulation and 5-10 feet above modern grade.....	Feet 0-5
——disconformity——	
<i>Sand Canyon formation</i> .—Deposits of reddish, jointed alluvium with powdery lime carbonate along joint planes. More compact than Wheatland deposits. Forms terrace 30-35 feet above modern grade.....	0-10
——disconformity——	
<i>San Jon formation</i> .—Deposits forming a terrace about 100 feet above modern grade. Extremely compact, well-developed joint planes stained by iron-manganese oxides. Lime-carbonate nodules $\frac{1}{4}$ inch in diameter in basal section.....	0-25

#### QUEEN CANYON

At point B, figure 1, is a small depression breached and partially dissected by the retreating headwall of Queen Canyon. Within this depression are fluvial deposits thought to be of Sand Canyon and Wheatland age and possibly of San Jon age. Outside of this depression in short drainageways to Queen Canyon three terraces are thought to represent, from highest to lowest, the San Jon, Sand Canyon, and Wheatland periods of alluviation. These relations are shown diagrammatically in figure 12.

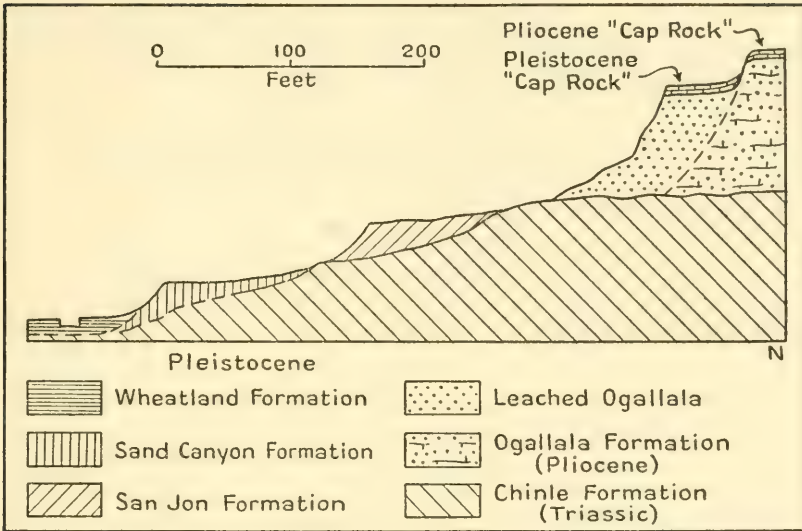


FIG. 11.—Section showing relation of late Pleistocene formation to the "cap rock" and leached Ogallala formation at Puerto Canyon.

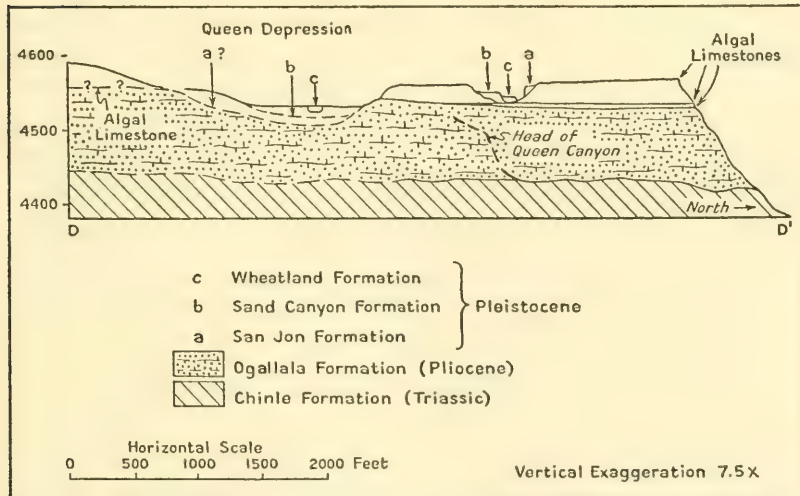


FIG. 12.—Section showing relation of multiple "cap rocks" and late Pleistocene formations to breached depression at the head of Queen Canyon.

## LANDRIGAN CANYON

Near the head of Landrigan Canyon at point C, figure 1, 200 yards west of the New Mexico-Texas State line is a small, breached, and partially dissected depression.

<i>Wheatland and Sand Canyon formation.</i> —Deposits not present in the depression but found as scattered exposures of stream deposits in the canyon below level of depression.	Feet
——disconformity——	
<i>San Jon formation.</i> —Compact sand and jointed sandy alluvium and clay. Iron-manganese oxides along joint planes. Lime-carbonate nodules up to 3 inches in diameter.....	0-27
——disconformity——	
<i>Leached Ogallala formation.</i> —Buff, unconsolidated sand. Upper 12 feet stained with limonite.....	75
——angular unconformity——	
<i>Chinle formation.</i> —(Triassic).	

## HATFIELD LAKE

West of Grady lies a large elliptical depression having a maximum width of over 4 miles. This major depression, which is over 50 feet in depth, contains three smaller depressions occupied by wet-weather lakes. The largest of the lakes is Hatfield Lake, which covered approximately one-quarter square mile in 1947 and had an elevation of about 4,615 feet. During the exceptionally rainy summer of 1941 the lake spread over an area approximately one-half square mile and rose to a level of approximately 4,625 feet. On the other hand, during the dry years of the 1930's the lake disappeared completely. To the east of Hatfield Lake lies double-crested Delaney Hill, the largest hill within the area mapped. It reaches an elevation of nearly 4,700 feet or about 80 feet above the 1947 level of Hatfield Lake.

During 1947 State Highway 18, which previously crossed the extreme southern portion of the lake on a low viaduct, was rerouted around the southern side of the lake as indicated in figure 13. In so doing several borrow pits and a drainage ditch were opened and an opportunity afforded to examine some of the water-laid deposits around the southern edge of the present lake. Furthermore, a sand pit in the western crest of Delaney Hill exposed eolian deposits considered to represent the erosion intervals separating the beds within the depression.

"Cap rock."—Exposures of "Pliocene cap rock" are present at various points around Hatfield Lake as indicated in figure 5. The limestone varies in elevation and appears to slope toward the center of the depression from all sides. At a locality marked A in figure 13 a quarry exposed "Pliocene cap rock" with a maximum thickness of 3 feet. A platy, almost pure limestone, brown to pink in color, with a botryoidal upper surface and internal concentric banding, overlies a massive sandy caliche not over 2 feet in thickness. One and one-half

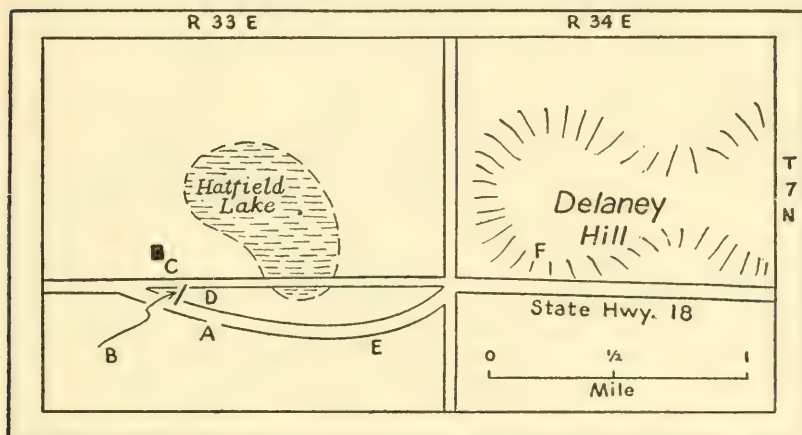


FIG. 13.—Sketch map of Hatfield Lake. Letters refer to localities mentioned in text.

to three feet of sandy, finely laminated and vertically jointed caliche overlies this "cap rock." The caliche contains gray and red irregular blotches, low in calcium carbonate. They have an upper maximum dimension of 2 feet and narrow downward in a manner suggesting solution from above. A gray, friable alluvium 18 to 24 inches thick overlies this caliche. Point A, figure 13, marks the farthest extent of the "cap rock" into the depression. Elsewhere on the slope around Hatfield Lake fragments of "Pliocene cap rock" ravel out on the surface but no vertical sections are present.

*Pre-San Jon deposits of Pleistocene age.*—Along the line B in figure 13 a run-off ditch from the new road exposes gravel, sand, and clay of Pleistocene age which is overlain by later deposits of the San Jon and Sand Canyon formations as shown in figure 14.

Stream-laid sand and gravel forms the floor of the ditch midway along its length. The gravel ranges in size from one-quarter of an inch to 3 inches in diameter and is composed entirely of rounded fragments of the "cap rock." Some coarse sand and a small percentage

of silt-size particles are mixed with the gravel. The deposit was excavated to a depth of 6 feet without reaching its lower limit. Test holes in the immediate vicinity show that the gravel has no great areal extent and suggest that it represents a discontinuous channel deposit. Southward along the trench as shown in figure 14, a heavily calichified sandy clay reaches 7 feet in total exposed thickness. The gravel appears to be laid within a channel cut into this deposit but the relations are obscure.

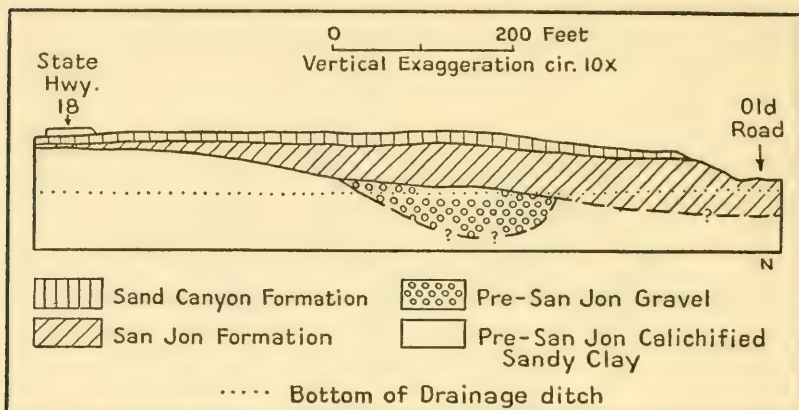


FIG. 14.—Section showing relations of Pleistocene deposits along drainage ditch southwest of Hatfield Lake (B, fig. 13).

*San Jon formation.*—Disconformably overlying the preceding deposits a greenish clay ranges up to 7 feet in thickness. As shown in figure 14, these beds pinch out to the south. The clay is compact, jointed, and grades upward into a black soil zone 18 to 24 inches thick. Clay films coat the joint planes and calcium-carbonate nodules reach three-quarters of an inch in diameter and are independent of the joint system. Lime carbonate is also present along the joints and in root tubules. Similar deposits were exposed during road construction at points D and E of figure 13. At E, 8 inches of powdery lime carbonate containing volcanic ash and fine sand is present near the base of the exposure. The beds here are about 4 feet thick and overlie a "cap rock." No fossils were found but at point C in figure 13 elephant bones were uncovered several years ago during the excavation of a trench for a water pipe. Additional elephant bones are reported to have been found within the depression approximately 2 miles to the north in beds no longer exposed. These deposits, one of which contains volcanic ash, resemble other lake beds of the San Jon formation with which they are correlated.

*Sand Canyon formation.*—The Sand Canyon formation is the top-most deposit exposed in the trench at B, figure 13. It averages 2 feet in thickness, as shown in figure 14, and is reddish brown, darkening toward the top. The upper 6 to 8 inches has been disturbed by the plow. The Sand Canyon formation is also present in the trench at locality E, figure 13, where it is 18 inches thick.

*Wheatland formation.*—The Wheatland formation is present as a thin layer 6 to 18 inches at localities A and E. It is a gray, friable alluvium containing little lime carbonate and in both instances forms the modern surface.

*Eolian deposits of Delaney Hill.*—Excavations of a sand pit in 1947 in the eastern crest of Delaney Hill (F, fig. 13) showed that Delaney Hill is composed of a series of wind-blown sands separated by soil zones and overlying "Pliocene cap rock." These sands represent periods of deflation within the basin to the west. They were removed from the depression by strong westerly winds during successive arid periods of the past and dumped here to form Delaney Hill. The intervening moist periods during which fluvial and lacustrine deposition in the basin curtailed deflation are recorded in the soil zones at the top of each sand body. The relation of these sand bodies and their capping soils to the deposits within the depression is shown in table 3.

Two feet of black, sandy to silty sand overlies the "Pliocene cap rock," and the weathering which produced this soil is correlated in time with the San Jon formation. Disconformably over this sand lies 17 feet of buff-colored sand. The lower 9 feet of this deposit contains little lime carbonate. Above this are 8 feet of sand high in lime and containing local patches of lime-cemented sand 1 foot in diameter. This zone also exhibits a columnar jointing which becomes more prominent upward. The upper 2 feet of this limy sand changes gradually from buff to red and finally to a dark gray. This is the soil zone equivalent in age to the Sand Canyon formation. The sand on which it is developed represents the arid period intervening between San Jon and Sand Canyon time.

Over the buff limy sand and the soil developed upon it was laid additional eolian material. This is a buff to reddish sand, 1½ feet thick, containing little lime carbonate. At its top it is gray, and this portion is a remnant of an immature soil. In this upper zone artifacts have been found which point to a relatively recent Spanish or immediately pre-Spanish age for the soil. This soil is correlated, in table 3, with the Wheatland formation and the sand on which it is developed with the interval between Sand Canyon and Wheatland time.

A thin skin of loose, unconsolidated, buff to gray sand, 2 to 5 inches thick, lies disconformably above the soil of Wheatland age. This sand is very recent and was blown in part from plowed land to the west and in part from the dried bed of Hatfield Lake and its environs during the "dust bowl" days of the 1930's.

TABLE 3.—*Correlation of soils and wind-blown sand in Delaney Hill with fluvial and lacustrine deposits in Hatfield depression*

Delaney Hill	Hatfield depression	Climate
Modern sand .....	Deposits of Ephemeral Lake.....	Dry
Soil .....	Wheatland formation .....	Moist
Sand .....	Erosional disconformity .....	Dry
Soil .....	Sand Canyon formation.....	Moist
Sand .....	Erosional disconformity .....	Dry
Soil .....	San Jon formation.....	Moist

#### COVER OF THE PLAINS

The soils and sand deposits of Delaney Hill lie above the "Pliocene cap rock." As such they form a portion of the "cover" of the Plains. Other hills such as those east of Watkins, Best, Owens, Rush, Big Beef, and Big Smith Lakes are similar to Delaney Hill in form and relation to neighboring depressions. They also form a part of this "cover" and probably have histories closely analogous to that of Delaney Hill. In addition to these "sand" hills lying east of the depressions there is an extensive blanket of material which mantles the "Pliocene cap rock." It lacks distinctive physiographic expression but is not uniform in thickness. Data from well logs show that the mantle is almost universally present and ranges up to 40 feet in thickness above the "cap rock." At localities where exposures are available this deposit consists of highly calichified sand with a large percentage of particles of silt and clay size. Distinctive horizons within this "cover" have not been recognized, nor does surface expression assist in a detailed geomorphic evaluation. It seems reasonable, however, to infer that the "cover" of the Plains is largely eolian in origin, that it is post-"cap rock" and Pleistocene in age. One can also infer that it has a long and complex history involving accumulation during periods of aridity and weathering during moist periods and that in general it antedates the late Pleistocene deposits already discussed in some detail.



## STRATIGRAPHY OF THE VALLEY

The broad Valley Plains of the Canadian have been described as butting abruptly against the northern escarpment of the Llano Estacado. This Valley, in places 50 miles wide, was cut during the Pleistocene epoch by the Canadian River and its tributaries. The detailed record of valley development is fragmentary, however, and includes only the most recent events in an otherwise long time interval. These events are represented by remnants of gravel-covered pediments lying between the ephemeral streams tributary to the Canadian River, by bodies of stream-laid sediments along these drainages, erosional intervals, and by deposits of wind-blown sand.

The stream-laid deposits repeat in major outline the late Pleistocene stratigraphy already described from the Plains. In general, water-laid deposits of the Valley are the result of alluviation in streams having exterior drainage, whereas on the Plains correlative deposits have been laid down in undrained depressions or in short streams near the escarpment. The deposits of the Valley are more continuous than those of the Plains and exposures are better and more frequent.

## PEDIMENTS

Two gravel-topped surfaces are developed across the Triassic Chinle formation, which almost everywhere underlies the Valley. The lower surface, or pediment, forms large segments of the present floor of the Valley, and the modern streams flow within narrow channels carved to a depth of as much as 40 feet below the general level of the pediment.

The higher pediment is preserved along the interfluves of the modern streams and particularly toward the escarpment of the Plains. It has an elevation of 50 to 80 feet above present stream grade, as indicated in figure 15, and is covered by up to 5 feet of gravel derived from local Mesozoic and Pliocene beds. The upper surface is in many places partially obscured by more recent eolian deposits and soils. No attempt has been made to map this pediment or to analyze the nature and pattern of the drainage system which formed it. Nevertheless, the surface represents a long period of planation during which the Canadian River and its tributaries were stabilized at a level much higher than the present. The gravel veneer was deposited by these streams during the final stages of erosion.

The second and lower pediment is approximately 25 to 40 feet above modern stream grade (fig. 15). It has been widely developed

at the expense of the higher pediment. This surface marks a second planation when local streams were graded to a level higher than the present but below that of the higher pediments. It, too, is capped by a gravel cover up to 5 feet in thickness which represents the closing stages of planation.

Comparatively narrow inner valleys and canyons have been cut into the lower of the two pediments and form the modern bedrock grades. The Canadian River itself flows in a bedrock gorge incised in places to a depth of 200 feet below the general grade of these tributary valleys. Figure 15 illustrates the relation of the modern bedrock channels of a tributary stream to the remnants of the higher and lower pediments.

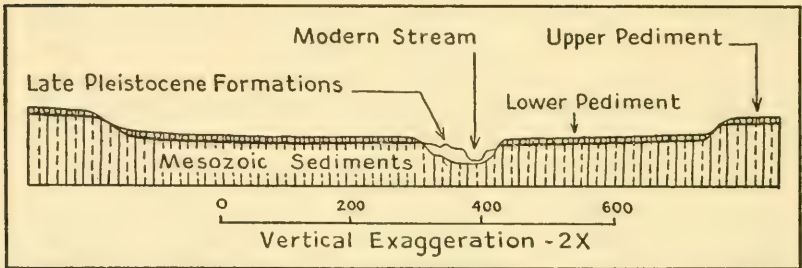


FIG. 15.—Diagram showing relation of pediments and late Pleistocene formations to the modern stream grade in the Valley.

#### SEDIMENTATION AND EROSION IN THE VALLEY

Within the bedrock channels cut into the lower pediment successive periods of fluvial sedimentation have left their record. The alluvium thus laid down can be divided on the basis of stratigraphic position, lithology, and content into the San Jon, Sand Canyon, and Wheatland formations, bounded in time by epicycles of erosion. During these erosive intervals wind activity was prominent, and today at favorable localities eolian material exists which has been trapped between successive bodies of fluvial deposits. Elsewhere wind-transported sand mantles the interfluves and testifies to the effectiveness of wind action during the epicycles of erosion. These events of sedimentation and erosion correlate with similar events at the San Jon site and elsewhere on the Plains and fall within the time represented by the "Alluvial Chronology" (table 2). Summaries of selected localities are presented below.

## FIREPIT ARROYO

In 1941 Roberts carried on excavations in the banks of a small stream just north of the San Jon site in SE $\frac{1}{4}$  sec. 21, T. 9 N., R. 34 E. The stream, here called Firepit Arroyo for the deeply buried hearths there found, is tributary to Sand Canyon which drains the San Jon depression.

*Wheatland formation.*—Gray, friable alluvium, thickest in channel filling in Sand Canyon formation. Little lime carbonate. Wood ash and charred bone and wood in deposit but no artifacts found..... 0-6

——disconformity——

*Sand Canyon formation.*—Reddish-brown sandy and silty alluvium, some gravel lenses. Alluvium compact, jointed and with lime carbonate along joint planes and in root tubules..... 0-12

Equivalent deposits in nearby Sand Canyon Arroyo contain mollusks identified by the late Frank C. Baker as follows:

Fresh-water species	Land species
<i>Helisoma tenue sinuosum</i> (Bonnet).	<i>Puŕpoides marginatus</i> (Say).
<i>Stagnicola bulimoides cockerelli</i> (Pilsbry and Ferriss).	<i>Heliodiscus singleyanus incrimis</i> (Baker)
<i>Helisoma plexatum</i> (Ingersoll).	<i>Succinea grosvenori</i> Lea.

Two humic zones present here and throughout deposits of this age in the Valley vary between 18 inches and 3 feet in thickness. They are dark brown to black silty to clayey zones with gradational contacts above and below. Locally they contain wood ash and evidence of human occupation. Near site of archeological excavations channel cutting has occurred at some time between the deposition of the two humic zones (see fig. 16). At the archeological site this erosion is represented by blown sand within the formation and between the two humic zones (see fig. 17).

A single projectile point of unknown affinities was found in the lower humic zone with bones of modern bison, antelope, and deer. (Roberts, 1942, p. 12, fig. 2d; pl. 3, fig. 2.)

——disconformity——

*San Jon formation.*—Discontinuous bodies of a red, extremely compact alluvium, correlated with beds of San Jon age..... 0-3

——disconformity——

*Chinle formation.*—(Triassic) on which are developed two pediments, one 25 feet and the other 50 feet above modern grade (see fig. 18).

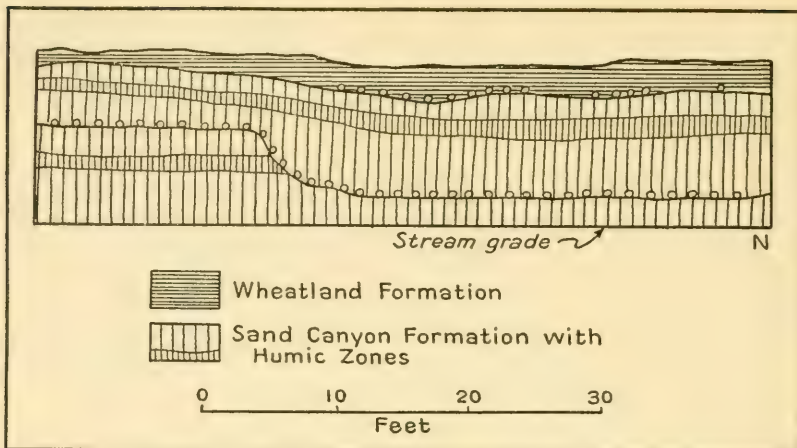


FIG. 16.—Section showing channel cutting intervening between upper and lower members of the Sand Canyon formation in Firepit Arroyo.

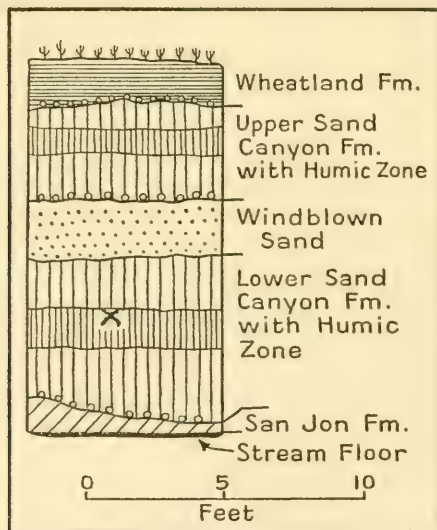


FIG. 17.—Section showing sequence of deposits at the locality of archeologic investigations in Firepit Arroyo. "X" indicates position of artifact and bone material.

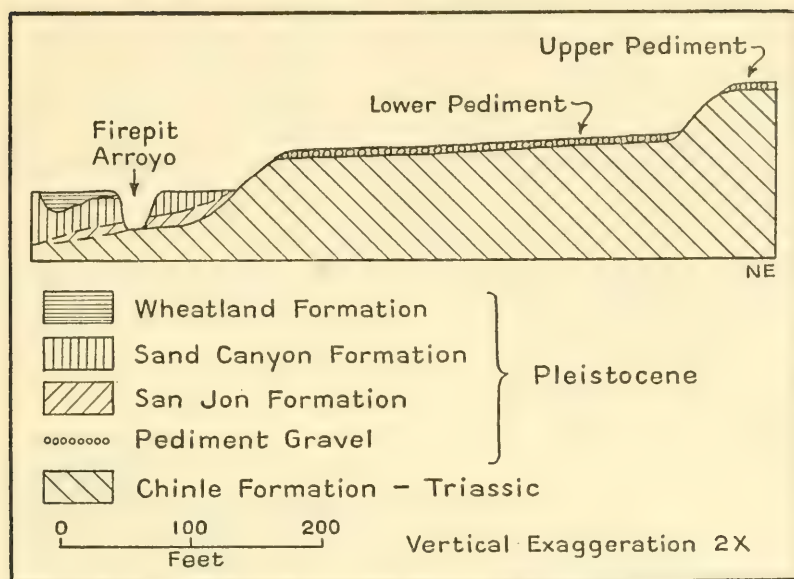


FIG. 18.—Section showing relation of pediments to late Pleistocene formations at Firepit Arroyo.

#### HODGES SITE

The Hodges site, consisting of two rock shelters, is located along Plaza Larga at point D, figure 1. The geology of the site is reported by Judson (in press) and the archeology by Dick (in press). Here deposits of wind-blown sand are trapped between deposits of Wheatland and Sand Canyon age.<sup>11</sup> This sand represents the erosional interval between Sand Canyon and Wheatland time. Pottery in the sand is dated by Dick (in press) as having a maximum range of A.D. 1150 to 1300.

#### MESA REDONDA

Excellent exposures of the San Jon formation are present along the eastern foot of Mesa Redonda, an outlier of the plains. They are found in sections 35 and 36, T. 9 N., R. 31 E., along small streams tributary to Barranca Arroyo (see E, fig. 1). The formation is a brick-red, very compact, well-jointed alluvium. Clay films are found along joint planes. Lime carbonate also found along joints as well as root tubules and as nodules averaging one-half inch in diameter.

<sup>11</sup> The San Jon, Sand Canyon, and Wheatland formations are referred to by Judson (in press) as fills No. 1, 2, and 3, respectively.

Deposits are terrace remnants up to 30 feet above modern grade. Bones of extinct animals occur in SW $\frac{1}{4}$ NE $\frac{1}{4}$  sec. 35. Nelson J. Vaughan, collecting in 1930 for the Colorado Museum of Natural History, removed parts of several mammoths (4 juveniles and 1 adult), ground-sloth teeth, and the lower jaw of a horse.<sup>12</sup> No evidence of associated human activity was reported by Vaughan or seen by the writer.

## BARRANCA ARROYO

Late Pleistocene deposits are well displayed along this arroyo, but the best single cut seen by the writer was found on a small tributary

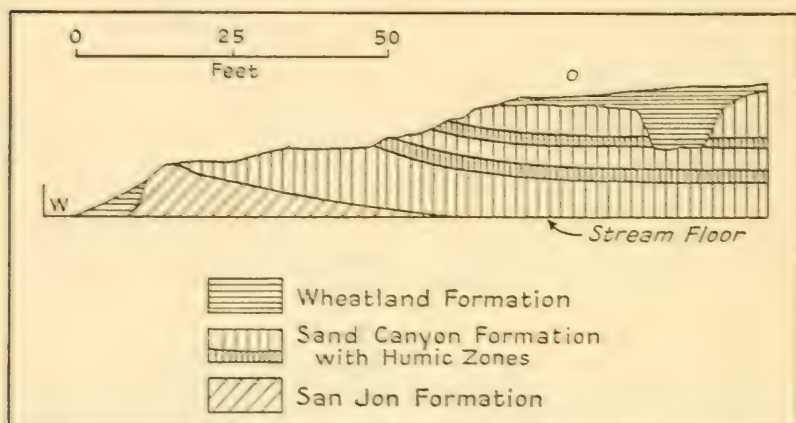


FIG. 19.—Section showing relations of late Pleistocene formations at point F, figure 1.

to the Barranca just north of the escarpment in SE $\frac{1}{4}$  sec. 16, T. 8 N., R. 32 E. (F. fig. 1). The relations of the deposits are shown in figure 19.

	Feet
<i>Wheatland formation</i> .—Gray friable alluvium occupying erosion channels in the underlying Sand Canyon formation.....	0-10
——disconformity——	
<i>Sand Canyon formation</i> .—Buff to reddish alluvium more compact than Wheatland deposits and has some secondary lime. Two humic zones indicate that upper and lower members are present.....	0-20
——disconformity——	
<i>San Jon formation</i> .—Brick-red, very compact alluvium. Blotches of secondary calcium carbonate.....	0-10

<sup>12</sup> Personal communication from H. C. Markham, Colorado Museum of Natural History, dated August 12, 1941.

## TUCUMCARI MOUNTAIN

Between Big and Little Tucumcari Mountains (G, fig. 1) the San Jon formation crops out in a low terrace about 15 feet above the present stream grading eastward to Plaza Larga. The terrace is present at various localities along the drainage in which deposits younger than the San Jon are not exposed because of lack of dissection.

The locality is of interest because of the archeological material raveling out of a veneer of wind-blown sand and dust 1 to 2 feet thick which caps the terrace. A large amount of stone material is present. Dr. Frank Hibben, University of New Mexico, has found here both stemmed and barbed points of uncertain affinities.

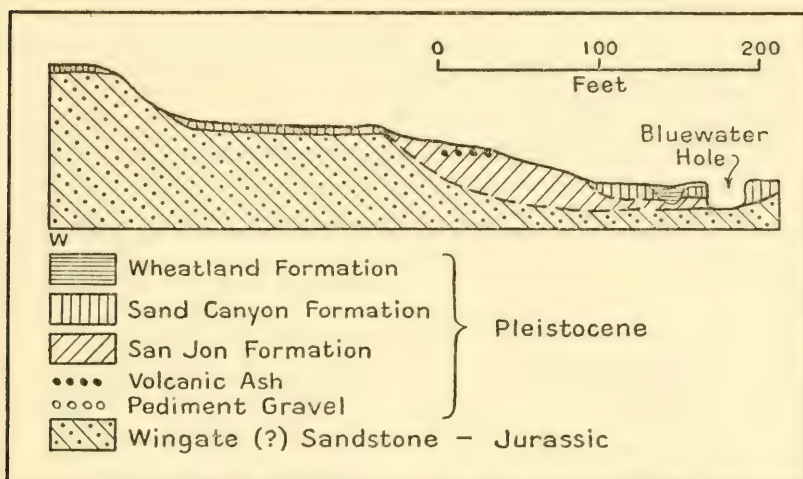


FIG. 20.—Section showing relations of pediments and late Pleistocene formations at Blue Water Hole (H, fig. 1).

## BLUE WATER HOLE

Blue Water Hole is located west of Tucumcari (H, fig. 1) along a tributary to Pajarito Creek. The locality is of interest not only because of the presence of two pediments and three late Pleistocene formations but also because of the occurrence of beds of water-laid volcanic ash similar to that described from that of the San Jon formation as shown in figure 20.

*Wheatland formation.*—Gray friable alluvium as fillings of channels cut in the Sand Canyon formation. A single pottery fragment identified by Roberts as "Rio Grande glaze or Kidder's glaze I or Mera's Group A"<sup>13</sup> and dating from the late 14th to early 15th century was found at this locality. . . . . 0-10

Feet

0-10

<sup>13</sup> Letter to Kirk Bryan dated October 7, 1942.

——disconformity——

*Sand Canyon formation.*—Buff to red, sandy to silty, jointed alluvium.

Lime carbonate along joints and root tubules. Two humic zones are present and locally contain wood ash but no artifacts were found. Lower humic zone locally missing suggesting erosion between upper and lower members at this place. Fragments of secondarily derived volcanic ash are present.....

0-15

Mollusks from the formation were identified by the late Dr. Frank C. Baker as follows:

Fresh-water species	Land species
<i>Helisoma anceps</i> (Menke).	<i>Succinea avara</i> (Say).
<i>Sphaerium</i> , valves.	
<i>Pisidium</i> , valves.	

The above forms are to be expected from the area today.

——disconformity——

*San Jon formation.*—Brick-red, very compact, well-jointed alluvium with lime-carbonate concretions independent of the joint system up to 1 inch in diameter.....

0-?

Mollusks collected from the deposit and identified by Baker are as follows:

Fresh-water species	Land species
<i>Sphaerium</i> , valves.	<i>Pupoides marginatus</i> (Say).
<i>Pisidium</i> , valves.	<i>Gastrocapta cristata</i> (Pilsbry and Ferriss).
<i>Helisoma anceps</i> (Menke).	<i>Valonia gracilicosta</i> Reinh.
<i>Fossaria</i> sp.	<i>Succinea grosvenori</i> Lea.

The above represent species to be expected in the area today.

On west side of stream about 30 feet above stream grade is a deposit of white, fine-grained, well-bedded volcanic ash partially cemented by calcium carbonate and reaching 8 feet in thickness. Petrographically similar to the ash at type section at San Jon formation. Here it dips up to 10° SW., which may be original or induced by later subsidence because of evaporite solution at depth. No secondary ash in San Jon deposit along modern stream. Although relations are obscure it is thought that the ash fall was probably during San Jon time.

——disconformity——

*Pediments.*—Two gravel-topped pediments, one 40 feet the other 80 feet above modern grade, are present as shown in figure.

——angular unconformity——

*Wingate (?) sandstone.*—A sandstone thought to be Wingate forms the bed rock at Blue Water Hole.



NORTHWEST OF SAN JON

Four and one-half miles northwest of San Jon, U. S. Highway 66 crosses a small valley one-quarter mile in width (I, fig. 1). On the eastern side of this valley is a succession of alluvial and eolian de-

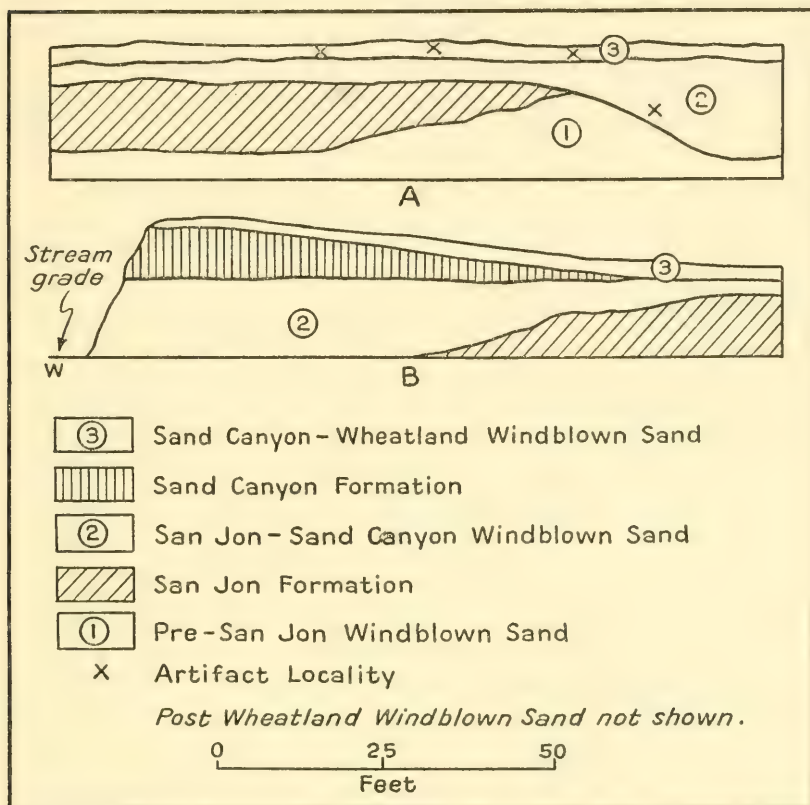


FIG. 21.—Sections showing relations of late Pleistocene deposits at point I, figure 1. A, immediately north of Highway 66; B, 300 yards south of Highway 66.

posits containing both bone and artifacts. The succession is complex and in places obscure. Although the sections presented in figure 21 are believed to be essentially correct, time may produce new exposures which will clarify the interpretation given below and in figure 21.

*Wheatland formation.*—Discontinuous bodies of gray friable alluvium along the modern stream grade. In sections of figure 21 it would be represented as thin gray soil on blown sand #3..... 0-5

Feet

——disconformity——	Feet
<p><i>Wind-blown sand #3.</i>—Buff-colored loose sand disconformably overlying the Sand Canyon formation and wind-blown sand #2. Thin, immature soil at top represents Wheatland time. Some undiagnostic artifacts from this sand and soil. A small triangular unnotched projectile point of white quartzite not found in place may originally have come from this sand or soil.....</p>	0-3
——disconformity——	
<p><i>Sand Canyon formation.</i>—Reddish compact alluvium with lime carbonate along joint planes and root tubules. Lies disconformably above wind-blown sand #2.....</p>	0-10
——disconformity——	
<p><i>Wind-blown sand #2.</i>—Buff-colored sand laid along eroded surface of San Jon formation and wind-blown sand #1. Sand becomes red toward upper surface. Top 2 inches a soft calcareous sandstone north of highway (section A, fig. 21). Mineralized bone and undiagnostic scrapers found in the sand as indicated.....</p>	0-15
——disconformity——	
<p><i>San Jon formation.</i>—Brick-red, jointed, compact alluvium with nodules of lime carbonate up to <math>\frac{1}{2}</math> inch in diameter. Lowest 10 feet of the deposit is clayey alluvium, above this more sandy. North of Route 66 it lies over the wind-blown sand #1. Bases of two projectile points not found in place may have come from upper contact of San Jon with wind-blown sand #2 where some chips were found. One base is Plainview in aspect, the other Scottsbluff-Yuma.....</p>	0-15
——disconformity——	
<p><i>Wind-blown sand #1.</i>—On the north side of the highway a wind-blown sand lies beneath the San Jon formation. It is red in color, contains a few stringers of clay, and is partially cemented by lime carbonate. Base not seen.....</p>	0-10

#### EOLIAN MATERIAL UNRELATED TO ALLUVIUM

In the above discussion bodies of wind-blown sand intimately related to the late Pleistocene fluvial deposits have been described. In places this sand intervenes between the fluvial formations and represents part of the wind work during the periods of erosion which separate the periods of alluviation. Wind-blown sand in such position is, however, rare. The great bulk of wind-transported material occurs in dune fields and as a discontinuous veneer on the interfluves. Most of the sand actually moving today is located along the eastern side of stream channels and in scattered patches in the largely stabilized dune fields. Modern sand movement in the dune fields is largely due to activation of old sand dunes by injudicious attempts at farming.

Near the streams, however, sand is blown out of dry channels and piled along the lea or eastern banks. The supply of sand thus derived is renewed by each of the floods of the stream. Only renewed aggradation and filling of the channels with alluvium will diminish the supply of sand and provide opportunity for vegetation to stabilize the dunes. Not only does this sand move onto the interfluves and their sandy cover, but it also reactivates old dunes both by smothering vegetation and erosion of the old dunes because of grain-to-grain impact of the new sand on the old. The sand of the recent geologic past must have been derived also from dry stream beds, and this sand must have assisted in the activation of previously formed dunes.

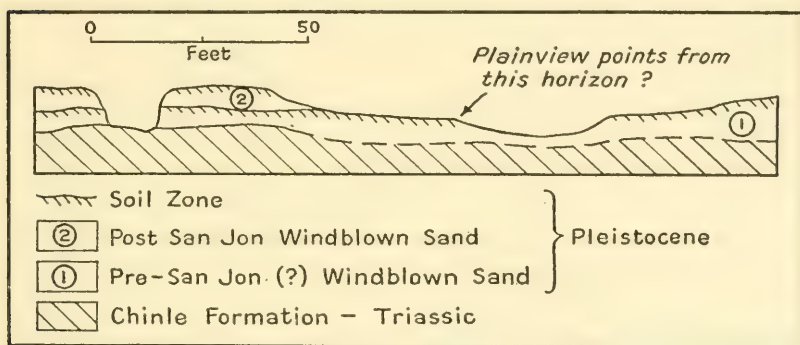


FIG. 22.—Section showing relations of wind-blown sand deposits and soil zones at Gibson ranch (J, fig. 1).

The fact that there are dunes now moving and also stabilized dunes indicates at least two periods of sand movement. The partially dissected dunes have a complex internal structure consisting of bodies of sand capped by soil zones. Thus stabilized dunes were formed in more than one period.

*Gibson site.*—On the ranch of Roy Gibson, approximately  $3\frac{1}{2}$  miles northeast of San Jon are several blowouts in a large dune area which show this complex internal structure (J, fig. 1).

In a blowout one-quarter of a mile east of the Gibson ranch house are two sands each with a soil zone at their upper surface. The oldest sand overlies red Triassic shale of the Chinle formation and forms the floor of the blowout. It has a known thickness of 5 feet. The sand is red, contains lime-carbonate concretions 1 inch in diameter, and carries a brown to black soil zone 2 to 3 feet thick at its top as shown in figure 22. Gibson has found three points identified by Roberts<sup>14</sup> as Plainview, raveling out of this old soil. A careful

<sup>14</sup> Personal communication dated February 13, 1948.

examination of the blowout produced no additional artifacts of similar type, although a few fragments of mineralized but unidentifiable bone were found in the soil horizon.

Over the lower sand lies 2 to 8 feet of buff to brown sand comparatively free of lime. It grades upward into a darker red at its top, a change in color undoubtedly due to soil-making process and indicating an old surface of stabilization. Spread over this upper sand is a discontinuous blanket of buff to white sand up to 12 inches in thickness.

Additional artifacts described by Roberts<sup>15</sup> as of comparatively recent age or of undiagnostic nature have been found in the blowout.

Eastward from this locality for about 2 miles are several additional blowouts which contain old bodies of wind-blown sand and each with a soil zone at its upper limit.

*Blowout north of San Jon.*—Two and three-quarter miles north of San Jon (K, fig. 1) State Highway 39 skirts a blowout in which are exposed two bodies of wind-blown sands. On the west side of the road there is exposed a buff to red sand 1 to 5 feet thick. It has a high lime-carbonate content, a considerable content of silt, and is capped by a lag gravel a few inches thick and composed of ironstone, quartzite, and sandstone pebbles. Above the lag gravel lies a sand of reddish color and small calcium-carbonate content. Its top supports a 12-inch zone of gray to black humic sand, an old soil zone, which is in turn overlain by recently deposited sand. On the east side of the highway, in the main excavation of the old sand, the blowout exposes this upper sand and its soil stands as a small ledge below the modern sand as shown in plate 5, figure 2. Presumably the lower sand was deposited in the San Jon-Sand Canyon interval and the upper sand in the Sand Canyon-Wheatland interval.

*Other localities.*—Two wind-blown sands predating the present have been seen at several other localities. Along Sand Canyon Arroyo (SE $\frac{1}{4}$ NE $\frac{1}{4}$  sec. 17, T. 9 N., R. 34 E.) a gray to white unconsolidated sand 5 to 7 feet thick overlies 3 feet of reddish silty sand. The older sand supports a vertical bank and at its top is a soil zone. The upper sand has a soil zone which carries the modern vegetative cover. Multiple eolian deposits are also present in the dune field east of Tucumcari Lake, east of Logan on the north side of the Canadian River and in various road cuts along U. S. Highway 66 as far east as Oklahoma. In none of these localities are there criteria by which the ages of the wind-blown sands may be determined.

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<sup>15</sup> Idem.

Five miles east of San Jon on the Gilstrap ranch ( $NE\frac{1}{4}SE\frac{1}{4}$  sec. 8, T. 10 N., R. 35 E.) pottery has been found in a modern blowout. This pottery, according to Roberts, probably dates from the late fourteenth or early fifteenth century. It may date from the deposition of the sand but more probably is correlative with the gray to brown soil developed at the top of this sand after its deposition and during Wheatland time.

#### SUMMARY

The foregoing discussions and summary tables of Pleistocene stratigraphy demonstrate that the sequence described from the San Jon site has a geographic extension well beyond the boundaries of the site. Although the deposits of a basin like that of the San Jon site are limited in area and cannot be traced outside the basin in which they were deposited, they reflect events which were neither singular nor unique but which obtained over a large area of the High Plains and the Valley Plains of the Canadian. Similar events in the same time intervals are recorded throughout the Southwest.

Fresh-water limestone and the formation, in part at least, of the "cover" of the Plains antedate the oldest Pleistocene horizon at the San Jon site. Pre-San Jon events in the Valley include the formation and dissection of a pair of gravel-covered pediments. Because these events cannot be fixed in time precisely and because they do not bear directly on the antiquity of the site, they will not be further considered.

The "Alluvial Chronology," which begins with San Jon time, is more important, however. A reexamination of table 2 will serve to fix it more firmly in the mind. In the Valley successive periods of alluviation in stream valleys are represented by the San Jon, Sand Canyon, and Wheatland formations. On the Plains lacustrine deposits of equivalent age collected in undrained depressions while alluvial phases of these deposits were laid down around the peripheries of these basins and in short streams draining to the escarpment. These periods of sedimentation were separated by epicycles of erosion. Valley streams incised their channels into previously deposited alluvium and took on an aspect very similar to the modern arroyos. Concurrently winds whipped sand and dust from the dry stream beds to form dunes on the interfluves and to reactivate stabilized dunes existing from an earlier time. Deflation predominated in the depressions of the Plains and loose material was piled up east of the depressions, and either added to the featureless "cover" of the Plains or removed entirely from the area. Where short drainages

flowed to the escarpment events duplicated on a small scale those of the Valley.

### THE "ALLUVIAL CHRONOLOGY"

The brief events of the "Alluvial Chronology," mere incidents in earth history, are unspectacular when viewed against the immense span of geologic time. Nevertheless, they coincide with the human occupation of the area from the time of the Paleo-Indian to the present. As such, these various events of the chronology are of intimate concern to the archeologist and demand a more careful examination. Thus it is important to consider the cause of alternate sedimentation and erosion and their wide distribution in the Southwest, and to discuss the relative age of the sequence of episodes.

#### CAUSES OF ALTERNATE SEDIMENTATION AND EROSION

The steep-walled, sandy-bottomed gullies of the ephemeral streams tributary to the Canadian River have characterized the Valley for the last half century. Previously, however—that is, from the time that the Spanish first crossed this country almost to the arrival of the first homesteaders—these streams had a much different aspect. Where today the deep gullies of the modern streams scar the valley floors, there were once smooth, grassy flood plains marked by shallow stream channels or quiet water holes, the *charcos*<sup>16</sup> of Spanish days. Vertically walled gullies, scarcely passable by foot, much less by horse or mule, today lie across the old Spanish trail which led from Santa Fe to San Antonio and crossed the streams of the Valley just north of the escarpment (fig. 1). In 1853 an exploratory survey seeking a route for a railroad to the Pacific and led by Lt. A. W. Whipple, U.S. Army Corps of Topographical Engineers, followed this trail quite closely. Whipple (1856) states that the "Arroyo de Barrancas" was a "flowing stream" and that "the water, tintured with red marl, was about two feet deep and six feet wide." He also reports the presence throughout the Valley of springs, pools of water, and stream bottoms bordered by groves of trees and green meadows, but no gullies are mentioned. In 1885 George Kilgore settled in the Valley before any gullies marked the tributary streams of the Canadian.<sup>17</sup>

<sup>16</sup> *Charco*, meaning stagnant pool of water, is still the name applied to a stream, tributary to the Plaza Larga, which must have been named by the Spanish before its present channel was scoured out. Arroyo Charco no longer has a *charco*.

<sup>17</sup> The writer is indebted to Wayne H. Miles of the Soil Conservation Office, Tucumcari, for the information on recent channel cutting gathered by him from the first American settlers in the area.

In January 1903, the *Quay County Democrat*, a weekly paper published in the vigorous frontier town of Tucumcari, eulogized "springs and pools of water" along the valleys which drained to the Canadian "across a billowy meadow unending."<sup>18</sup> But this eulogy was truly funereal for a wave of erosion was already sweeping over the "billowy meadow" and leaving deep, red, ugly gashes as it went. T. L. Reid passed through the country in 1902 and found that the Plaza Larga was channeled west of what is now Highway 18 and that Charco Arroyo, a tributary, was cut to a distance of 3 miles beyond this point. Returning in 1905, Reid found that the Charco had been channeled for another 9 miles upstream, and he reports that by 1910 the gully had reached the escarpment, 8 miles farther. According to Robert Abercrombie, the Barranca Arroyo was badly eroded when he arrived in the Valley in 1904, but local stockmen told him at the time that a few years previously it was unchanneled. Bull Canyon, a tributary to the Pajarito west of Tucumcari, began to cut its channel in 1908 or 1909. Fifty years ago Ute Creek, entering the Canadian from the north, was a permanent stream. According to Mosé Romero, who has lived his entire life in the area, the Ute was rapidly eroded and became intermittent in flow about 1904. Specific information is lacking for many streams. But, in general, rapid erosion swept up the major tributaries of the Canadian sometime around 1900, slightly earlier in some instances, and a bit later in others.

The cause of this sudden change in stream regime is in dispute. It of course could be effected by a change of gradient through tilting of the land downstream. Huntington (1905) and Hack (1942) have pointed out that orogeny so nicely adjusted to the drainage pattern is inconceivable and that it is completely unacceptable as a prime cause of erosion. Nor is it possible to believe that periods of sedimentation were the result of the reversal of such warping. Furthermore, sedimentation and wind erosion within the depressions on the Plains and correlative in time with filling and trenching in the streams of the Valley can in no way be explained by differential warping of the land.

As pointed out by Hack (1942) the explanation of the steepened stream gradients necessary to produce erosion must be a result of a change in the transporting power of the streams because of an increased rate of discharge. He further argues that this increased discharge is due not to increased precipitation but to a decrease in the effectiveness of the vegetative cover. Thus rate of run-off is increased by a thinned and weakened plant cover and erosion follows.

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<sup>18</sup> *Quay County Democrat*, vol. 2, No. 19, p. 1, Saturday, January 16, 1903.

Disagreement arises as to the manner in which the vegetation is weakened. A change in climate toward the dry to a degree sufficient to decrease the amount of grass would in itself start an erosion interval. On the other hand, it is argued that overgrazing and improper cultivation of the land is a more reasonable cause of erosion than a change in climate (Antevs, 1952). This second argument can be applied with some justification to the Valley. The modern epicycle of erosion began just before a wave of homesteaders displaced large herds of longhorn cattle. Erosion continued while these same homesteaders overworked land holdings too small for their needs. The apparent cause-and-effect relationship between injudicious land use and erosion is very persuasive and climatic change as a cause of gullying in this area might be logically untenable were it not for the record of the past.

The climate during San Jon time was moister than it is today. The very presence on the Plains of lakes of some permanence points to either increased precipitation or decreased evaporation. Even the existence of large and now-extinct animals indicates a better vegetative cover. It is inconceivable that a mammoth could survive on the meager vegetation and surface water of today, and its presence in San Jon time indicates a lusher plant cover thriving in a climate effectively "moister" than the present. The subsequent epicycle of erosion was obviously drier, for wind-blown sand dates from this period and an old dune system thought to be of equivalent age is found throughout the area.

It has been shown that the depressions of the Plains are excavated by deflation during periods of aridity and that these dry periods are separated by moist periods during which lakes exist in the basins. Deflation of the basin containing Hatfield Lake occurred both during and after the deposition of the Sand Canyon formation. It must be assumed that a moist climate obtaining during Sand Canyon time was preceded and followed by a more arid climate. In the Valley deposition in Sand Canyon time healed the old channel scars and presumably occurred in a moister climate than that of the preceding erosion interval.

Douglass's tree-ring chronology, as summarized by Schulman (1938), shows four major droughts since A.D. 11. The greatest of these occurred between A.D. 1276 and 1299, or immediately preceding the epicycle of erosion separating the Sand Canyon and Wheatland formations. It seems logical to presume that this drought precipitated the erosion which spanned most of the fourteenth century.



The same tree-ring record shows that a fifth drought, perhaps of major proportions, began in 1880, and Bryan (1925) has shown that the last half of the nineteenth century was unusually dry and culminated in the present epicycle of erosion everywhere in the Southwest after 1880.

More recently Leopold (1951) has analyzed the frequency of rainfall as recorded at long-record weather stations in New Mexico. He has shown that, although the variation in the total annual rainfall has been slight during the last 100 years, the variation in the frequency of rains of differing sizes has been significant. Thus in the early part of the last 100 years New Mexico experienced a low frequency of small rains. Such rains provide the main moisture for grass growth. Therefore a low frequency would tend to weaken the grass cover and make the ground susceptible to erosion.

During the last half of the nineteenth century the frequency of rains of intermediate size was slightly higher than the present and the frequency of large rains about the same. These are the rains that, because of rapid run-off, promote erosion. They would be most effective during periods of low frequency of small rains. Here then is a factor that would encourage erosion which began in this area about 1900 and elsewhere in the Southwest about 15 years previously.

Thus the immediate geologic past has been marked by periods of erosion during dry climates and by intervening periods of more effective moisture during which sedimentation occurred. The modern epicycle of erosion, while perhaps abetted by misuse of the land, has probably been largely conditioned by increasing aridity. In all likelihood man has merely hastened an inevitable period of stream channeling.

In the preceding discussion aridity has been correlated with erosion and increased moisture with sedimentation. During the latter half of the "Alluvial Chronology," however, it is quite probable that variation in the frequency of rains of different sizes as well as increases in evaporation rates due to rising temperatures did more to promote aridity and hence erosion than did decreases in the total precipitation. On the other hand, the San Jon formation, as will be seen later, is correlated in part with glacial advance in more northerly latitudes. Under such conditions the belt of cyclonic westerlies must have been displaced southward by a more southerly polar front than now exists. The now arid and semiarid Southwest may very well have enjoyed a greater actual precipitation as a result.

## DATING THE EVENTS OF THE "ALLUVIAL CHRONOLOGY"

The Sand Canyon-Wheatland epicycle of erosion, the Wheatland formation, and the modern channel cutting can be dated by archeologic and historical methods. Thus the modern gulches date from the turn of the last century. The Wheatland formation has yielded a single fragment of late fourteenth- to fifteenth-century pottery, and pottery thought to come from a soil equivalent to the Wheatland is of the same age. Pottery and artifacts dated as falling somewhere between A.D. 1150 and 1300 have been found in eolian deposits of the Sand Canyon-Wheatland interval. Probably the erosive interval occupied the greater part of the fourteenth century, and the Wheatland formation began to collect about 1400. Alluviation was initially rapid until the old channel was filled and the stream reached grade. Thereafter, and until the onset of the modern erosion, sedimentation was for all practical purposes nonexistent. The Sand Canyon-Wheatland interval also provides an upper date for Sand Canyon time, A.D. 1300. The upper part of the Sand Canyon formation, therefore, must have occupied a part of the Christian era.

The artifacts and fossils from the Sand Canyon and San Jon formations are of little help in precise dating. The hope is that eventually the artifacts, at least, will be well enough defined to serve as definite time markers. Until then the earlier events of the "Alluvial Chronology" must be dated by some other means. Included would be the use of the climatic argument, pollen analysis, and the newly developing technique of dating by radiocarbon. These three approaches are used in the following discussion.

The climatic argument is based on the assumption that the deposits containing evidence of man's presence reflect events which have a wide geographic extension related to world-wide climatic fluctuations which in themselves can be assigned dates in terms of actual years.

It has already been seen that the "Alluvial Chronology" is developed throughout the area here studied and that the sequence at the San Jon site is related to it. This same chronology is reported across the Southwest from the Big Bend of Texas to the Hopi Country of Arizona, as shown in tabular form in table 4. The climatic pulsations represented by these various periods of sedimentation and erosion can be tied by argumentation to the already dated events of glacial advance and retreat in North America and Europe. Such a correlation involves the following assumptions: (1) That late Pleistocene climatic fluctuations are world-wide and synchronous, and (2) that they

are expressed in the geologic record. The discussion to date has demonstrated that man at the San Jon site is related to a local sequence and that this sequence has climatic implications and a wide geographic extension. It is assumed from this point that the local record and its southwestern equivalents are correctly interpreted and reflect world-wide and synchronous climatic changes susceptible to a dating in terms of years. What, then, are the phases of this world-wide chronology, what are the dates, and how do they relate to the "Alluvial Chronology"?

In general and oversimplified terms the last major advance of continental and mountain glaciers throughout the Northern Hemisphere has been followed by an increase in heat to a maximum well in excess of our present temperatures. From this point of maximum warmth temperatures dropped, a trend which has continued, with minor interruptions, to the present.

The central section of this climatic curve, the period of great warmth following upon the last deglaciation, occupies a key position in dating the "Alluvial Chronology." This intensification of heat, this Megathermal Phase, is recorded throughout Europe and the United States and is the "Postglacial optimum" of many writers.<sup>19</sup>

Dates are assigned the Megathermal Phase by pollen analysis, salt concentration of southwestern lakes, and the newly developing method

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<sup>19</sup> "Postglacial optimum," although widely used, is not a satisfactory designation for this time period. "Postglacial" is obviously inappropriate because we are still in the Pleistocene, an epoch characterized by recurrent glacial advances and retreats. "Optimum" here refers to the most favorable growth conditions for a temperate flora. As such it is applicable to much of Europe where increased temperature combined with greater moisture. Throughout the United States, however, and probably throughout much of the rest of the world, the increase in warmth was not accompanied by increased moisture. In the American Southwest increased temperature produced aridity, and conditions favoring a temperate flora were at a minimum. Furthermore, "optimum" is a superlative and implies a single point in time and we wish to designate a period of time which includes this point.

An acceptable term, therefore, would eliminate the concept of "Postglacial," would include the fact that increased heat is the only universally present climatic change, and would avoid the use of a superlative.

Antevs (1948), in discussing this problem of nomenclature, has suggested "Altithermal" to replace "Postglacial optimum" and his old "Middle Postglacial" (Antevs, 1931). It is here suggested that "Megathermal" would be more correctly derived, having both roots in Greek ( $\mu\epsilon\gamma\alpha$  = great or large, and  $\theta\epsilon\rho\mu\acute{o}\varsigma$  = heat). For a period or periods of minimum heat Oligothermal ( $\acute{o}\lambda\iota\gamma\omicron$  = least, and  $\theta\epsilon\rho\mu\acute{o}\varsigma$  = heat) is immediately available.

Megathermal is used below combined with "Phase" to avoid the obvious inappropriate use of "age" or "period."

TABLE 4.—Correlation of the "Alluvial Chronology" and human cultures from selected localities in the Southwest

EVENTS	EASTERN NEW MEXICO JUDDSON	HIGH PLAINS OF WEST TEXAS	BIG BEND, TEXAS	HOPI COUNTRY, ARIZONA	WHITewater DRAW, ARIZONA
EROSION AND WIND ACTION *	MODERN DUNES MODERN CHANNEL CUTTING	PRESENT ACTION PRESENT ACTION	MODERN CHANNEL CUTTING	MODERN DUNES MODERN CHANNEL CUTTING	MODERN CHANNEL CUTTING
DEPOSITION NO. 3	SINCE 1910 SINCE 1900	MONAHANS FM. (UPPER PART) MODERN CHANNEL CUTTING O	KOKERNOT FORMATION	PRESENT ACTION SINCE 1910 †	SINCE 1885?
EROSION AND WIND ACTION	WHEATLAND FORMATION	LOW TERRACE O AND RECENT FILL	CHISOS FOCUS 800 - 1400 A.D. LIVERMORE FOCUS	AFTER 1300 A.D.	POTTERY CULTURE AFTER 1300 A.D.
EROSION AND WIND ACTION	CHANNEL CUTTING ON STREAMS DEFLATION OF SOME DEPRESSIONS	MONAHANS FM. (MAIN BODY) CHANNEL CUTTING O	CHANNEL CUTTING	AFTER 1200 A.D. BEFORE 1500 A.D. PROBABLY ABOUT 1300 A.D.	AFTER 1200 A.D. POTTERY
DEPOSITION NO. 2B	UPPER SAND CANYON FORMATION	INTERMEDIATE TERRACE O	UPPER CALAMITY FORMATION	OCCUPATION OF UNKNOWN AGE	SAN PEDRO STAGE 2463 ± 310
EROSION AND WIND ACTION	CHANNEL CUTTING WINDBLOWN SAND	RECENT FILL	EROSION ?	2000 B.C. ± ?	BROAD CHANNELS CUT
DEPOSITION NO. 2A	LOWER SAND CANYON FORMATION	CLAY FILL (?) "CLAY FILL" YUMA - AFTER 3500 - 2000 B.C.	LOWER CALAMITY FORMATION	POSSIBLY EROSION	BROAD CHANNELS CUT
EROSION AND WIND ACTION	CHANNEL CUTTING SAND DUNES DEFLATION OF DEPRESSIONS	JUDKINS FM. O CHANNEL CUTTING (MEGATHERMAL PHASE)	MARAVILLAS COMPLEX CHANNELS CUT (MEGATHERMAL PHASE)	"POST-GLACIAL OPTIMUM" (MEGATHERMAL PHASE)	CLAY AND SAND CLAY AND SAND
DEPOSITION NO. 1	SAN JON FORMATION	HIGH TERRACE O LATE PLEISTOCENE FILL TAHOCA CLAY	NEVILLE FORMATION	DUNES CHANNEL CUTTING	BROAD CHANNELS CUT (MEGATHERMAL PHASE)
	BEFORE 5400 - 5000 B.C. SAN JON POINT FOLSOM POINT? PLAINVIEW POINT? TAYLOR, EQUUS.	PLAINVIEW POINTS ELEPHAS, BISON TAYLOR, EQUUS.	NO KNOWN OCCUPATION ELEPHAS, EQUUS.	PRIOR TO 6000 B.C.? NO KNOWN OCCUPATION PROBOSCIDEA	SULPHUR SPRINGS STAGE 6210 ± 450 7156 ± 360 EQUUS, ELEPHAS, CAMELOPS, ETC.

† IN PART REINTERPRETED \* LACUSTRINE DEPOSITION CONTINUES WITHIN UNDRAINED DEPRESSIONS  
 \* NOT REFLECTED AT SAN JON SITE ◊ SELLARDS ET AL.. (1947) ▲ IN PART REINTERPRETED  
 ◊ ALONG EASTERN MARGIN OF PLAINS  
 ● RADIOCARBON DATES FROM LIBBY (1952)

of radiocarbon. The pollen method needs no amplification here. Two studies are of prime importance, however. Both claim an absolute value in terms of our calendar. In 1938 Fromm was able to tie his pollen study to Liden's varve sequence in Lake Ragunda in Sweden and thus construct an absolute chronology extending from 6700 B.C. to A.D. 900. He considered that the Megathermal Phase began about 5000 B.C., reached a peak about 4200 B.C., and ended with a degeneration of climate commencing about 3500 B.C. Welten (1944) has studied the pollen in a Swiss bog that contains annual laminations from 7550 B.C. to A.D. 1920. His pollen profile shows a Megathermal Phase extending from perhaps 5400 B.C. and certainly 5000 B.C., reaching a thermal maximum at 4300-4200 B.C., and ending about 3200 B.C.

Van Winkle (1914) concluded that certain undrained lakes in the Great Basin came into existence about 2000 B.C. Antevs (1948) arbitrarily adds 500 years to this figure and considers that 2500 B.C. is terminal for the Megathermal Phase.

The development of the radiocarbon technique holds great promise of adding exactitude to dates in the late Pleistocene throughout the world. Numerous radiocarbon dates have already been released (Libby, 1952). The writer is not in a position to evaluate the exactitude of the dates or the method. Undoubtedly future work will refine the method and encourage more accurate and extensive collection of usable material. Several dates are referred to below with the realization that additional work may demand their revision.

Of the radiocarbon dates thus far available a single determination applies directly to the Megathermal Phase. A peat sample from this horizon at Shapwick Heath, Somerset, England, gave an age of  $6,044 \pm 380$  years before the present. This agrees with the dates reported by Welten and Fromm.

The epicycle of erosion separating the San Jon and Sand Canyon deposition is the most extensive erosional in the "Alluvial Chronology." The evidence also indicates it to be the warmest and incidentally the driest in the chronology. Therefore it is correlated with the Megathermal Phase.

The Megathermal Phase precedes Sand Canyon time and defines its lower limit. We have already seen that Sand Canyon time ended with an erosional interval which occurred in the fourteenth century A.D. Therefore Sand Canyon time, and hence the Sand Canyon formation, must have begun as temperatures fell from their highest during the Megathermal Phase and continued to the fourteenth century A.D. The lower limit of Sand Canyon time corresponds to the

end of the Megathermal Phase, a date which is as yet unfixed and probably varied from place to place. The dates given in a preceding paragraph suggest that it ended between 3500 and 2000 B.C.

The "Alluvial Chronology" of southeastern Arizona has been reported by Sayles and Antevs (1941). Radiocarbon dates have since been obtained within this chronology. The San Pedro cultural stage reported by Sayles and Antevs is here considered in part contemporaneous with Sand Canyon time. A single radiocarbon date in this cultural stage is listed as  $2,463 \pm 310$  years (Libby, 1952). This is within the limits suggested above for Sand Canyon time. A radiocarbon date from the Chiricahua cultural stage is listed as  $4,006 \pm 270$  years. The Chiricahua stage is stratigraphically below the San Pedro and is separated from older beds by a well-marked erosional interval here presumed to represent the Megathermal Phase. Thus the Chiricahua stage is considered to fall within Sand Canyon time. The radiocarbon date is within the limits previously suggested for Sand Canyon time.

It has been shown that the Sand Canyon formation is double and that a period of erosion splits the formation. An erosional interval of deposits here correlated with the Sand Canyon formation is reported from southeastern Arizona (Sayles and Antevs, 1941), from northeastern Arizona (Hack, 1942), from western New Mexico (Leopold and Snyder, 1951), and from Trans-Pecos, Texas (Albritton and Bryan, 1939).

One of the difficulties arising in considering the age of the San Jon formation is the lack of adequate exposures. No guarantee exists that the sediments assigned a San Jon age do not actually represent several stages of alluviation separated by intervals of erosion. In any event the end of San Jon time has been defined by the beginning of the Megathermal Phase or between 5400 and 5000 B.C. Lacking definite evidence to the contrary, San Jon time is considered as uninterrupted by epicycles of erosion.

San Jon time was relatively cool and moist. Because of this and because it preceded the Megathermal Phase it is correlated in part with a time when glacial climate obtained to the north. It is reasonable that this time was marked by either the Corral Creek or Long Draw substages of the Rocky Mountains (Bryan and Ray, 1940) and represented elsewhere on the North American continent by the Late Mankato (St. Johnsbury) or Cochrane (?) substages, respectively. The writer knows of no evidence in eastern New Mexico or elsewhere in the Southwest which would indicate with which substage the earliest formation of the "Alluvial Chronology" is correlative.

Very probably, however, San Jon time covers both glacial substages and the climatic oscillation which separated them is not reflected in the "Alluvial Chronology."

Radiocarbon dates of the Two Creeks forest beds, Wisconsin, average  $11,404 \pm 350$  years (Libby, 1952). This forest bed is of the same age as the advance of the Valdres (Mankato) ice at Two Creeks about 100 miles north of its terminus near Milwaukee. Therefore its maximum stand is younger than the Two Creeks forest bed by some unknown amount. Because the Valdres ice produced no marked terminal moraines or outwash plains it is not thought to have stood long at its maximum advance (Thwaites, 1943). The exact age of its maximum advance, however, does not affect this discussion. San Jon time includes the advance, maximum, and retreat of the Mankato ice and the Cochrane stand up until the beginning of the Megathermal Phase between 5400 and 5000 B.C.

Furthermore, a radiocarbon date from a horizon near Lubbock, Tex., regarded as Folsom by E. H. Sellards, Grayson Meade and Glen L. Evans, is given as  $9,883 \pm 350$  years (Libby, 1952). This date falls well within the interval suggested for San Jon time and is about 1,500 years younger than the arrival of the Valdres ice at Two Creeks, Wis. This ice continued another 100 miles to the south before reaching its greatest advance.

Radiocarbon dates from the Sulphur Springs culture of southeastern Arizona (Sayles and Antevs, 1941) are given as  $7,756 \pm 370$  and  $6,210 \pm 450$  years. The sediments in which the culture is entombed are here considered correlative with the San Jon formation. The latter date seems a little young. If correct, it points to a somewhat later beginning for the Megathermal Phase than here suggested.

In the preceding discussion the Sand Canyon formation is considered to represent a slightly cooler and moister time following the Megathermal Phase, and San Jon time to represent a cool, moist period preceding this Megathermal Phase and spanning both the Mankato and Cochrane ice maxima of the north. Another possibility exists, namely, that the San Jon formation is correlative with the Mankato ice advance, the Sand Canyon formation is equal in time to the Cochrane advance, and the erosive interval separating them reflects withdrawal of ice between Mankato and Cochrane advances. Future work may prove such a correlation but on the basis of the evidence now at hand, it is discarded because: (1) The interval separating San Jon and Sand Canyon time was marked by great aridity, wind action and erosion; (2) this desert climate was so marked that it seems doubtful that it is a reflection of the minor

climatic oscillation separating the Mankato and Cochrane ice maxima, but only of the major increase in warmth during the Megathermal Phase; (3) certain facts suggest that the Sand Canyon formation lies at least partially in the Christian Era; and (4) the time from the Mankato climax to the present is best filled by considering the Sand Canyon formation as deposited after the Megathermal Phase.

The dates of the various events of the "Alluvial Chronology" in eastern New Mexico are included in table 2. The events in eastern New Mexico are correlated in table 4 with similar events elsewhere in the Southwest.

## GEOLOGIC ANTIQUITY OF THE SAN JON SITE

### GENERAL STATEMENT

The discussion contained in the preceding section, although detailed and laborious, has set the stage for a consideration of the antiquity of the San Jon site. Archeologic investigations by Roberts (1942) established four distinct cultural levels at this site. From oldest to youngest these contain: (1) A point termed San Jon in association with extinct bison; (2) points called "Collateral" Yuma having affinities to both Eden and Scottsbluff-type Yuma, but in association with modern bison; (3) points related perhaps to the Clear Fork type of West Texas and also associated with modern bison; and (4) an obviously more recent group of artifacts with associated pottery. The relative stratigraphic positions of these four levels as set forth by Roberts is confirmed by geologic methods. More precise ages for the three earlier levels than can be inferred from their cultural and faunal content are suggested below.

### THE SAN JON LEVEL

The single San Jon point was found near the top of the San Jon formation. This formation reflects a cool, moist climate partially correlative in time with the presence of glacial ice in northern United States and southern Canada. Its deposition began with the first stages of Mankato ice advance. San Jon time continued to the beginning of the Megathermal Phase at 5400 to 5000 B.C. and perhaps slightly later.

Because the San Jon point comes from a level high in the formation, it is probably late in San Jon time. Because it was found in deposits indicating continuing moisture it is probably older than the stage immediately preceding the Megathermal Phase. A classic-type Folsom point was discovered at the site raveling out of a level correlative



with that in which the San Jon point was found and is thus similar in age to the San Jon point. This San Jon point lies in time between the Two Creeks forest bed, 9454 B.C.  $\pm$  350 years (11,404  $\pm$  350 years before the present), and 5400 to 5000 B.C.

The Plainview points found on the Gibson ranch in the Valley bear an uncertain relation to the San Jon point. They are said to have come from a soil zone which is developed on wind-blown sand. This soil may have formed in San Jon time, in which case the Plainview points could be more or less contemporaneous with the San Jon point. In this regard it is appropriate to note that the Plainview points at the type locality (Sellards et al., 1947) are found in association with extinct bison and at the top of a fluvial deposit correlated with the San Jon formation. (See table 4.)

#### "COLLATERAL" YUMA LEVEL

A long period of time separates the people who made the San Jon point, and presumably the Folsom point, from those who fashioned the "Collateral" Yuma projectiles found in the next youngest cultural level. During this period the climate of San Jon time became increasingly warmer and drier, until it ended with the beginning of the Megathermal Phase between 5400 and 5000 B.C. This phase was a time of great aridity in which moving sand was common throughout the area and stream erosion was rampant. At the site the depression containing the lake sediments of San Jon age was breached by a stream eating headward into the escarpment from the valley below and broad channels were carved in the San Jon formation. At some time between 3500 and 2000 B.C. the Megathermal Phase ended and the deposits of the Sand Canyon formation began to fill the old stream channels at the site. The giant buffalo, failing to survive the arid Megathermal Phase, was replaced by the smaller modern bison. A people using "Collateral" Yuma projectile points hunted this new arrival and the points are found associated with the bones of *Bison bison*, in the earliest deposits of Sand Canyon time. The occurrence of the "Collateral" Yuma points indicates a maximum age of between 3500 and 2000 B.C. for the people who made them. Whatever the exact age it must lie early in Sand Canyon time shortly after the end of the Megathermal Phase.

The above dates are assigned on the assumption that the Sand Canyon formation was deposited subsequent to the Megathermal Phase. If, as previously discussed, the Sand Canyon formation antedates the Megathermal Phase, then a much earlier date for the

"Collateral" Yuma points is indicated. The same is true in relation to the Clear Fork (?) points discussed below.

#### CLEAR FORK (?) LEVEL

In deposits of Sand Canyon age but at a level stratigraphically higher than that containing "Collateral" Yuma points are projectiles bearing affinities to those of the Clear Fork complex of West Texas. They must be younger than the "Collateral" Yuma and older than the end of Sand Canyon time, i.e., A.D. 1300. A more precise age is difficult to determine. The break in Sand Canyon time recorded in the Valley below is not reflected at the site, or, if it is, has not been identified. Therefore, the Clear Fork (?) cannot be placed in relation to this horizon. Furthermore, Kelley's review of the Clear Fork (1947) indicates that it occurs throughout deposits correlative with the Sand Canyon formation. The Clear Fork (?) points, therefore, are younger than the "Collateral" Yuma points. They are older than A.D. 1300 by an unknown interval of time.

#### POTTERY LEVEL

The stone cultures associated with pottery were found in trenches excavated in the gentle slopes east of the deep gullies of the San Jon site and cannot be directly tied to the "Alluvial Chronology." Roberts (1942), however, dates the pottery as late as the fourteenth or early fifteenth century A.D. On this basis the material is probably of early Wheatland age.

#### GENERAL CONSIDERATIONS

The single most interesting fact gleaned from the geologic investigation is the relatively late date of "Collateral" Yuma and its relation to the much older San Jon and Folsom levels. Sellards has reported (1950) that the Yuma points of the Clovis-Portales region 45 miles south of San Jon are stratigraphically above the true Folsom and the Clovis-fluted points. The Yuma points found at the San Jon site are of a younger age than that usually assigned to this type of projectile. Radiocarbon, for instance, dates the Yuma of the Horner site, near Cody, Wyo., as  $6,867 \pm 250$  years (Libby, 1952). Moss (1951) states that at the Eden site, Wyoming, the Yuma predates the Megathermal Phase. On the basis of the available evidence there is little doubt, however, that at San Jon they postdate the Megathermal Phase and are separated by a considerable time span from the earliest cultural level at the site.

The physical evidence also tends to demonstrate that if this Yuma evolved from one or more of the earlier stone cultures then this evolution has not been accomplished in the vicinity of the site. The break in time between San Jon and Yuma peoples is too great. Furthermore, it is marked by extreme aridity which both man and beast must have found inhospitable. We do not know whether man roamed the deserts which intervened between San Jon and Sand Canyon times, but if he did it is safe to assume that his numbers were small. Certainly the giant buffalo did not survive the interval and was replaced by the modern, smaller form. The horse and mammoth, also present in San Jon time, were extinct by Sand Canyon time.

Dates have been applied to the prepottery cultures of the San Jon site with the full realization that they lack precision. This inadequacy is due in part to the uncertain nature of the dates of the late Pleistocene climatic fluctuations, and in part to the lack of distinctive intraformational horizons in San Jon and Sand Canyon time. Nevertheless, these dates seem of the correct order of magnitude, and the relative chronologic positions of the various cultures appear firmly established.

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SMITHSONIAN MISCELLANEOUS COLLECTIONS  
VOLUME 121, NUMBER 2

THE BIRDS OF THE ISLANDS OF  
TABOGA, TABOQUILLA, AND  
URAVÁ, PANAMÁ

BY  
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(PUBLICATION 4099)

CITY OF WASHINGTON  
PUBLISHED BY THE SMITHSONIAN INSTITUTION  
DECEMBER 2, 1952

The Lord Baltimore Press  
BALTIMORE, MD., U. S. A.

# THE BIRDS OF THE ISLANDS OF TABOGA, TABOQUILLA, AND URAVÁ, PANAMÁ

BY ALEXANDER WETMORE

*Secretary, Smithsonian Institution*

(WITH THREE PLATES)

The island of Taboga lies in Panama Bay, off the Pacific entrance of the Panama Canal, slightly less than 6 miles south from Bruja Point, the nearest spot on the mainland. Taboguilla is a mile and a half north of east from Taboga, and Uravá Island is immediately adjacent to Taboga on the southwest, the two being separated by a narrow channel. An islet, El Morro, on the northeast, is in reality a part of the larger island, as the two are joined by a sandy beach that is covered at high tide. The pleasant town of Taboga (pl. 1, fig. 1), crowded between the inland hills and the beach, has narrow streets terraced one above the other, with Restinga, a tourist development especially popular on weekends, situated along the sandy beach at its northern extension. There are few houses outside the town, except for the installations of the Air Force on the summit of the island for the operation of a radio beacon. On Taboguilla and Uravá there are small houses used by farmers who come from the larger island, but there is now no permanent population.

Although I have not made exhaustive search into the history of the Spanish use of Taboga, it appears that it was settled early, as would be expected from its reputation for healthy and pleasant living conditions as a result of its lack of mosquito-breeding swamplands and its location in the cooling passage of the trade winds. Vázquez de Espinosa, who traveled through the Spanish part of the New World for ten years at the beginning of the seventeenth century and wrote in meticulous detail of what he saw, does not mention Taboga in his account of Panamá, a circumstance that perhaps may mean that at that early date the island was merely the site of fincas, or perhaps was not permanently occupied. The buccaneer captains Sawkins and Sharp, accompanied by their physician Lionel Wafer, in May 1680 are said to have landed for a time on Taboga to rest in the dry-season homes of the Spaniards, so that apparently there was a small settlement then.

From this early date onward Taboga was noted as a resort for convalescents and for those who sought relief from the humid heat of the city of Panamá. In World War II the islands were strongly fortified, with a considerable concentration of military forces, which have left heavy mark on the natural features, though now the shelters and stations are abandoned and have in considerable part disappeared. Fortunately camouflage demanded preservation of cover, so that parts of the forest escaped destruction, and the abundant plant growth of the rainy seasons has gone far in covering these man-made scars.

In journeys across the open Bahía de Panamá, beginning in 1921, I have had views of Taboga and its smaller neighbor islands on various occasions, both from the sea and from the air, and have been intrigued by the possibilities that the bird life there might offer. Naturalists have collected the reptiles, amphibians, and plants, but little has been recorded of the birds, except the belief that, aside from the nesting sea birds, they were practically nonexistent. Opportunity to visit Taboga came in the dry season of 1952 when, after an excursion to the Río Indio on the Caribbean coast of Panamá, I had ten days free before I had to return to an administrative desk in Washington.

Through the friendly interest of Brig. Gen. E. C. Kiel and the assistance of Col. Philip D. Coates, Commanding Officer, Albrook Air Force Base, and Lt. Col. J. M. Martin, in charge of transportation, I crossed to Taboga on an Air Force crash boat the morning of March 14, returning to Balboa on March 24 on an LSM of the same service. W. M. Perrygo, of the U. S. National Museum, who has been my companion in work in Panamá since 1946, accompanied me. While on the island we were particularly indebted to Sgt. Joe E. Curlott, Jr., stationed on Taboga, who took us by truck on several occasions to the summit of the island and lightened our work in other ways by transportation during the strong heat of midday. We lived comfortably and pleasantly in the Hotel Taboga, of Julio Chu and his brother. On March 18 and 20 we crossed to Taboguilla Island and on March 22 visited Uravá. Our other days were spent on Taboga. In all we secured 127 birds, representing 23 species (with 2 additional subspecies).

Taboga Island is about  $2\frac{1}{2}$  miles long by  $1\frac{1}{4}$  miles wide, with a cove on each side that constricts the diameter considerably near the center. The high point on the island (pl. 1, fig. 2) rises to 1,010 feet, with a steep face on the west, a more gradual one to the east, and sloping, low-lying flats to the north. Another low area makes connection with the southwestern section, where a steep hill rises to 665 feet (pl. 2, fig. 2). The southern side has a considerable tract of original forest,

rather difficult of access, with other forested areas on the west and along the bases of the steeper slopes. The higher levels above 800 feet on the northern portion and above 450 feet on the southwest part are areas of poor, stony soil, with many rock exposures, without forest but grown thinly to bunch grass and with occasional thickets of low bushes. There is permanent water in the higher sections that even near the close of the dry season supplies small pools in the stream beds at the bases of the hills. The village lies near the center of the eastern side of the higher section, where it receives the welcome sweep of the northeast trade winds.

Taboguilla Island (pl. 2, fig. 1) is about a mile long and two-thirds of a mile wide, rising in a peak to 610 feet. Two rocks, with summits covered with shrubs, lie off the southwest end, and an open bay on the northwest has an extensive sandy beach that is mainly covered at high tide (pl. 3, fig. 1). The island is wooded, with small clearings for cultivation. I found scanty water seeps in the lower stream beds that descend from the peak.

Uravá Island, connected with the southeastern end of Taboga by a shallowly submerged reef, has a central peak 600 feet high (pl. 3, fig. 2). It is wooded, with clearings for cultivation on the western side, where there are scanty water seeps.

Rains on the islands are reported to be heavy, while the dry season is equally dry. During March the view of the mainland was frequently obscured by smoke from fires set to burn off the brush and trees felled in clearing land for planting.

Although, as I have stated, naturalists have studied the plants, reptiles, amphibians, and mollusks of Taboga, few have given attention to its birds. The abundant avifauna of the mainland has so overshadowed the few species found on these islands that there has been little incentive to make collections on them. The earliest collector of whom I find record is Fred Hicks, who sent to the Smithsonian Institution a yellow warbler and four hummingbirds taken on Taboga on January 31, 1865. Among specimens purchased for the National Museum from the Rev. H. Th. Heyde there are five hummingbirds from Taboga taken in August and September 1888.

In the collection made by Thomas Hallinan in 1915, now in the American Museum of Natural History, there are 11 skins, including 6 species, that were taken on Taboga and Taboguilla on March 27, August 15, September 12, and December 5, all except one tropical kingbird being sea birds. Ludlow Griscom was on Taboga on February 17, 1924, in company with Thomas Barbour, W. S. Brooks, and Ned Wigglesworth. Eugene Eisenmann has visited Taboga on several

occasions during the rainy season, and I am indebted to him for notes on certain species that I did not find myself. Undoubtedly there have been other ornithologists who have made visits of a day or so, of whom I have not learned, but so far as I am aware no systematic collection of birds has been made prior to my work of 1952.

The list assembled in the present paper includes 54 forms, of which two, the large-billed hawk and the golden warbler, were found only on Taboguilla. Of the total, 21 are passage migrants, among which the black and fluttering petrels, except on rare occasions, are found only at sea. The caracara is without doubt a wanderer from the mainland.

Of those remaining, 23 are assumed to nest, while the others may do so in small numbers, but this is not certain. The small list of those that are believed to breed includes two kinds of pigeons, four of hummingbirds, and four flycatchers, the others being single representatives of their families. At least 15 times as many kinds nest on the mainland in the area visible from the summit of Taboga, which makes the small list for the islands surprising, in view of the short space of ocean involved. The lack of the ruddy ground dove is especially noticeable, as is the absence of ant-shrikes, additional flycatchers, tanagers, and other members of the sparrow family. It is possible, of course, that some forms have become extinct through human occupation, but this could hardly apply to the smaller, inconspicuous species of birds that on the mainland of Panamá live regularly around fields and gardens.

Relationship of the avifauna on the whole seems close to that of the Pearl Islands, out of sight below the horizon to the southwest. This is demonstrated in the hummingbird *Amazilia edward margaritarum*, which is the form of the larger islands in the Perlas group and is distinct from the representative race of this species found on the adjacent mainland. It is revealed also in the elainea, and in the saltator, described here as new, that are nearer to the island form in each case than to that of the mainland. The vireo *Vireo flavoviridis insulanus*, which is found on the mainland from the Canal Zone eastward, as well as in the Pearl Islands, seems to attain the maximum of its subspecific characters on Taboga and its neighboring islets.

According to paleogeographers the existing land connection between North America and South America through the Isthmus of Panamá has been continuous since its establishment in Late Pliocene time. It is supposed that the land area on the Pacific side of the isthmus may have been more extensive in the early stages, so that the mainland may have included the area where we now find the islands under discussion. On this premise, purely as a matter of speculation,

the recession of the shoreline, leaving Taboga, Taboguilla, and Uravá as islands, may have come early, toward the end of the Pliocene or in early Pleistocene time. The islands, in the beginning, may have been barren and rocky, like some of the other islands I have seen along this coast—Pelado, off the mouth of the Río Chimán, for example. As soil formed and plant and tree cover developed there would be suitable habitat for the small birds that reached the islands by casual means. The water barrier, though not wide, would seem to have prevented many of the common mainland forms from crossing. Whether this has been true history or not, isolation over a long period seems to have been the factor that has so greatly restricted the variety in the present bird life of this island group to a point even below what is found in the Pearl Islands farther out in the Gulf of Panamá.

It is obvious that there are many additions to be made to this list of the birds of Taboga, Taboguilla, and Uravá in the form of migrant species that come regularly to the mainland of Panamá. In fact, islands such as these, because of their limited area, are usually better points for the detection of casual wanderers of unusual species than the more extensive habitats of the mainland. We may expect therefore to encounter here any and all of the migrants that reach Panamá. I would suggest also a visit to the forested part of the peak above the village of Taboga, which we did not cover thoroughly because of lack of time.

There is probability also of regular occurrence at other periods than the dry season of various species of the indigenous birds of Panamá. When I remarked on the absence of parrots, residents of Taboga told me that small pericos (probably the Tovi parakeet, *Brotogeris jugularis*) were common at times. It would be surprising also if the blue-headed parrot, or casanga, did not come to Taboga, as it does to San José Island in the Perlas Archipelago. Dr. Eugene Eisenmann tells me that he saw a pair of one of the small native swifts of the genus *Chaetura* on Taboga on July 5, 1951. One evening in the village I had a glimpse of a nighthawk flying near the sea, but was not certain of the species.

Mention must be made of a number of specimens to be found in the Rothschild Collection in the American Museum that are marked "Taboga" but that obviously are attributed erroneously to that island. These are trade skins bearing original tag labels cut from rather stiff cards, on which the name and address of Bartlett, of London, presumably the dealer Edward Bartlett, had been printed, this being evident when various of the sections are examined together. Zimmer<sup>1</sup>

<sup>1</sup> Amer. Mus. Nov., No. 1246, Dec. 17, 1943, p. 10.

has commented on two of these supposed Taboga specimens, which actually are *Tangara cayana flava*, a small tanager of northeastern Brazil, and mentions others. One of these is a skin of another tanager, *Tangara musica*, apparently the race *intermedia* of northern South America. Another bird bearing this locality is a skin of *Zonotrichia capensis*, which is discussed by Chapman<sup>2</sup> in his review of this species. The specimen is small and pale in color, so that Chapman believed it to be an undescribed subspecies of uncertain locality. I saw this skin several years ago, noting its peculiarities, and recently have studied it in detail. Careful examination shows that it is a Baía trade skin, the legs being interlocked by crossing twice at the tibiotarsal joint as usual in this type of study skin. With this in mind it became obvious that the bird is merely a somewhat light-colored example of *Zonotrichia capensis matutina* (Lichtenstein) of eastern and southern Brazil. The sex is not recorded, but the small size indicates that it is a female. The legs are so concealed in the feathers that the peculiarity of crossing mentioned is visible only on close examination, so that originally I overlooked it, as apparently Dr. Chapman did also. It is obvious that all these South American birds bear an erroneous locality.

In passing Taboga at sea in previous years I had noted the open, grass-grown, higher slopes which are exactly similar to the habitat of *Zonotrichia capensis orestera* of Cerro Campana on the mainland not far away. And the chance that this sparrow might be found was one of the possibilities that I had in mind in planning the visit to Taboga. However, Perrygo and I covered the high ridges in detail but found nothing, though we were impressed by the suitability of the habitat, with the exception that the highest levels reached only a little over 1,000 feet, which is below the 1,800- to 3,000-foot range where we found these sparrows on Campana.

#### ANNOTATED LIST

##### Family HYDROBATIDAE: Storm Petrels

##### **LOOMELANIA MELANIA** (Bonaparte): Black Petrel

*Procellaria melania* BONAPARTE, Compt. Rend. Acad. Sci. Paris, vol. 38, 1854, p. 662 (coast of California).

The black petrel is seen regularly by day offshore in the Bahía de Panamá, and apparently at night it may roam closer to land. On the evening of March 21, a few minutes after I had captured the least

<sup>2</sup> Bull. Amer. Mus. Nat. Hist., vol. 77, Dec. 10, 1940, pp. 410-411, fig. 6.



petrel mentioned in the following account, a black petrel came blundering into the brightly lighted, open dining room of the Hotel Taboga and dropped to the floor beside my table. It was captured without difficulty and added to the collection, giving me another of my desiderata. On March 24 at noon, while crossing to Balboa, I saw a black petrel about 5 miles off the entrance of the Canal.

This species, like the following, is marked by plain, dark coloration, but is larger.

**HALOCYPTENA MICROSOMA** Coues: Least Petrel

*Halocyptena microsoma* COUES, Proc. Acad. Nat. Sci. Philadelphia, March-April [June 30] 1864, p. 79 (San José del Cabo, Baja California).

On various occasions in recent years I have observed the least petrel offshore in the Bahía de Panamá and have looked forward to some opportunity that would bring one to hand. While sitting in the open dining room, overlooking the sea, in the Hotel Taboga on the evening of March 21, I saw what I thought was a good-sized bat flutter against the inner wall and drop behind an open door. Going over to investigate I captured one of these small petrels. The ceiling and solid rear wall were painted white, and the place was brilliantly lighted by electric light.

The species is easily identified by its small size and its uniformly dark color without markings of white.

Family PELECANIDAE: Pelicans

**PELECANUS OCCIDENTALIS CAROLINENSIS** Gmelin: Eastern Brown Pelican

*Pelecanus carolinensis* GMELIN, Systema naturae, vol. 1, pt. 2, 1789, p. 571 (Charleston Harbor, S. C.).

The brown pelican is found by scores and hundreds in the waters adjacent to Taboga, and it is unusual to look out over the sea without having one or many in view. There is a considerable nesting colony on the northwestern and western slopes of the island, the nests being in trees on the steep, almost precipitous slopes, 400 to 800 feet above the rocky shores (pl. 1, fig. 2). Breeding is somewhat irregular, as we observed well-grown young on February 3, and as late as March 15 found birds that had completed nests but had not yet laid. The two taken were such a mated pair, while in a nest nearby, only 6 feet from the ground on a very steep slope, I took a set of three eggs about one-fourth incubated. These are considerably stained with blood. They measure 73.0 by 51.0, 74.3 by 49.4, and 74.5 by 51.4 mm.

We found other nesting colonies in trees on rocky islets, off the northwestern shore of Taboguilla, and on Uravá recorded small breeding groups in the trees around the base of the slope leading to the high point of the island. From a distance the slopes housing the colonies appear white from the excrement of the birds.

Pelicans fed on the great schools of small fishes that were scattered irregularly for miles over the sea. The plunging of the diving birds was heard often when we were near the shore, though the birds themselves might be hidden by branches of the low forest in which we were working. When the schools of sardines were stationary the pelicans often rested on the water in close flocks, stabbing at the fish with their great bills. The pelican is known here to the fishermen as the *quacco*.

The hindneck in the two taken is definitely darker brown than the average of *carolinensis* from southeastern United States, but otherwise the birds appear similar. Measurements are as follows: Male, wing 512, tail 135, culmen from base 311, tarsus 79 mm.; female, wing 485, tail 152, culmen from base 284, tarsus 75 mm. In the darker coloration of the hindneck these two resemble specimens I have seen from the Pearl Islands.

#### Family SULIDAE: Boobies, Gannets

##### **SULA NEBOUXII NEBOUXII** Milne-Edwards: Blue-footed Booby

*Sula Nebouxii* A. MILNE-EDWARDS, Ann. Sci. Nat. Zool., vol. 13, art. 4, April 1882, p. 37, pl. 14 (Pacific coast of America).

On March 18 I saw a blue-footed booby fly from a rocky islet on the western side of Taboguilla Island. In the American Museum of Natural History there are two specimens taken by Thomas Hallinan, one marked Taboga, March 27, 1915, and one labeled Taboguilla, September 12, 1915.

##### **SULA LEUCOGASTER ETESIACA** Thayer and Bangs: Colombian Brown Booby

*Sula etesiaca* THAYER and BANGS, Bull. Mus. Comp. Zoöl., vol. 46, June 1905, p. 92 (Gorgona Island).

On March 18 I recorded a dozen of these boobies resting on a rock ledge on a small islet off the western side of Taboguilla Island. Several were seen here on March 20. Thomas Hallinan secured three on Taboguilla, September 12, 1915, and two on Taboga, December 5, 1915, the specimens now being in the American Museum of Natural History.

## Family PHALACROCORACIDAE: Cormorants

**PHALACROCORAX OLIVACEUS OLIVACEUS** (Humboldt): Southern Olivaceous Cormorant

*Pelecanus olivaceus* HUMBOLDT, in Humboldt and Bonpland, Recueil d'observations de zoologie et d'anatomie comparée, 1805, p. 6 (Magdalena River, lat. 8°55'N., Colombia).

The great bands of cormorants found regularly over the Bay of Panamá pass near Taboga at times in their search for fish. Many were recorded on February 3. During our visit in March, daily in late afternoon a few perched in trees above the water on the outer side of the islet of El Morro, off Restinga. I recorded a few around Taboguilla on March 18 and 20.

## Family FREGATIDAE: Frigate-birds

**FREGATA MAGNIFICENS** Mathews: Magnificent Frigate-bird

*Fregata magnificens* MATHEWS, Austr. Avian Rec., vol. 2, Dec. 19, 1914, p. 120 (Barrington Island, Galápagos Islands).

In the latter part of March many hundreds of frigate-birds roosted at night in trees on the steep western and northwestern sides of Taboga, and I noted smaller groups on tree-covered islets off the northwestern side of Taboguilla. At dawn the birds rose from their rookeries, towered high in air, and then crossed in front of the village over the sea, sailing with set wings into the steady breeze. Often they were spread out in a broad line over a mile long, spaced 50 to 200 feet apart. Similar flights were noted in evening when the birds were searching for food or were returning to their roosts. At such times their long-winged, angular forms seemed to fill the sky, a sight that remains in memory.

They are agile fishermen, circling at high speed and dropping swiftly to pick minnows off the tops of the waves. As they pass they snap at the fish, the head on the relatively long neck swinging far underneath. The bill is then brought forward to normal position, projecting ahead, and the fish is swallowed, all without check in speed of flight. All that I observed were fishing on their own, no instances of piracy on other fish-eating birds being noted. On March 23 I recorded one bird with the red throat pouch developed, but most were in nonbreeding condition at this time.

A male taken at Taboguilla on December 5, 1915, by Thomas Hallinan is now in the collection of the American Museum of Natural History.

## Family ARDEIDAE: Herons, Bitterns

**CASMERODIUS ALBUS EGRETTA** (Gmelin): American Common Egret  
*Ardea Egretta* GMELIN, Systema naturae, vol. 1, pt. 2, 1789, p. 629 (Cayenne).

Eight to a dozen egrets were usually to be found on rock shelves or ledges above the sea on the western side of Taboga. I saw one fly in from the mainland to Taboguilla, and recorded others on Uravá.

**NYCTANASSA VIOLACEA CALIGINIS** Wetmore: Panamá Yellow-crowned  
Night Heron

*Nyctanassa violacea caliginis* WETMORE, Proc. Biol. Soc. Washington, vol. 59, Mar. 11, 1946, p. 49 (Isla San José, Archipiélago de las Perlas, Panamá).

There is an adult specimen of this race in the American Museum of Natural History taken on Taboga on August 15, 1915, by Thomas Hallinan. On March 18 I saw an adult very near at hand on the rocky northern end of Taboguilla Island. Because of its dark color I was satisfied that it was the present form. On March 21 a yellow-crowned night heron called at dawn on the shore below the hotel on Taboga.

## Family THRESKIORNITHIDAE: Ibises, Spoonbills

**GUARA ALBA** (Linnaeus): White Ibis

*Guara alba* LINNAEUS, Systema naturae, ed. 10, vol. 1, 1758, p. 145 (South Carolina).

One specimen of the white ibis in the collection of the American Museum of Natural History was taken on Taboguilla, December 5, 1915, by Thomas Hallinan.

## Family CATHARTIDAE: New World Vultures

**CORAGYPS ATRATUS** (Meyer): Black Vulture

*Vultur atratus* MEYER, Zool. Annal., vol. 1, 1794, p. 290 (St. Johns River, Fla.).

The black vultures on Taboga Island in the main were beach scavengers that frequented the water front at the village. Sometimes as many as 50 congregated about one huge dead fish cast up on the sand.

**CATHARTES AURA** (Linnaeus): Turkey Vulture

*Vultur Aura* LINNAEUS, Systema naturae, ed. 10, vol. 1, 1758, p. 86 (Veracruz, México).

Turkey vultures appeared daily in the skies of Taboga and were seen also over Uravá. Usually I observed them over the high, open slopes of the island summit. There were never many of them, 12 to

14 being the maximum number for one day. Supposedly, at least two forms were represented, one resident and one migrant from the north.

Family ACCIPITRIDAE: Hawks, Old World Vultures, Harriers

**BUTEO PLATYPTERUS PLATYPTERUS** (Vieillot): Northern Broad-winged Hawk

*Sparvius platypterus* VIEILLOT, Tabl. Encycl. Méth., vol. 3, 1823, p. 1273 (Schuylkill River, Pa.).

Migrant broad-winged hawks were seen on Taboguilla on March 20, on UraVá and Taboga on March 22, and on Taboga on March 23. These were evidently strays from the main northern flight which passes over the mainland. It is interesting to note that while they come to Taboga and the adjacent islands which are in sight of the Panamanian coast, as yet none has been recorded on the Pearl Islands, which lie farther out at sea.

**BUTEO SWAINSONI** Bonaparte: Swainson's Hawk

*Buteo Swainsoni* BONAPARTE, A geographical and comparative list of the birds of Europe and North America, 1838, p. 3 (Fort Vancouver, Wash).

On March 20 several of these hawks were observed passing north over Taboguilla Island. The line of flight of this species in coming north from South America, like that of the broad-winged hawk, lies over the Panamanian mainland.

**BUTEO MAGNIROSTRIS** (Gmelin): Large-billed Hawk

*Falco magnirostris* GMELIN, Systema naturae, vol. I, pt. I, 1788, p. 282 (Cayenne).

On March 18 on Taboguilla Island I saw one of these birds in high forest on the upper slopes, obtaining a distinct view of the brown-banded tail. They were said to be rare here, and I had no report of them on Taboga. The subspecies must remain uncertain until a specimen has been obtained.

Family PANDIONIDAE: Ospreys

**PANDION HALIAETUS CAROLINENSIS** (Gmelin): American Osprey

*Falco haliaetos carolinensis* GMELIN, Systema naturae, vol. I, pt. I, 1788, p. 263 (South Carolina).

Ospreys were seen along the shores of Taboga on March 17 (two recorded), 21, and 22. On the last date one rested in a tree near the summit of El Morro.

## Family FALCONIDAE: Falcons, Caracaras

**CARACARA CHERIWAY** (Jacquin): Caracara

*Falco cheriway* JACQUIN, Beiträge zur Geschichte der Vögel, 1784, p. 17, pl. 4, (Aruba and the coast of Venezuela).

On March 17 we flushed a caracara on a high open slope on Taboga. The record is interesting as it indicates wandering from the distant mainland on the part of this bird. As two races, typical *cheriway* and *audubonii*, are recorded from Panamá, the subspecies is uncertain.

The usual generic name for this group, *Polyborus* Vieillot, 1816, is found to be a synonym of *Circus*, so that it must be replaced by the next available term, *Caracara* Merrem, 1826.<sup>3</sup>

**FALCO PEREGRINUS ANATUM** Bonaparte: Peregrine Falcon

*Falco Anatum* BONAPARTE, A geographical and comparative list of the birds of Europe and North America, 1838, p. 4 (Great Egg Harbor, N. J.).

On Taboga on March 15 we watched two beautiful peregrines for some time as they circled over the higher slopes. They were male and female, shown by their difference in size, though there was no indication that they were paired. Early on the morning of March 22 another appeared over these same high slopes. This one, in play, stooped repeatedly at a turkey vulture, to the very obvious alarm of that poor bird, which swooped and turned in useless efforts to escape.

The peregrine falcon is of regular occurrence on the Pacific side of central Panamá, and it is of interest to record them on this island in the sea.

**FALCO ALBIGULARIS ALBIGULARIS** Daudin: Bat Falcon

*Falco albigularis* DAUDIN, Traité . . . d'ornithologie, vol. 2, 1800, p. 131 (Cayenne).

On March 14 a bat falcon rose from the forest at the southern end of Taboga and circled over the summit. Presumably this was a resident bird.

## Family SCOLOPACIDAE: Snipe, Woodcock, Sandpipers

**ACTITIS MACULARIA** (Linnaeus): Spotted Sandpiper

*Tringa macularia* LINNAEUS, Systema naturae, ed. 12, vol. 1, 1766, p. 249 (Pennsylvania).

This common migrant was seen on Taboga and Taboguilla, March 18, and at Restinga, on Taboga, March 19.

<sup>3</sup> See Hellmayr and Conover, Catalogue of the birds of the Americas, pt. 1, No. 4, Aug. 19, 1949, p. 281; and Twenty-fifth Supplement to the American Ornithologists' Union Check-list of North American Birds, Auk, vol. 67, 1950, p. 369.

## Family LARIDAE: Gulls, Terns

**LARUS ATRICILLA** Linnaeus: Laughing Gull

*Larus atricilla* LINNAEUS, *Systema naturae*, ed. 10, vol. 1, 1758, p. 136 (Bahamas).

In crossing from Balboa to Taboga on February 3 early in the morning I noted scattered individuals and small groups of laughing gulls for the entire distance. On my return, in late afternoon, hundreds had come from farther out in the bay. All were in winter dress with no indication of molt. The main body must have moved north when we returned on March 14, as none were seen during the passage on that date. On our return on March 24 I noted one midway, and four or five others, all in winter dress, resting on a buoy at the entrance to the Panama Canal.

**THALASSEUS MAXIMUS MAXIMUS** (Boddaert): American Royal Tern

*Sterna maxima* BODDAERT, *Table des planches enluminées*, 1783, p. 58 (Cayenne).

On March 15 and 16 I saw one of these terns resting on a buoy off Restinga.

## Family COLUMBIDAE: Pigeons, Doves

**COLUMBA CAYENNENSIS PALLIDICRISSA** Chubb: Pale-vented Pigeon

*Columba pallidicrissa* Chubb, *Ibis*, January 1910, p. 60 (Costa Rica).

A number of these pigeons were noted during our work on Taboga, and they apparently nested there as I saw a male in display flight on March 17. They move about, however, as Perrygo saw one rise, tower high in air, and then fly toward the mainland. They were so shy that I did not succeed in obtaining specimens, the identification being based on specimens taken elsewhere on the Pacific side of Panamá.

**LEPTOTILA VERREAUXI VERREAUXI** (Bonaparte): Verreaux's Dove

*Leptotila verreauxi* BONAPARTE, *Compt. Rend. Acad. Sci. Paris*, vol. 40, 1855, p. 99 (Colombia).

This pigeon was common on all three islands, specimens being taken on Taboga and Taboguilla. They were found in second-growth thickets and in forest. Although they were hunted to some extent, they were fairly tame. Though these doves usually remained under cover, I saw them flying between the trees at Restinga and the wooded islet of El Morro, a distance of 300 meters or more, wholly in the open. This readiness to fly over water, since the birds crossed directly when the beach that connects the islet with Taboga at low tide was

submerged, made me speculate on the possibility of longer flights to the mainland.

On Taboguilla they came to drink at water seeps on the rocky slopes back of the beach. Two males taken here on March 20 had the crop glands developed, indicating that they were near breeding.

The four males and one female prepared as specimens from Taboga and Taboguilla are similar to skins from the mainland of Panamá.

#### Family CUCULIDAE: Cuckoos, Roadrunners, Anis

##### CROTOPHAGA ANI Linnaeus: Ani

*Crotophaga Ani* LINNAEUS, *Systema naturae*, ed. 10, vol. 1, 1758, p. 105 (Jamaica).

The ani was fairly common about the small cultivated fields of all three islands. I collected two females on Taboga, March 16, that show the same tendency toward enlarged keel on the bill that I have noted elsewhere<sup>4</sup> in birds from the Pearl Islands and from the adjacent mainland.

#### Family APODIDAE: Swifts

##### CHAETURA PELAGICA (Linnaeus): Chimney Swift

*Hirundo Pelagica* LINNAEUS, *Systema naturae*, ed. 10, vol. 1, 1758, p. 192 (South Carolina).

We recorded one of these swifts in morning and one in evening on Taboga on March 15. I have seen chimney swifts from time to time in northward migration in central Panamá, and it is interesting to record one so far at sea.

#### Family TROCHILIDAE: Hummingbirds

##### CHLOROSTILBON ASSIMILIS Lawrence: Allied Emerald Hummingbird

*Chlorostilbon assimilis* LAWRENCE, *Ann. Lyc. Nat. Hist. New York*, vol. 7, January 1861, p. 292 (Atlantic slope of Panamá, near Panama Railroad).

During March this was the most common of the hummingbirds on Taboga Island, where it was found about flowers, usually low down near the ground. In town it came regularly to patios, and to the small plaza on the water front, to search the blossoms of ornamental shrubbery, and often perched fearlessly on low wires over the narrow streets. We saw them in equal number on Taboguilla and recorded several crossing from Taboga to Taboguilla, flying low over the water surface (as did the large bees that made the same flight). Our speci-

<sup>4</sup> Smithsonian Misc. Coll., vol. 106, No. 1, Aug. 5, 1946, p. 40.



mens are identical with those from the Pacific side of Panamá, and it is probable that these hummers move regularly between the islands in the Gulf of Panamá and the mainland. Years ago W. W. Brown, Jr., noted them in flight between the continental shores and Rey Island.

There are three old specimens from Taboga in the National Museum, one taken by Hicks on January 31, 1865, and two by Heyde and Lux, one marked August and the other September 1888.

Though Peters<sup>5</sup> treats *assimilis* as a race of *Chlorostilbon canivetii*, I feel certain that he was influenced in this decision by general resemblances and that these two are specifically distinct. In both, the males are mainly metallic green and the females whitish below, so that they look alike in general appearance. Both sexes of *canivetii* have the lower mandible flesh-colored except at the tip, and in the males the tail is deeply furcate. While *C. c. salvini* of Costa Rica seems to bridge the gap toward *assimilis* in darker bill, the base of the mandible remains uniformly light-colored. Zimmer<sup>6</sup> in a more recent study has gone much farther by placing all the emerald hummers under a single specific name, *Chlorostilbon mellisugus*, a procedure that simplifies completely the handling of names but one that I am not convinced expresses the true relationships. The problem, like that involving the crows of the world, is one that is highly complicated because of a general uniformity in color. The relationships of *assimilis* seem close to the black-billed forms of northern South America. I treat it here, temporarily at least, as specifically distinct.

**AMAZILIA TZACATL TZACATL (De la Llave): Rieffer's Hummingbird**

*Trochilus tzacatl* DE LA LLAVE, Registro Trimestre, vol. 2, No. 5, 1833, p. 48 (México).

I saw a Rieffer's hummingbird distinctly on Taboga, March 23, the only one that we recorded.

**AMAZILIA EDWARD MARGARITARUM (Griscom)**

*Saucerottia edwardi margaritarum* GRISCOM, Amer. Mus. Nov., No. 282, Sept. 12, 1927, p. 4 (Isla Pedro González, Archipiélago de las Perlas, Panamá).

This hummingbird was fairly common on Taboga, where it was encountered frequently in stands of dry, woody-stemmed growth standing head high in old fields, or was observed feeding at flowers from ground level up to the tops of tall trees. We secured one and

<sup>5</sup> Check-list of birds of the world, vol. 5, 1945, p. 38.

<sup>6</sup> Amer. Mus. Nov., No. 1474, Nov. 10, 1950, pp. 6-12.

saw others on Taboguilla on March 20. I noted them occasionally feeding at flowers in gardens in town, and once observed one in flight between the shade trees at Restinga across to the little islet of El Morro. The white abdomen shows clearly as the birds move and serves to identify them readily.

In the collections of the National Museum there are two old specimens from Taboga, one marked January 31, 1865, by Fred Hicks, and another without date but taken probably in 1888 by H. Th. Heyde. There is also one, without date or collector indicated, in the American Museum of Natural History.

It has been a distinct surprise to find that our eight specimens from Taboga and Taboguilla are inseparable from the birds of the Pearl Islands, out of sight over the horizon to the southwest.

Material now at hand permits a clearer view of the forms of this group of hummers, showing that they are surprisingly plastic for birds of this family and allowing clear presentation of intergradation between *niveoventer* and the group of subspecies that has separated from typical *edward*. It has been a matter of much interest to find two additional populations that merit recognition. The species as a whole ranges from southeastern Costa Rica in the drainage of the Río Diquis to the lower elevations of the Chucunaque valley and Punta Garachiné in Darién. The following review of the races that may be distinguished presents them in geographic order from west to east.

*Amazilia edward niveoventer* (Gould) :

*Trochilus* (——?) *niveoventer* GOULD, Proc. Zool. Soc. London, pt. 18, 1850 (Feb. 28, 1851), p. 164 (near David, Chiriquí, Panamá).

Tail dark; blackish with more or less bluish, or violet, reflections; back strongly iridescent copper-color or bronze; under tail coverts mouse gray, edged with whitish, sometimes with a mixture of avel-laneous.

Southwestern Costa Rica (Boruca) to Chiriquí (Bugaba, Boquerón, El Volcán, El Banco, Boquete), Veraguas, and Bocas del Toro, wandering or straggling to the Canal Zone (Gatún). It is uncertain whether it is this form or the next that is found on the western side of the Azuero Peninsula.

*Amazilia edward ludibunda*, subsp. nov. :

*Characters*.—Similar to the preceding race, *Amazilia edward niveoventer* (Gould), but slightly darker green above; green of the lower back more extensive, with coppery or bronzy iridescence; under tail coverts decidedly darker.

*Description*.—Type, U.S.N.M. No. 400314, male, Quebrada Chitabé, 4 miles west of Pesé, Herrera, Panamá, March 30, 1948, collected by A. Wetmore and W. M. Perrygo (orig. No. 14081). Crown, sides of head, hindneck, and upper back iridescent, between grass green and Cossack green; lower back, primary and greater coverts, and rump iridescent cinnamon-rufous, producing a coppery sheen; upper tail coverts duller, more chestnut-brown, with reduced iridescence; lesser and middle wing coverts iridescent parrot green; primaries and secondaries dull violet-black; rectrices dusky slate-violet, the longer ones tipped slightly with russet; throat, foreneck, and upper breast strongly iridescent meadow green; sides bordered toward back with iridescent peacock green; lower breast, abdomen, and bordering portion of sides white; under tail coverts dark olive-gray, with a slight greenish reflection, the feathers tipped with cinnamon, the lateral ones whitish basally. Base of mandible avellaneous; rest of bill, tarsi, and feet dull black (from dried skin).

*Measurements*.—Males, 4 specimens, wing 51.1-53.6 (52.2), tail 28.5-29.6 (29.1), culmen from base 18.2-19.8 (19.1) mm.

Females, 2 specimens, wing 51.1-54.3 (52.7), tail 27.2-28.7 (27.9), culmen from base 19.0-19.6 (19.3) mm.

Type, male, wing 52.9, tail 29.5, culmen from base 19.6 mm.

*Range*.—The eastern side of the Azuero Peninsula, western Panamá (specimens examined from El Barrero and Pesé, Herrera).

*Remarks*.—The decidedly duller color separates this race at a glance from *Amazilia edward niveoventer*. The assumption is that it ranges over the eastern slope of the Azuero Peninsula, probably being found throughout the area during the rainy season, retreating to the foothill country, in the vicinity of heads of the streams where water is permanent, during the long dry season.

*Amazilia edward collata*, subsp. nov.:

*Characters*.—Similar to the following race, *Amazilia edward edward* (De Lattre and Bourcier), but darker green above, with coppery iridescence much reduced; tail darker; under tail coverts with brown markings duller and less in extent.

*Description*.—Type, U.S.N.M. No. 433638, head of Río Antón, 1,900 feet elevation, near El Valle de Antón, Coclé, Panamá, March 28, 1951, collected by A. Wetmore and W. M. Perrygo (orig. No. 16563). Crown, sides of neck, and upper back iridescent Cossack green; lower back and upper tail coverts iridescent grass green with scattered coppery reflections; rump dull citrine drab; remiges dull purplish black,

with a faint violaceous sheen; rectrices rather dull neutral red, slightly iridescent, the feathers edged lightly with fuscous, the edging showing a faint brassy sheen; throat, foreneck, upper breast, and sides shining, iridescent vivid green; lower breast and abdomen white; under tail coverts deep mouse gray, edged with whitish with some mixture of avellaneous; under wing coverts shining parrot green. Base of mandible avellaneous; rest of bill, tarsi, and toes black (from dried skin).

*Measurements*.—Males, 8 specimens, wing 51.1-56.0 (53.5), tail 27.5-31.0 (28.9), culmen from base 19.0-21.3 (19.8) mm.

Females, 5 specimens, wing 50.7-53.4 (51.7), tail 26.9-29.2 (28.0), culmen from base 19.9-21.0 (20.5) mm.

Type, male, wing 54.2, tail 31.0, culmen from base 19.0 mm.

*Range*.—Known from eastern Coelé (El Valle de Antón) to the extreme western section of the Province of Panamá (La Campana); probably ranging west to Veraguas.

*Remarks*.—This race in its darker tail serves as a link to connect typical *edward* of the Canal Zone with *niveoventer* of Chiriquí. In its darker, duller back it differs from both, resembling here the blackish-tailed form *ludibunda* of the eastern side of the Azuero Peninsula. In one area of low, woody-stemmed weeds near El Valle de Antón we found these birds very abundant.

*Amazilia edward edward* (De Lattre and Bourcier):

*Trochilus edward* DE LATTRE and BOURCIER, Rev. Zool., September (November) 1846, p. 308 (Isthmus of Panamá).

Back and rump with extensive copper and bronze reflections; tail distinctly iridescent reddish brown, usually near liver brown; under tail coverts grayish olive centrally, edged widely with cinnamon-buff.

The Canal Zone (Gatún; near Juan Mina; Corozal), and adjacent sections of the provinces of Colón (Portobelo) and Panamá (to the west to La Chorrera, and to the east to Pacora and Utivé).

The specimens from Pacora and Utivé are intermediate toward the next race, *rosbyi*.

*Amazilia edward rosbyi* (Griscom):

*Saucerottia edwardi rosbyi* GRISCOM, Amer. Mus. Nov., No. 282, Sept. 12, 1927, p. 5 (Punta Garachiné, Darién, Panamá).

Lower back extensively coppery bronze like *edward*; tail golden bronze; under tail coverts cinnamon, with some markings of clay color or pinkish cinnamon on flanks, especially in females.

Eastern part of the Province of Panamá (Cerro Ultima, at 2,000 feet on the western end of Cerro Azul; Chepo; Quebrada Cauchero, at the southern base of Cerro Chucantí) to the Pacific slope of western Darién (Río Capetí; Boca de Cupe; Garachiné).

Some of the specimens from Chepo are intermediate toward *edward*.

*Amazilia edward margaritarum* (Griscom) :

*Saucerottia edwardi margaritarum* GRISCOM, Amer. Mus. Nov., No. 282, September 12, 1927, p. 4 (Isla Pedro González, Archipiélago de las Perlas, Panamá).

Closely similar to *crobyi*, but under tail coverts somewhat duller brown, being sayal brown to tawny-olive; with more brown on the flanks, particularly in females.

Archipiélago de las Perlas (Isla El Rey, Saboga, San José, Pedro González) ; Taboga, Taboguilla.

Differences between this form and *A. e. crobyi* in the relatively few specimens of the latter available are slight. It is possible that it may be found necessary to merge these two when more material is examined. In that event the name *margaritarum* will be used.

**ANTHOSCENUS LONGIROSTRIS LONGIROSTRIS** (Audebert and Vieillot)

*Trochilus longirostris* AUDEBERT and VIEILLOT, Oiseaux dorés . . . , vol. 1, 1801, p. 107, pl. 59 (Trinidad).

There are two specimens in the National Museum from Taboga Island taken by Heyde and Lux in September 1888. These are unquestionably the basis, through a typographical error, of Ridgway's record<sup>7</sup> from "Saboga Island," that locality being in the Pearl Islands, from which this hummer has not been recorded.

A large hummingbird of this size that I saw indistinctly below the summit of Taboga on February 3 was probably this species.

Family TYRANNIDAE: Tyrant Flycatchers

**MUSCIVORA TYRANNUS MONACHUS** (Hartlaub): Northern Fork-tailed Flycatcher

*Tyrannus (Milvulus) monachus* HARTLAUB, Rev. Zool., vol. 7, 1944, p. 214 (Guatemala).

A fork-tailed flycatcher seen by Eugene Eisenmann at Restinga on Taboga, July 5, 1951, is presumed to be a straggler of the race found on the mainland.

<sup>7</sup> U. S. Nat. Mus. Bull. 50, pt. 5, 1911, p. 347.

**TYRANNUS TYRANNUS (Linnaeus): Eastern Kingbird**

*Lanius tyrannus* LINNAEUS, *Systema naturae*, ed. 10, vol. 1, 1758, p. 94 (South Carolina).

Found in migration. I noted several of these kingbirds on Taboguilla, March 20, two flocks and scattered individuals on Uravá, March 22, and many on Taboga, March 22 and 23. They apparently pass directly across the Bay of Panamá, as they are common as passage migrants on the Pearl Islands.

**TYRANNUS MELANCHOLICUS CHLORONOTUS Berlepsch: Lichtenstein's Tropical Kingbird**

*Tyrannus chloronotus* BERLEPSCH, *Ornis*, vol. 14, 1907, p. 474 (Temax, Yucatán).

The tropical kingbird was common on the three islands in more open areas and several were collected. On February 3 we noted a number along the road leading to the summit of Taboga, and in March recorded them as common around the fields. On Uravá and Taboguilla they were found in open areas where clearings had been made, and elsewhere along the shore. One was taken on Taboguilla on August 15, 1915, by Thomas Hallinan.

**MYIODYNASTES LUTEIVENTRIS Sclater: Sulphur-bellied Flycatcher**

*Myiodynastes luteiventris* SCLATER, *Proc. Zool. Soc. London*, pt. 27, May 1859, p. 42 (Vera Paz, Guatemala, and Orizaba, México).

On March 20 I saw a flycatcher of this species in forest near the summit of Taboguilla but did not succeed in collecting it. When the bird is clearly observed the blackish chin and side of the throat and the yellower underparts mark this species clearly and distinguish it from the resident form of this genus, *Myiodynastes maculatus difficilis*, found commonly in the tropical zone in Panamá. The latter ranges in the Pearl Islands, but we did not find it on Taboga.

**MYIARCHUS FEROX PANAMENSIS Lawrence**

*Myiarchus panamensis* LAWRENCE, *Ann. Lyc. Nat. Hist. New York*, vol. 7, May 1860, p. 284 (Atlantic slope of Canal Zone on the Panama Railroad).

This was one of the most common of the passeriform birds, being found through the open woodland on all three islands. The birds were quiet, except for their low notes, and though not wary often remained unseen except to a keen eye. On one occasion on Taboga I saw eight at one time within 75 yards of me. They were beginning to nest at the end of March.

The series from Taboga, Taboguilla, and Uravá has the bill averaging very slightly heavier than in the mainland birds. In addition the average color of the dorsal surface is very faintly darker. In size of bill they approach specimens from the Perlas Islands. The differences are slight and there is much overlap, a fair number in the extensive series from mainland Panamá being indistinguishable.

Lawrence notes that the two specimens from which he described this bird were collected by McLeaman on the "Atlantic side of the Isthmus of Panama, along the line of the Panama Railroad."<sup>8</sup>

#### CONTOPUS VIRENS (Linnaeus): Eastern Wood Pewee

*Muscicapa virens* LINNAEUS, *Systema naturae*, ed. 12, vol. 1, 1766, p. 327 (South Carolina).

Two males of this migrant species were taken on Taboguilla Island, March 18 and 20. One other bird of this genus was seen on the latter date.

#### EMPIDONAX VIRESCENS (Vieillot)

*Platyrhynchus virescens* VIEILLOT, *Nouv. Dict. Hist. Nat.*, nouv. éd., vol. 27, 1818, p. 22 (near Philadelphia, Pa.).

Migrant; taken on Taboguilla Island, March 18. This bird had the lower mandible dark except at the extreme base, instead of light throughout as is the normal condition.

#### SUBLEGATUS GLABER ARENARUM (Salvin)

*Elainea arenarum* SALVIN, *Proc. Zool. Soc. London*, 1863, p. 190 (near Puntarenas, Costa Rica).

This small species is much less common than the other resident flycatchers. On March 18 I collected two females on Taboguilla Island at the edge of cultivated fields. One rested in the middle branches of a mango tree, and the other was in a bush near the ground. A small grayish flycatcher seen indistinctly on March 23 near the beach back of Restinga on Taboga Island was supposed to have been this species, but it is possible that it may have been a small elainea (*E. chiriquensis*).

The two taken are slightly darker above than the average from the mainland but are equaled in this respect by some individual specimens. In placing a name on these two I have followed the ten-

<sup>8</sup> Ann. Lyc. Nat. Hist. New York, vol. 7, 1861, p. 295.

tative usage adopted in connection with specimens from San José and Pedro González Islands, in the Perlas group.<sup>9</sup>

The subspecies to be recognized in Panamá and the name to be applied to it are at present uncertain.

**ELAENIA FLAVOGASTER CRISTULA, subsp. nov.**

*Characters.*—Similar to *Elaenia flavogaster pallididorsalis* Aldrich<sup>10</sup> but grayer, less greenish olive above; light edgings of rectrices slightly less greenish.

*Description.*—Type, U.S.N.M. No. 445281, male, Taboga Island, Panamá, March 16, 1952, collected by A. Wetmore and W. M. Perrygo (orig. No. 17311). Crown dark olive, the feathers margined with deep olive, a broad concealed line of white centrally, which is visible when the short crest is elevated; hindneck, back, and lesser wing coverts deep olive; rump and upper tail coverts grayish olive; rectrices dull hair brown, margined faintly externally with citrine drab; primaries, secondaries, tertiaries, greater and middle wing coverts fuscous-black; greater and middle wing coverts edged irregularly with dull white, forming two prominent bars; tertiaries margined externally with dull white; outer webs of secondaries margined lightly with primrose yellow, and of primaries with dark olive-buff; rectrices clove brown, the outer one margined indistinctly with deep olive-buff, the others edged with citrine-drab, the color more prominent toward the base of the feather; loreal area and region below eye light grayish olive, mixed with white, the latter forming an indistinct line extending from above the lores to above the anterior part of the eye; cirlet of small feathers bordering margin of eyelids white; auricular area deep grayish olive; chin, throat, and upper foreneck dull white mixed with smoke gray; an indefinitely delimited band of light grayish olive across upper breast, some of the feathers margined lightly with dull primrose yellow; lower breast and abdomen primrose yellow, becoming duller laterally to merge with the deep olive-buff of sides and flanks; under wing coverts dull primrose yellow, becoming primrose yellow on edge of wing; a broken line of clove brown inside edge of wing; axillars olive-buff; inner webs of primaries and secondaries edged with dull white. Maxilla hair brown at base, fuscous-black at tip; tarsus and toes dull black (from dried skin).

<sup>9</sup> Wetmore, A., Smithsonian Misc. Coll., vol. 106, No. 1, Aug. 5, 1946, pp. 50-51.

<sup>10</sup> *Elaenia flavogastra pallididorsalis* Aldrich, Sci. Publ. Cleveland Mus. Nat. Hist., vol. 7, Aug. 31, 1937, p. 106 (Paracoté, Veraguas, Panamá).



*Measurements.*—Males, 13 specimens, wing 75.4-83.3 (79.5), tail 69.5-78.2 (74.0), culmen from base 12.5-14.7 (13.7), tarsus 19.0-21.4 (20.0) mm.

Females, 6 specimens, wing 74.2-77.9 (76.0), tail 65.0-71.0 (68.4), culmen from base 12.2-14.6 (13.3), tarsus 19.5-21.3 (20.3) mm.

Type, male, wing 76.5, tail 69.7, culmen from base 12.5, tarsus 20.0 mm.

*Range.*—Taboga, Taboguilla, and Uravá Islands, Panamá.

*Remarks.*—The new race is definitely darker above than *E. f. silvicultrix* Wetmore of the Pearl Islands. The separation from the mainland form on the darker gray dorsal coloration is for some specimens an average difference. Some individuals are close to the mainland birds, but the series as a whole is distinct.

This is one of the most abundant birds on the three islands when it is found. On Taboga on February 3 we noted it commonly along the road leading to the summit of the island, and in our later work recorded it every day. By March 17 the birds were mating and preparing to nest. The wheezy songs were heard constantly through the daylight hours as this is one of the species that remains active regardless of the heat of the sun. The birds ranged in the open forest, in low second growth, and along the edge of the clearings. They were usually tame and frequently perched with the crest elevated forming an attractive silhouette. Their food was berries and drupes of various kinds, all so small in size that they were swallowed entire. The flight was tilting, and, while only moderately strong, I saw them crossing spaces of 200 to 300 yards, as for example from the trees at Restinga across the water to the islet of El Morro. We had no indication, however, that they flew longer distances.

#### Family VIREONIDAE: Vireos

##### VIREO FLAVOVIRIDIS FLAVOVIRIDIS (Cassin): Common Yellow-green Vireo

*Vireosylva flavoviridis* CASSIN, Proc. Acad. Nat. Sci. Philadelphia, vol. 5, June 30, 1851, p. 152, pl. 11 (San Juan de Nicaragua).<sup>11</sup>

Migrant. A male was taken on Taboga on March 16. It is probable that the typical form, marked by brighter green back, passes regularly through these islands in its migration between its winter home in the upper Amazon Valley and its breeding grounds in Central America.

<sup>11</sup> Originally described from four specimens from Panama City and San Juan de Nicaragua; type locality designated as "western Nicaragua" by van Rossem and Hachisuka, Proc. Biol. Soc. Washington, vol. 50, Sept. 30, 1937; and as "San Juan de Nicaragua" by Zimmer, Amer. Mus. Nov., No. 1127, June 26, 1941, p. 2.

**VIREO FLAVOVIRIDIS INSULANUS** Bangs: Panamá Yellow-green Vireo

*Vireo insulanus* BANGS, Proc. New England Zoöl. Club, vol. 3, Mar. 31, 1902, p. 73 (San Miguel Island = Isla El Rey, Archipiélago de las Perlas, Panamá).

This is one of the most common of the small breeding land birds of Taboga and its neighboring islands, being found through the forested areas and in the taller thickets near the cultivated fields. I noted a number on February 3, and during our work in the latter part of March they were recorded daily after March 16. They were usually in pairs, with males singing steadily and displaying, so that the nesting season then was beginning. They were much disturbed by our calling to attract small birds and often came within a few feet. Ten specimens were collected as follows: Taboga, March 16, 17, and 23; Taboguilla, March 18 and 20; Uravá, March 22.

The status of the race *insulanus* has been uncertain, owing to the migration of other subspecies, including typical *flavoviridis* and *hypolucucus*, through its breeding range in Panamá. It is probable that *V. f. forreri* of the Tres Mariás Islands, off the coast of northwestern México, also travels through the Republic, though specimens have not been taken to date. All four races move south after the close of the nesting season to the upper Amazon Basin, where the species is found from southeastern Colombia to northeastern Bolivia. As the breeding season approaches they return northward to their respective nesting grounds between Panamá and northern México.

Several years ago in a survey of limited material,<sup>12</sup> mainly from the Pearl Islands, I was unable to separate *insulanus* and *flavoviridis*, an opinion held by Zimmer<sup>13</sup> on the basis of other material. A steady accumulation of specimens, however, has given a better perspective, so that now I find that the series from San José Island that I examined originally contains examples of both *insulanus* and *flavoviridis*, which explains the confusion under which I labored earlier.

Peters<sup>14</sup> has published an excellent summary of this species, maintaining it as an entity apart from the red-eyed vireo (*Vireo olivaceus*), with which I agree. It is readily evident that these two, as well as certain related groups are closely allied, but they differ sufficiently to warrant specific separation; to merge them under one specific name causes confusion rather than orderly presentation.

<sup>12</sup> Smithsonian Misc. Coll., vol. 106, No. 1, 1946, p. 54.

<sup>13</sup> Amer. Mus. Nov., No. 1127, June 26, 1941, p. 3.

<sup>14</sup> Auk, vol. 48, 1931, pp. 575-587.

Although Peters (l. c.) includes birds from the Térraba valley, southwestern Costa Rica, in the breeding territory of *V. f. insulanus*, there is definite question in my mind as to whether the breeding range of this race on the mainland extends west of the Canal Zone. Apparently it is found on the Pacific slope of the mainland of Panamá from the mouth of the Río Bayano through the Canal Zone, but all that I have examined to date from the western edge of the Province of Panamá to the eastern side of the Azuero Peninsula and Veraguas are *flavoviridis*. Possibly these are migrants, but some of them seemed to be on their breeding grounds.

The race *insulanus* is definitely duller, less yellowish green above, than *flavoviridis*, and slightly duller on the sides and flanks, these being its main characters. In fact, it is the darkest of any of the four races into which the species is divided at present. The mainland specimens are very slightly brighter on the back than those from the Pearl Islands. The birds from Taboga are slightly darker than those from the islands of San José and Pedro González, so that they seem to represent the race in its most specialized form.

**VIREO FLAVOVIRIDIS HYPOLEUCUS** van Rossem and Hachisuka:  
Northwestern Yellow-green Vireo

*Vireo olivaceus hypoleucus* VAN ROSSEM and HACHISUKA, Proc. Biol. Soc. Washington, vol. 50, Sept. 30, 1937, p. 159 (1,200 feet elevation in San Francisco Canyon, lat. 27°N., eastern Sonora, México).

Two females of this migrant were taken on Taboga on March 16 and 18. The form nests in northwestern México, from Sonora to Nayarít, and migrates to the upper Amazon Basin. The present report is the first record for the Republic of Panamá. In the field I did not distinguish the two taken from *insulanus*, the breeding form of the islands.

As *Vireo f. hypoleucus* was described after publication of the paper by Peters mentioned above, it is pertinent to summarize its characters here. From the adjacent *V. f. flavoviridis* the race *hypoleucus* is separated by decidedly duller green color above, thus being closer in appearance to *insulanus*. From the latter form it differs in being slightly more grayish green. Usually, the loreal area is whiter than in *insulanus*, and the sides and flanks are somewhat brighter yellowish green. *V. f. forreri* of the Tres Mariás Islands has the loreal area duller than any of the other races, it being nearly concolor with the anterior part of the pileum.

**VIREO FLAVIFRONS** Vieillot: Yellow-throated Vireo

*Vireo flavifrons* VIEILLOT, Oiseaux de l'Amérique septentrionale, vol. 1, 1808, p. 85, pl. 54 (eastern United States).

On March 17 we recorded several of these vireos, evidently passage migrants.

## Family COEREBIDAE: Honey-creepers

**CYANERPES CYANEA CARNEIPES** (Sciater): Northern Blue Honey-creeper

*Coereba carneipes* P. L. SCLATER, Proc. Zool. Soc. London, 1859 (February 1860), p. 376 (Playa Vicente, Oaxaca).

Eugene Eisenmann saw two beside the road leading to the summit of Taboga on July 5, 1951. A boy told me that this bird was present on Taboguilla, but I did not find it. It is common in the Pearl Islands. This species, like the blue tanagers, often flies far above the forest trees, so that it is possible that it may cross to these islands from the mainland.

## Family PARULIDAE: Wood Warblers

**MNIOTILTA VARIA** (Linnaeus): Black and White Warbler

*Motacilla varia* LINNAEUS, Systema naturae, ed. 12, vol. 1, 1766, p. 333 (Hispaniola).

Migrant, apparently fairly common. On March 17 on Taboga I saw three and collected an adult male. I saw another on March 21 and the following day noted one on the Island of Uravá.

**PROTONOTARIA CITREA** (Boddaert): Prothonotary Warbler

*Motacilla citrea* BODDAERT, Table des planches enluminées, 1783, p. 44 (Louisiana).

Migrant. I collected two females, one on the summit of Taboguilla Island, March 20, and one on Taboga, March 23. The latter was very fat.

**DENDROICA PETECHIA AEQUATORIALIS** Sundevall: Panamá Golden Warbler

*Dendroica petechia* h) *aquatorialis* SUNDEVALL, Öfv. Kongl. Vet.-Akad. Förh., vol. 26, 1869 (1870), p. 609 (Panamá City, Panamá).

On Taboguilla on March 18 and 20 we found the golden warbler fairly common, ranging from near the shore through the forested areas halfway to the summit of the island (pl. 2, fig. 1). As usual there was no difficulty in calling them, and thus they were easily seen. In careful search we did not locate any on Taboga, so that if

they occur they must be very rare. None were seen on Uravá. The present assumption is that at present they are confined to Taboguilla. It is interesting to observe that in the scarcity of mangroves they range through the forests as they do on the islands of San José and Pedro González in the Archipiélago de las Perlas.

The series of eight taken includes well-marked males which agree with available *aequatorialis* from the mainland coast, from Chico, Chimán, and Majé.

**DENDROICA PETECHIA AMNICOLA** Batchelder: Newfoundland Yellow Warbler

*Dendroica aestiva amnicola* BATCHELDER, Proc. New England Zool. Club, vol. 6, Feb. 6, 1918, p. 82 (Curslet, Newfoundland).

A female in molt was taken on Taboguilla on March 20. Other yellow warblers were seen in Uravá on March 22 and on Taboga on March 23, so that it was apparent that migration was in progress. To date I have record of five migrant subspecies from Panamá, of which two, *D. p. aestiva* and *D. p. amnicola*, are common, while *D. p. rubiginosa* is less often found. *D. p. morcomi* and *D. p. brewsteri* at present are represented respectively by one and two specimens.

Fred Hicks collected a yellow warbler on Taboga on January 31, 1865, according to the catalog of his collection. As the specimen cannot be found, the subspecific identity is not known.

**DENDROICA CERULEA** (Wilson): Cerulean Warbler

*Sylvia cerulea* WILSON, American ornithology, vol. 2, 1810, p. 141, pl. 17, fig. 5 (Philadelphia, Pa.).

Migrant. An adult male was taken on Taboga in an area of large trees on March 23.

Family ICTERIDAE: Blackbirds, Troupials

**CASSIDIX MEXICANUS PERUVIANUS** (Swainson): Southern Boat-tailed Grackle

*Quiscalus Peruvianus* SWAINSON, Animals in menageries, Dec. 31, 1837, p. 354 (Perú).

Resident, common, on Taboga, Taboguilla, and Uravá. This is a bird of the coastal areas that ranges back around the groves and small fields in lowlands. There was a colony in the crowns of tall coconut palms in the village on Taboga, where females were carrying food to the nests on March 19. At the same time numerous males were

in active mating display, while flocks of immature birds of the last brood ranged in company around the inland fields. At low tide scattered birds fed about pools on the shore in front of the village. A pair was taken on Taboga on March 16 and 17, and a pair on Taboguilla on March 20.

Family THRAUPIDAE: Tanagers

**THRAUPIS VIRENS DIACONUS** (Lesson): Northern Blue Tanager

*Tanagra (Aglaia) diaconus* LESSON, Rev. Zool., June 1842, p. 175 (Realejo, Nicaragua).

The blue tanager was one of the common birds on the three islands, being found in the tree-covered areas. These birds came constantly to the papaya plantations to feed on the ripening fruit, and at this season at least they did considerable damage. They were especially common on Taboguilla, where I had as many as 50 about me at one time, attracted by my calling for small birds. On such occasions they peer about, moving nervously, with soft calls. At other times they are seen in bounding flight over the trees.

The three taken on Taboga March 16 and 17, and the two from Taboguilla shot March 18, all refer to the race found from east-central Panamá (including the Pearl Islands) northward. Gyldenstolpe<sup>15</sup> finds that the type of *Loxia virens* Linnaeus,<sup>16</sup> which is preserved in the Zoological Museum of the University of Uppsala, is to be identified without question as an example of this species, being what has been considered the typical race from Surinam. The term *virens* therefore is taken as the species name to replace *episcopus* Linnaeus, which occurs in the same work on page 316.

**PIRANGA RUBRA RUBRA** (Linnaeus): Eastern Summer Tanager

*Fringilla rubra* LINNAEUS, Systema naturae, ed. 10, vol. 1, 1758, p. 181 (South Carolina).

Migrant. Single birds of this species were seen on Taboga on March 18 and 21 and on Taboguilla on March 20. Natives reported that at times they came in great abundance. The full-plumaged males were known as *sangre toro*, the name given on the mainland to *Ramphocelus dimidiatus*, another red-colored tanager.

<sup>15</sup> Kungl. Svenska Vet.-Akad. Handl., vol. 22, No. 3, 1945, p. 311.

<sup>16</sup> Systema naturae, ed. 12, vol. 1, 1776, p. 303.

## Family FRINGILLIDAE: Grosbeaks, Finches, Buntings

**SALTATOR ALBICOLLIS MELICUS**, subsp. nov.

*Characters*.—Similar to *Saltator albicollis isthmicus* Sclater<sup>17</sup> but with larger, heavier bill; sides of head grayer; streak on either side of throat averaging darker; flanks averaging darker; dorsal surface of tail, and upper tail coverts averaging slightly darker gray.

*Description*.—Type, U.S.N.M. No. 445589, male, Taboga Island, Panamá, March 19, 1952, collected by A. Wetmore and W. M. Perrygo (orig. No. 17356). Hindneck, back, and wings olive-citrine, the crown duller, being yellowish olive; outer webs of primaries and secondaries edged with yellowish citrine; rump and upper tail coverts dark olive-gray; rectrices dull mouse gray, edged with dark olive-gray, the shafts blackish, the two outer feathers edged narrowly with whitish on lower surface; remiges dark mouse gray; edge of upper eyelid narrowly Marguerite yellow, becoming dull white in front of eye, and broadening above lores to extend to the nasal fossa; lores, space below eye and ramal area deep mouse gray, becoming deep grayish olive over auriculars; throat white, bordered externally by a fairly broad line of dark greenish olive, which becomes iron gray where it borders the mandibular rami; rest of under surface, in general, white, washed with light yellowish, except in center of abdomen, changing to light pinkish buff on under tail coverts and the adjacent posterior section of the flanks; breast streaked with dark greenish olive, forming an indefinite chest band; sides of breast and neck adjacent to this band yellowish olive; streakings fewer and much narrower on lower breast, changing to dark olive-gray and becoming heavier on flanks; edge of wing barium yellow; under wing coverts and axillars cream-buff; inner webs of primaries whitish basally. Bill slate black; tarsus dull benzo brown; toes fuscous-black; claws slate black (from dried skin).

*Measurements*.—Males (7 specimens), wing 88.2-92.5 (90.8), tail 79.3-85.0 (82.4); culmen from base 18.8-20.9 (19.8), depth of bill at base 12.3-13.0 (12.6), tarsus 22.3-24.1 (23.2) mm.

Females (4 specimens), wing 85.7-90.0 (87.5), tail 79.4-83.6 (81.0), culmen from base 19.4-20.0 (19.6), depth of bill at base 12.6-13.7 (12.9), tarsus 22.8-24.8 (23.7) mm.

Type, male, wing 91.8, tail 82.9, culmen from base 18.8, depth of bill at base 13.0, tarsus 24.1 mm.

*Range*.—Taboga Island, Panamá.

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<sup>17</sup> *Saltator isthmicus* P. L. Sclater, Proc. Zool. Soc. London, August 1861, p. 130 (Isthmus of Panamá).

*Remarks.*—The more swollen bill, while not seeming of great extent in actual measurement, is easily apparent on comparing skins. In 21 males of *S. a. isthmicus* the depth of the bill at base measures 11.2-12.5 (11.8) and in 14 females 11.5-12.8 (12.2) mm. In other dimensions *melicus* and *isthmicus* are identical. In general appearance the new race is similar to *isthmicus* of the adjacent mainland, and is more remote from *speratus* of the Perlas Islands. The latter is closer to *striatipictus* of Colombia, being another indication of affinity in the avifauna of that island group with northwestern South America.

The name of the form described from Taboga is given in allusion to the sweet-voiced song.

We heard the notes of these birds on our first visit to Taboga on February 3 and later found them fairly common but shy. They ranged in the thickets bordering the fields, or in the scrub on the lower slopes, where we found them most active early in the morning. In such areas males sang from elevated perches near the tops of trees, under open cover, while others ranged through the leaf-covered branches often uttering low notes as they searched for food. At times they decoyed rather easily, and on other occasions they were quite shy, so that it took considerable work to secure our series of 11 skins. The clear song, rather cardinal-like in its tone, was the principal pleasing bird note of the island, usually heard in contrast to the rasping calls of the elainea. The flight was rapidly tilting and covered only short distances at a time. At the end of March the birds were about to nest. One taken March 16 was an immature barely grown, with yellow-tipped bill, so that the breeding season may be irregular.

As five races of this saltator are now recognized in the Republic of Panamá, it will be of interest to list them, with their characters and their distribution.

*Saltator albicollis striatipictus* Lafresnaye:

*Saltator striatipictus* LAFRESNAYE, Rev. Zool., vol. 10, March 1847, p. 73 (Cali, Valle de Cauca, Colombia).

Undersurface clearly and predominantly white, with little wash of yellowish green; streakings slightly grayer.

Trinidad, northern Venezuela, and northern Colombia; Cana, Darién. (Apparently of restricted range in Panamá.)



*Saltator albicollis speratus* Bangs and Penard:

*Saltator striatipictus speratus* BANGS and PENARD, Bull. Mus. Comp. Zoöl., vol. 63, June 1919, p. 33 (Saboga Island, Archipiélago de las Perlas, Panamá).

Similar in general appearance to *striatipictus*, but with more pronounced yellowish-green wash on under surface; slightly less heavily streaked.

The Pearl Islands, where recorded from El Rey, San José, Pedro González, Moreno, Saboga, and Viveros.

This form is slightly intermediate toward *isthmicus* but is definitely more closely allied to *striatipictus*. It is of particular interest as another element in the avifauna of the Pearl Islands that seems to have been derived from northwestern Colombia.

*Saltator albicollis isthmicus* Sclater:

*Saltator isthmicus* P. L. SCLATER, Proc. Zool. Soc. London, August 1861, p. 130 (Isthmus of Panamá).

Similar to *striatipictus*, but strongly washed with olive-green below, with the streaks more olive than dark gray; flanks and under tail coverts distinctly buffy; the entire lower surface less strongly white.

Mainly on the Pacific slope of Panamá from San Antonio, on the lower Río Bayano, and Chepo through the Canal Zone to the Azuero Peninsula and Veraguas; ranging on the Caribbean slope to Gatún, in the northern part of the Canal Zone, and on the Río Indio to El Uracillo, in extreme northeastern Coclé. Probably extending up the valley of the Río Bayano in eastern Panamá, and on the west into eastern Chiriquí.

*Saltator albicollis melicus* Wetmore:

Described above, on page 29.

Similar in general to *S. a. isthmicus*, but with larger, heavier bill; sides of head grayer; streak on either side of throat averaging grayer; flanks averaging darker; dorsal surface of tail and upper tail coverts averaging slightly darker gray.

Taboga Island.

*Saltator albicollis furax* Bangs and Penard:

*Saltator striatipictus furax* BANGS and PENARD, Bull. Mus. Comp. Zoöl., vol. 63, June 1919, p. 32 (near Boruca, Costa Rica).

Similar to *isthmicus* but darker below, with the streaking heavier and more definitely green.

Western Chiriquí (David, El Volcán) to the Térraba valley, southwestern Costa Rica.

**SPOROPHILA NIGRICOLLIS NIGRICOLLIS (Vieillot): Yellow-bellied  
Seedeater**

*Pyrrhula nigricollis* VIEILLOT, Tabl. Encycl. Méth., Orn., livr. 93, July 1823,  
p. 1027 (Brazil).

Eugene Eisenmann recorded this species near Restinga on June 24, 1948, and reports it as common on July 5, 1951. We did not find it in February and March 1952. Distribution of the species in Panamá is not clearly understood at present and seems in part to be seasonal, as the birds are reported to appear during the rains in localities where they are absent during the dry season. The birds are easily recognized from other seedeaters in any plumage by the light-gray bill.



1, THE VILLAGE AND BAY ON TABOGA ISLAND, WITH THE ISLET EL MORRO  
AT THE RIGHT

March 17, 1952



2, THE WESTERN SIDE OF TABOGA ISLAND, SITE OF NESTING COLONIES  
OF THE BROWN PELICAN

March 17, 1952



1. TABOQUILLA ISLAND, FROM THE VILLAGE OF TABOGA  
March 16, 1952



2. HILLS ON THE SOUTHERN END OF TABOGA ISLAND, AS SEEN FROM  
THE VILLAGE  
March 16, 1952



1. BEACH ON TABOQUILLA ISLAND, WITH TABOGA AND ITS VILLAGE  
IN THE DISTANCE

March 18, 1952



2. URAVÁ ISLAND, AT THE LEFT, AND THE SOUTHERN END OF  
TABOGA ISLAND

March 18, 1952









SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 121, NUMBER 3

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Mary Vaux Walcott Fund for  
Publications in Botany

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A REVISION OF THE COLOMBIAN  
SPECIES OF MONNINA  
(POLYGALACEAE)

BY

RAMÓN FERREYRA

University of San Marcos, Lima, Perú



(PUBLICATION 4100)

CITY OF WASHINGTON  
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The Lord Baltimore Press  
BALTIMORE, MD., U. S. A.

In the generous bequest of Mrs. Charles D. Walcott to the Smithsonian Institution there was included the undistributed edition of the beautiful illustrations of *North American Wild Flowers*, printed from water colors made by Mrs. Walcott from nature and reproduced by special process under her personal supervision. These plates, in five portfolio volumes, have been highly popular and have been sold in considerable numbers.

In accordance with an indication given to me by Mrs. Walcott in discussing these matters a number of years ago, the Board of Regents of the Smithsonian Institution has set aside the first proceeds derived from these sales as a special fund in Mrs. Walcott's name for publications dealing with the science of botany. It is anticipated that these studies will be mainly technical in nature and will relate to researches made principally in the United States National Herbarium, in which Mrs. Walcott was so deeply interested.

With this paper there is instituted the first of this series, to appear in the Smithsonian Miscellaneous Collections under the heading MARY VAUX WALCOTT FUND FOR PUBLICATIONS IN BOTANY.

ALEXANDER WETMORE,  
*Secretary, Smithsonian Institution.*

September 1952



## PREFACE

The present paper by Dr. Ramón Ferreyra, professor of botany at the University of San Marcos, Lima, Perú, was prepared while he was pursuing studies at the United States National Herbarium as a Fellow of the John Simon Guggenheim Memorial Foundation.

The genus *Monnina* (Polygalaceae) is exclusively American, occurring principally in the Andes of northwestern South America. A revision of the Peruvian species has already been published, and future papers dealing with those of Ecuador and Venezuela are in the course of preparation. Regional treatments are planned since many species are endemic to each country.

There are 32 species herein credited to Colombia, 11 of which are described as new. A discussion of the morphology of *Monnina* is included, as well as a brief discussion of the distribution of the species in Colombia.

JASON R. SWALLEN  
*Head Curator, Department of Botany  
United States National Museum*





Mary Vaux Walcott Fund for  
Publications in Botany

A REVISION OF THE COLOMBIAN SPECIES OF  
MONNINA (POLYGALACEAE)

BY RAMÓN FERREYRA  
*University of San Marcos, Lima, Perú*

INTRODUCTION

THE present paper is limited to a taxonomic revision of the species of *Monnina* known to occur in Colombia. Since the publication of his revision of the Peruvian species of this genus,<sup>1</sup> the writer has extended his work to a consideration of *Monnina* in other Andean countries and hopes to present future considerations of the species occurring in Ecuador and Venezuela.

The genus is exclusively American and occurs principally in the Andes of northwestern South America. The greatest concentration of species appears to be in the Peruvian Andes, although certain annual species are endemic to the coastal region of Peru, somewhat apart from the Andes. However, the present study, in which 32 species are recognized, indicates that Colombia also is an important distributional center for *Monnina*. Most of the species recognized are endemic to the country, often with a limited distribution, but a few extend southward into Ecuador, Peru, and even Bolivia. During the past 30 years botanical collecting in Colombia has been greatly accelerated; the recent material assembled by Dr. José Cuatrecasas, for example, has added several new entities to *Monnina*.

The genus *Monnina* was founded by Ruiz and Pavon in 1798, with a discussion of several Peruvian species; the type species is *M. polystachya* R. & P. It is a very distinct genus, distinguished from its closest relative, *Polygala* L., by having the stamens conspicuously grouped into two fascicles, the filaments being united upward almost to the attachment of the anthers, and the truncate stigma having two dissimilar lobes.

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<sup>1</sup> A revision of the Peruvian species of *Monnina*. Journ. Arn. Arb. 27: 123-167, pls. 1-10. 1946.

## MORPHOLOGY

Although most species of *Monnina* are shrubs, a few are slender trees. Farther south several of the species are annuals, but in Colombia only one species, *M. santamartensis*, appears to have an annual habit. In this species the root is conspicuously branched and attains a length of about 12 cm., while the branches are flexuose.

The predominant type of stem is, of course, woody, but several species in addition to *M. santamartensis* would be better defined as having herbaceous stems. Such species as *M. chodatiana*, *M. arborescens*, *M. bracteata*, and *M. mollis* have been described by collectors as trees, while several others are characterized by a twining, subscandent habit. Among the latter may be mentioned *M. subscandens*, *M. cuatrecasii*, and *M. speciosa*. The stem in *M. aestuans* is conspicuously branched in the upper part; *M. revoluta* has corymbose branches, while in other cases (*M. involuta* and *M. salicifolia*) the branches are nodose. The branchlets may be either striate or terete, and usually they are more or less pubescent, although in such species as *M. cuatrecasii*, *M. glaberrima*, and *M. oblanceolata* the branchlets are glabrous.

The leaves of *Monnina* are alternate and usually fairly well separated, although in *M. aestuans* and *M. revoluta* they are congested and not obviously alternate. The blades vary in shape from elliptic, oblong, or lanceolate to oblanceolate or almost linear; leaf shape is a fairly consistent character within species. In texture the blades are prevailingly more or less herbaceous, being coriaceous in only a few species, such as *M. cuatrecasii*, *M. obtusifolia*, *M. aestuans*, and *M. pennellii*. The apex is frequently acute to acuminate, less commonly obtuse and mucronate, as in *M. obtusifolia*, *M. aestuans*, and *M. mollis*. The margins, usually entire and flattened, may sometimes be more or less obviously revolute, conspicuously so in such species as *M. revoluta*. The venation is pinnate, the lateral nerves varying from 4 to 12 per side; however, *M. oblanceolata* and *M. revoluta*, owing to their obscure secondaries, are better described as having one-nerved leaves. In the Colombian species the leaves are always petiolate, the length of the petiole ranging from 2 mm. (in *M. revoluta*) to 15 mm. (in *M. subspeciosa*); the petiole is occasionally narrowly winged. Although leaf indument of more or less density is the usual condition, the leaves of many species become glabrate very early or, as in *M. cuatrecasii*, *M. chlamydantha*, *M. glaberrima*, and *M. oblanceolata*, the leaves may be described as strictly glabrous.

As a general rule the indument is composed of short hairs, either

simple or multicellular, which ordinarily are not very persistent, the majority of plants being glabrescent. Sometimes the hairs are rigid and yellowish (in *M. speciosa*), but more frequently they are whitish or grayish.

A considerable number of species of *Monnina* have the inflorescences simply racemose, the racemes being terminal or axillary, while a somewhat smaller group of species have paniculate inflorescences. A peduncle is always present, varying in length, among the Colombian species, from 4 mm. (in *M. revoluta*) to 60 mm. (in *M. chlamydantha*). The lateral branches of paniculate inflorescences are usually ascending but sometimes divaricate, as for instance in *M. crassinervia*, *M. speciosa*, and others.

The flowers of *Monnina* are bisexual and zygomorphic. The persistent calyx consists of five concave sepals, three exterior and two interior, all of them diverse in size. It may be observed that most species with paniculate inflorescences have the two lower sepals (of the outer three) more or less united; on the other hand, the majority of species with simply racemose inflorescences have the two lower sepals completely free. The degree to which the lower sepals are united, if at all, usually provides a dependable specific character. The two inner sepals (wings) are petaloid and usually deep blue in color. Most species of the genus have the three outer sepals smaller than the two inner ones (wings), but the reverse is the case in a few species, such as *M. involuta*, *M. latifolia*, and *M. bracteata*. In *M. involuta* the apices of the outer sepals are strongly involute. The wings are characteristically bent inward and have the dorsal surfaces either glabrous or densely pubescent (as in *M. chodatiana* and *M. latifolia*). The base of the wings is usually obtuse, being acute only in *M. parviflora*, *M. rupestris*, and *M. andreana*. Measurements of calyx parts in my descriptions represent the maximum and minimum observed in the available specimens, but the illustrations have been prepared with reference to the maximum measurements.

The corolla is composed of three petals, a median inferior one called the keel and two superior lateral ones; these lateral ones are more or less ligulate in shape and are united with the staminal tube. The keel is usually yellow and its apex is trilobed, rarely inconspicuously so (as in *M. obtusifolia*, *M. involuta*, and *M. angustata*). In many species the middle lobe is the largest of the three, but in *M. crassinervia*, *M. speciosa*, and *M. parviflora* it is smaller than the lateral lobes. The inner surface of the keel may be either glabrous or pubescent. The superior petals in most species are elongate-spatulate

(sometimes shortly spatulate), and indument is usually present to a certain degree.

The stamens are eight and completely united into two groups. Ordinarily the short free portions of the stamens are glabrous, but in *M. obtusifolia* they show some pubescence. In length the filaments vary from 2.6 mm. (in *M. parviflora*) to 5.5 mm. (in *M. subscandens*). The anthers are always apically dehiscent.

The ovary is usually ovoid or ellipsoid and glabrous. However, *M. crassinervia* and *M. chodatiana* have densely pubescent ovaries, the hairs in the latter case being 2.5 mm. long. In certain species (e. g., *M. subscandens*, *M. cuatrecasasi*, and *M. elongata*) the ovary is partially pubescent, and in *M. colombiana* it is slightly winged in the upper part. The style is usually cylindric and always geniculate, in several species being distally thickened. The style may be either glabrous or, if pubescent, with indument in the middle portion or toward the stigma (as in *M. obtusifolia*). The stigma is bilobed, the lower lobe being almost acute and the upper one tuberculate and papillose. The disk is reduced to a gland at the base of the ovary.

The fruit of *Monnina* is a 1-celled and 1-seeded drupe, usually ellipsoid in shape, but in *M. colombiana* and *M. rupestris* it may be described as samaroid, as the upper portion is slightly winged. The drupe of *M. arborescens* is truncate at base. In most species the fruit is glabrous, *M. chodatiana* being an exception and having a strongly canescent-pubescent fruit.

The pedicels are terete and pubescent, in length ranging from inconspicuous (less than 1 mm. long in *M. pilosa* and *M. pennellii*) to fairly obvious (3.2 mm. long in *M. speciosa*).

#### DISTRIBUTION

In Colombia, *Monnina* occurs in all three cordilleras of the Andes, at elevations of 1,000 to 4,200 meters. *Monnina subspeciosa* has been found at the lower of these extremes, *M. revoluta* at the higher. Many species grow in the forested areas of the subtropical and temperate zones, the major concentration occurring in the central and southwestern parts of the country. Of species occurring in Colombia, *M. salicifolia* has the most extensive distribution, being found southward to Bolivia; *M. pilosa* also occurs southward, extending through Ecuador into Peru. *Monnina phytolaccaefolia* is another common species of wide distribution, being found in Colombia and Ecuador. Many species of the genus, however, are local endemics with a comparatively small range, but future collecting must determine the real geographic limits of species now known from too few specimens.

## MATERIAL

All the available Colombian specimens of *Monnina* in the herbaria of the following institutions have been examined and are cited in this treatment: Chicago Natural History Museum (Ch); Gray Herbarium of Harvard University (GH); New York Botanical Garden (NY); U. S. National Museum (US). To the directors and curators of these institutions I am grateful for the many courtesies they have extended. Many types and photographs have been examined, and without these it would have been impossible to solve satisfactorily certain problems of identification. In many species the superficial vegetative characters are very similar, and therefore it is necessary to examine the floral structure in order to make even provisional identifications. The flowers of each species have been illustrated by the writer, in the hope that these text figures will facilitate identification for those who use this treatment.

## ACKNOWLEDGMENTS

The studies resulting in this publication have been pursued during the writer's tenure as a Fellow of the John Simon Guggenheim Memorial Foundation, and the work was done in the Department of Botany, U. S. National Museum, Smithsonian Institution. To the authorities of these organizations I wish to express sincere thanks for the support and facilities offered. In particular, my friends on the staff of the Smithsonian Institution, Jason R. Swallen, E. P. Killip, A. C. Smith, and L. B. Smith, have given me much encouragement and many useful suggestions.

## SYSTEMATIC TREATMENT

*Monnina* R. & P. Syst. Veg. 169. 1798; for references to subsequent treatments of the genus see Ferreyra in Journ. Arn. Arb. 27: 128. 1946.

Herbs, shrubs, or trees, sometimes scandent. Leaves alternate, entire, without stipules, pubescent or glabrous, mostly lanceolate, elliptic, or oblong, rarely spatulate, linear, or oblanceolate, penninerved or rarely 1-nerved, petiolate. Flowers in terminal or axillary racemes, sometimes in panicles; peduncle short to long, the inflorescence axis bracteate. Sepals 5, the 3 outer ones herbaceous, free or the two lower united, the two inner (wings) petaloid and usually much larger, more or less concave. Petals 3, the lowermost (keel) carinate, the two upper ones ligulate, usually elongate, united below to the staminal sheath. Stamens 8, the filaments united nearly to apex into a sheath

split on the upper side; anthers 2-celled. Ovary 1-celled; style geniculate, glabrous, sometimes pubescent; stigma with two dissimilar lobes, the lower one acute, the upper papillose with 1 tubercle. Disk reduced to a gland at base of ovary (hypogynous). Fruit a drupe with thin fleshy coat, rarely samaroid, the surface rugose, glabrous or pubescent.

## KEY TO THE SPECIES

Inflorescence paniculate, the lateral branches usually divaricate.

Lower sepals usually  $\frac{1}{2}$  or  $\frac{2}{3}$  united, rarely only  $\frac{1}{3}$  or inconspicuously united at base.

Ovary pubescent, sometimes only in the upper part.

Leaves oblong, conspicuously coriaceous, the nerves prominulous beneath, the apex obtuse.....1. *M. crassinervia*

Leaves elliptic-lanceolate, usually membranaceous, rarely coriaceous, the nerves not prominulous beneath, the apex acuminate or acute.

Small tree; branches densely hirsute; leaves acute; outer sepals densely pubescent beneath, the two lower ones  $\frac{1}{2}$  united; ovary with conspicuous indument (hairs to 2.5 mm. long).....2. *M. chodatiana*

Scandent plants; branches glabrous; leaves acuminate; outer sepals glabrous beneath, the two lower ones  $\frac{2}{3}$  or  $\frac{1}{2}$  united; ovary pubescent with very short hairs.

Leaf blades membranaceous; lower sepals  $\frac{2}{3}$  united, acute, 1-nerved; keel densely pubescent within, glabrous without; style glabrous.

3. *M. subscandens*

Leaf blades coriaceous; lower sepals  $\frac{1}{2}$  united, obtuse, 5-nerved; keel glabrous within, pubescent without; style pubescent.

4. *M. cuatrecasii*

Ovary always completely glabrous.

Scandent plant; leaves ovate-lanceolate, the base conspicuously rounded.

5. *M. speciosa*

Erect shrubs; leaves lanceolate or more or less elliptic, the base attenuate.

Lateral branches of panicle obtuse at apex; leaves large, to 32 cm. long; lower sepals slightly united; ovary slightly winged in the upper part.....6. *M. colombiana*

Lateral branches of panicle acuminate or acute at apex, rarely obtuse; leaves smaller, to 23 cm. long; lower sepals usually  $\frac{2}{3}$ , sometimes  $\frac{1}{2}$ , united; ovary not winged.

Panicle with few divaricate lateral branches (about 3); flowers completely covered with bracts, these broad, glandular beneath; outer sepals obtuse.....7. *M. chlamydantha*

Panicle with crowded, ascending, lateral branches (about 14); flowers with linear bracts, these glabrous beneath; outer sepals acute, rarely obtuse.

Habit tomentose; leaves to 23 cm. long, with 10 or 11 pairs of lateral veins; flowers small (3.5-3.8 mm. long); wings pubescent beneath; keel pubescent within.....8. *M. parviflora*

Habit glabrescent; leaves to 15 cm. long, with 6-8 pairs of lateral veins; flowers larger (4-5 mm. long); wings glabrous beneath; keel glabrous within.

Branches glabrescent, terete; leaves acuminate, not mucronate, the base of lower leaves rounded; axis of inflorescence glabrescent; wings acute at base; style pubescent, cylindrical.

9. *M. glaberrima*

Branches hirsute, striate; leaves acute, mucronate, the base of lower leaves attenuate; axis of inflorescence hirsute; wings obtuse at base; style glabrous, thicker toward apex.

Leaves conspicuously spatulate, revolute; flower-subtending bracts triangular, 3-nerved, to 5.5 mm. long; lower sepals obtuse, 3-nerved.....10. *M. solandraefolia*

Leaves elliptic, not revolute; flower-subtending bracts linear, 1-nerved, to 2.2 mm. long; lower sepals acute, 1-nerved.

11. *M. subspeciosa*

Lower sepals free.

Upper branches conspicuously hirsute; leaves oblong, acute; flower-subtending bracts broadly acute-triangular; outer sepals obtuse.

12. *M. pilosa*

Upper branches slightly tomentose, becoming glabrescent; leaves narrowly lanceolate, acuminate; flower-subtending bracts linear; outer sepals acute.

Leaves always about 4 times as long as wide (up to 160 x 40 mm.), with 7-9 pairs of lateral veins; flower-subtending bracts 3-4 times as long as broad (up to 11.2 x 2.8 mm.); keel pubescent within; arborescent.

13. *M. arborescens*

Leaves more than 5 times as long as wide (up to 225 x 40 mm.), with 10-12 pairs of lateral veins; flower-subtending bracts about 8 times as long as broad (up to 7 x 0.8 mm.); keel glabrous within; frutescent.....14. *M. erecta*

Inflorescence simply racemose.

Lower sepals conspicuously joined, usually  $\frac{1}{2}$  united, sometimes  $\frac{2}{3}$  or rarely only slightly united at base.

Branches glabrous; leaves glabrous, oblanceolate, with inconspicuous lateral veins; bracts of racemes rounded, oblanceolate, 4- or 5-nerved, the base hood-shaped; lower sepals slightly united.....15. *M. oblanceolata*

Branches strigose; leaves finely pubescent, elliptic or lanceolate, with conspicuous lateral veins; bracts of racemes filiform or triangular, 1-nerved; lower sepals  $\frac{1}{2}$  or  $\frac{2}{3}$  united.

Style pubescent, the hairs sometimes only distal.

Leaves lanceolate, to 130 mm. long, acute; axis of racemes elongate, to 29 cm. long, the bracts filiform (7.2-11.5 mm. long); lower sepals  $\frac{2}{3}$  united, acute, 1-nerved.....16. *M. schultesii*

Leaves oblong, to 90 mm. long, obtuse; axis of racemes shorter, to 11.5 cm. long, the bracts ovate-triangular (1-2.2 mm. long); lower sepals  $\frac{1}{2}$  united, obtuse, 3- or 5-nerved.....17. *M. obtusifolia*

Style always glabrous.

Upper branches with crowded leaves, the blade coriaceous, obtuse, mucronate, to 72 mm. long; bracts of racemes triangular; keel pubescent within.....18. *M. aestuans*

Upper branches with comparatively spaced leaves, the blade herbaceous, acuminate or acute, not mucronate, to 225 mm. long; bracts of racemes filiform, rarely triangular; keel glabrous within, sometimes slightly pubescent.

Branches herbaceous; axis of racemes to 28 cm. long, the bracts to 6 mm. long; outer sepals acute (to 4.8 mm. long).

19. *M. santamartensis*

Branches woody; axis of racemes to 15 cm. long, the bracts to 4.2 mm. long; outer sepals obtuse (to 3.2 mm. long).

Leaves herbaceous, acuminate; axis of racemes to 9 cm. long, the bracts filiform; wings acute at base; keel glabrous within.

20. *M. rupestris*

Leaves more or less coriaceous, acute; axis of racemes to 15 cm. long, the bracts triangular; wings obtuse at base; keel pubescent within. . . . . 21. *M. phytolaccaefolia*

Lower sepals completely free.

Leaves linear, conspicuously revolute, 1-nerved, decurrent, crowded.

22. *M. revoluta*

Leaves elliptic or lanceolate, not revolute, with several pairs of lateral veins, not decurrent or crowded.

Ovary pubescent, at least in the upper part.

Apex of leaves acuminate, the blade with 8 or 9 pairs of lateral veins; axis of racemes to 11 cm. long, the bracts oblanceolate (6-7 mm. long); outer sepals obtuse; ovary pubescent in the upper part.

23. *M. elongata*

Apex of leaves acute, the blade with 4 or 5 pairs of lateral veins; axis of racemes to 6 cm. long, the bracts linear or narrowly triangular (1.8-3 mm. long); outer sepals acute; ovary entirely pubescent.

24. *M. andreana*

Ovary completely glabrous.

Outer sepals (to 6 mm. long) larger than the wings.

Branches glabrescent; leaves to 50 mm. long; racemes inconspicuously bracteate; apex of outer sepals strongly involute; wings glabrous beneath; keel glabrous within. . . . . 25. *M. involuta*

Branches hirsute; leaves to 215 mm. long; racemes with conspicuous filiform bracts (to 11.6 mm. long); apex of outer sepals not or very slightly involute; wings pubescent beneath; keel pubescent within.

Leaf blades elliptic-lanceolate (to 215 mm. long); petioles to 3 mm. long; axis of racemes to 30 cm. long, the bracts 6-7.2 mm. long; apex of outer sepals straight; wings densely pubescent beneath; style pubescent. . . . . 26. *M. latifolia*

Leaf blades lanceolate (to 155 mm. long); petioles to 8 mm. long; axis of racemes to 9.5 cm. long, the bracts 6-11.6 mm. long; apex of outer sepals curved; wings slightly pubescent beneath; style glabrescent. . . . . 27. *M. bracteata*

Outer sepals (to 4 mm. long) always smaller than the wings.

Leaves elliptic, coriaceous; bracts of racemes inconspicuous, triangular (up to 4 mm. long).



Leaves acute, to 145 mm. long and 92 mm. wide, with 9 or 10 pairs of lateral veins; lower sepals 5-nerved; style pubescent.

28. *M. pennellii*

Leaves obtuse, to 75 mm. long and 35 mm. wide, with 5 or 6 pairs of lateral veins; lower sepals 3-nerved; style glabrous.

29. *M. salicifolia*

Leaves lanceolate, rarely oblong, herbaceous; bracts of racemes conspicuous, filiform, rarely hood-shaped (usually more than 4 mm. long).

Leaves oblong, obtuse, sometimes acute; bracts of racemes triangular, hood-shaped, densely pubescent beneath. . . . .30. *M. mollis*

Leaves lanceolate, acuminate; bracts of racemes filiform, slightly pubescent beneath.

Branches finely pubescent; axis of racemes to 23 cm. long, the bracts lax (7-14 mm. long); outer sepals obtuse; keel glabrous within. . . . .31. *M. smithii*

Branches conspicuously hirsute; axis of racemes to 11.5 cm. long, the bracts ascending (3-5 mm. long); outer sepals acute; keel pubescent within. . . . .32. *M. angustata*

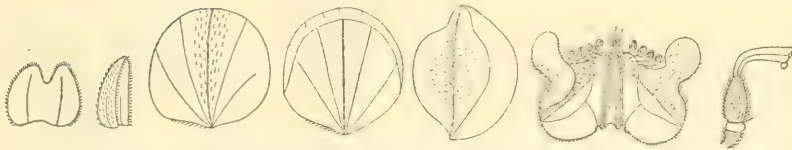


FIG. 1.—*Monnina crassinervia*: Left to right, lower sepals, upper sepal, wing (outer), wing (inner), keel, upper petals and stamens, gynaecium. All  $\times 3$ .

1. *Monnina crassinervia* Tr. & Pl. in Ann. Sci. Nat. IV. 17: 143. 1862.

Frutescent, branched, the branches 3-4 mm. in diameter, tomentose, striate; leaves conspicuously oblong, 44-70 mm. long, 21-35 mm. wide, obtuse, strigose and becoming glabrescent above, hirsute beneath, entire, revolute, attenuate at base, the costa prominulous beneath, with 5 or 6 pairs of prominulous lateral veins; petioles 2-7 mm. long, concave above, convex beneath, hirsute; inflorescence paniculate, the axis to 6 cm. long and 3 mm. in diameter, striate, hirsute, the lateral branches divaricate, acute, 3.5-4.5 cm. long, 7-9 mm. wide, bracteate, the bracts linear, conspicuous, deciduous; flowers 4.2-5.2 mm. long, the pedicels 1-1.2 mm. long, finely hirsute; outer sepals ovate-triangular, obtuse, ciliate, densely pubescent beneath, the two lower ones 2.4-2.5 mm. long, 1.5-1.6 mm. wide,  $\frac{1}{2}$  united, 1-nerved, the upper one 2.8-3 mm. long, 2.4-2.5 mm. wide, 3-5-nerved; wings 4.5-5.5 mm. long, 4.2-5.2 mm. wide, obovate, obtuse at base, 3-nerved, pubescent beneath, ciliate; keel 4.6-5.6 mm. long, 3.2-3.8 mm. wide, orbicular, plicate, pubescent within, obtuse at base, 3-nerved, 3-lobed, the middle lobe obtuse-emarginate, smaller; upper petals elongate-

spatulate, pubescent; stamens 8, the filaments 3–3.2 mm. long, almost entirely united, the free part 0.5–0.8 mm. long, glabrous; ovary ovoid, 1.5–1.8 mm. long, 0.8–1 mm. wide, densely pubescent; style 2–2.4 mm. long, geniculate above base, glabrous, slightly thicker toward apex; stigma with 2 lobes, the lower one acute, the upper 1-tubercled, the tubercle papillose; fruit unknown.

DISTRIBUTION: Central Colombia, Department of Antioquia, 2,700 meters altitude.

ANTIOQUIA: "Pentes occidentales du páramo d'Herveo," Triana s. n. (fragments of type US; photographs of type Ch, GH, US).

This species, as indicated by fragments and photographs of the type, is distinguished by its coriaceous and oblong leaves with nerves conspicuously prominulous beneath. The description given above is adapted from the original, supplemented by the cited fragments and photograph.



FIG. 2.—*Monnina chodatiana*: Left to right, lower sepals, upper sepal, wing (inner), wing (outer), keel, upper petals and stamens, gynaecium. All  $\times 3$ .

## 2. *Monnina chodatiana* Ferreyra, sp. nov.

Arbor *M. subscandenti* Tr. & Pl. affinis, habitu hirsuto-lanuginoso, foliis acutis, sepalo exteriore dense pubescente, sepalis duobus inferioribus  $\frac{1}{3}$  connatis differt.

Small tree to 3 m. high, branched, the branches 6–10 mm. in diameter, terete, conspicuously hirsute; leaves elliptic, 37–155 mm. long, 17–80 mm. wide, acute, pubescent above, becoming glabrescent, slightly hirsute beneath, entire, attenuate at base, the costa prominulous beneath, with 9 or 10 pairs of lateral veins; petioles 3–8 mm. long, more or less concave above, convex beneath, pubescent; inflorescence paniculate, the axis 6–12 cm. long, 2–4 mm. in diameter, striate, densely hirsute, the lateral branches 3 or 4 in number, 3–8.5 cm. long, 9–11 mm. wide, acute at apex, pedunculate (peduncle 4–12 mm. long), bracteate, the bracts triangular, 2.8–3 mm. long and wide, acute, densely pubescent beneath, ciliate, deciduous, 3-nerved; flowers 5–6 mm. long, the pedicels 1.6–2 mm. long, densely pubescent; outer sepals ovate, obtuse, ciliate, densely pubescent beneath, the two lower ones 2.2–2.6 mm. long, 2–2.2 mm. wide,  $\frac{1}{3}$  united, 5-nerved, the upper sepal

2.2–3 mm. long, 2.4–2.6 mm. wide, 7-nerved; wings blue, 5.8–6 mm. long, 4.2–5 mm. wide, obovate, obtuse at base, 3- or 4-nerved, densely pubescent beneath, eciliate; keel 5–6.2 mm. long, 3.6–4 mm. wide, orbicular, plicate, pubescent within, obtuse at base, 3- or 4-nerved, 3-lobed, the middle lobe obtuse-emarginate, larger; upper petals elongate-spatulate, densely pubescent; stamens 8, the filaments 4–4.5 mm. long, almost entirely united, the free part 0.5–1.2 mm. long, glabrous; ovary ellipsoid, 2–2.5 mm. long, 1.5–2 mm. wide, strongly pubescent, the hairs ascending, 2–2.5 mm. long; style 2.6–2.8 mm. long, slightly pubescent near base, geniculate at base, more or less cylindrical; stigma with 2 lobes, the lower one acute, the upper 1-tubercled, the tubercle papillose; drupe ellipsoid, 7–8 mm. long, 3.5–4.2 mm. wide, densely canescent-pubescent, reticulate.

Type in the herbarium of the Chicago Natural History Museum, No. 1367478, collected in Loma de Barragán, valley of Río Bugalagrande, western slope, Cordillera Central, Department of El Valle, alt. 2,800–2,900 meters, April 18 or 19, 1946, by J. Cuatrecasas (No. 20920).

ADDITIONAL SPECIMEN EXAMINED:

EL VALLE: La Laguna, Barragán, valley of Río Bugalagrande, western slope, Cordillera Central, *Cuatrecasas* 20887 (Ch).

DISTRIBUTION: Endemic in the southwestern Andes of Colombia, between 2,800 and 2,900 meters altitude.

The new species is characterized by its densely hirsute habit, the outer sepals being strongly pubescent beneath, the wings pubescent beneath, and the ovary densely pubescent with hairs up to 2.5 mm. long. It is near *M. subscandens* Tr. & Pl., from which it differs in having the branches almost hirsute-lanuginose, the sepals pubescent beneath, the ovary pubescent, and in its habit. It is a pleasure to name this new species in honor of the distinguished Swiss botanist Dr. R. Chodat, in recognition of his valuable studies of the genus *Monnina*.

3. *Monnina subscandens* Tr. & Pl. in Ann. Sci. Nat. IV. 17: 143. 1862.

Scandent to 2 m. high, branched, the branches 22–32 cm. long, 3–5 mm. in diameter, terete, finely pubescent, becoming glabrescent; leaves elliptic-lanceolate, 40–130 mm. long, 15–58 mm. wide, acuminate, rarely more or less acute, slightly pubescent above, becoming glabrescent, finely pubescent beneath, entire, attenuate at base, the costa prominulous beneath, with 7 or 8 pairs of lateral veins; petioles 2–8 mm. long, concave above, convex beneath, slightly pubescent; inflorescence paniculate, the axis 8.5–18 cm. long, 1.5–2.5 mm. in diameter, striate, finely pubescent, the lateral branches numerous,

almost acute at apex, 3–15 cm. long, 10–12 mm. wide, pedunculate (peduncle 5–11 mm. long), bracteate, the bracts lanceolate-linear, 4.8–5.5 mm. long, 1–1.6 mm. wide, acuminate, slightly pubescent beneath, ciliate, deciduous, 1-nerved; flowers 5.5–7 mm. long, the pedicels 1.6–2 mm. long, finely pubescent; outer sepals more or less triangular, acute, ciliate, glabrescent beneath, the two lower ones 2–3 mm. long, 1.2–2 mm. wide,  $\frac{2}{3}$  united, 3-nerved, the nerves inconspicuous, the upper sepal 3–4.2 mm. long, 1.8–3.8 mm. wide, 5–7-nerved; wings blue, 5–7 mm. long and wide, obovate, obtuse at base, 3- or 4-nerved, slightly pubescent beneath, becoming glabrescent, ciliate at base; keel 5.2–8 mm. long, 3.2–4.8 mm. wide, orbicular, plicate, pubescent within, sometimes glabrescent, obtuse at base, 3- or 4-nerved, 3-lobed, the middle lobe obtuse-emarginate, larger; upper petals elongate-spatulate, pubescent; stamens 8, the filaments 4.5–5.5 mm. long,

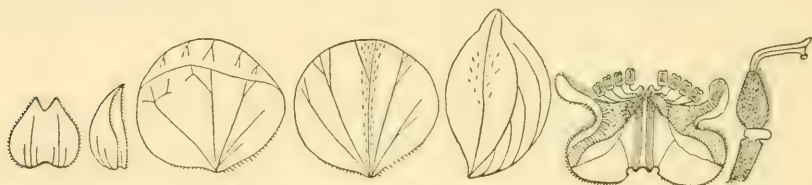


FIG. 3.—*Monnina subscandens*: Left to right, lower sepals, upper sepal, wing (inner), wing (outer), keel, upper petals and stamens, gynaecium. All  $\times 3$ .

almost entirely united, the free part 0.8–1.5 mm. long, glabrous; ovary ellipsoid, 2–2.6 mm. long, 1.2–1.8 mm. wide, usually entirely pubescent, rarely pubescent only in the upper part; style 2.6–3.2 mm. long, geniculate above base, almost cylindric, glabrous; stigma with 2 lobes, the lower one acute, the upper 1-tubercled, the tubercle papillose; drupe ellipsoid, 6–10 mm. long, 2.8–7 mm. wide, slightly pubescent, sometimes glabrescent, reticulate.

DISTRIBUTION: From central to southwestern Colombia and northern Ecuador, between 1,950 and 3,600 meters altitude.

CUNDINAMARCA: Facativita-Anolaima highway, *Haught 6221* (US).

TOLIMA: Quindio, *Triana* s. n. (fragments of type US, photographs of type Ch, GH, US).

CALDAS: Río San Rafael, below Cerro Tatamá, Cordillera Occidental, *Pennell 10335* (US); "Pinares," above Salento, Cordillera Central, *Pennell 9395* (US).

EL VALLE: Las Colonias, above Queremál, valley of Río Dígua, western slope, Cordillera Occidental, *Cuatrecasas 23907* (Ch); north of Albán, near the crest between Departments of El Valle and Intendencia del Chocó, western slope, Cordillera Occidental, *Dugand & Jaramillo 2996* (US); Quebrada de Juntas, Río Pichindé, valley of Río Cali, eastern slope, Cordillera Occidental, *Cuatrecasas 21616* (Ch); El Cairo, Río Pichindé, Cordillera Occidental, *Cuatrecasas*

21973 (Ch); El Tabor, above Las Brisas, Cordillera Occidental, *Cuatrecasas* 22316 (Ch).

CAUCA: Aguabonita, valley of Río San José, eastern slope, Cordillera Central, *Cuatrecasas* 23518 (Ch); Páramo de Buena Vista, Paez Valley, Cordillera Central, *Pittier* 1477 (US); San Miguel, *Bro. Apollinaire-Marie* 523 (Ch).

This scandent plant is distinguished by the long axis of its inflorescence (to 18 cm. long), the lax and numerous lateral branches, the inconspicuous nerves of the outer sepals, and the large keel (to 8 mm. long).

4. *Monnina cuatrecasasii* Ferreyra, sp. nov.

Frutex scandens a *M. subscandente* Tr. & Pl., cui affinis, foliis coriaceis, sepalo exterioro obtuso, sepalis duobus inferioribus  $\frac{1}{2}$  connatis 5-nerviis, carina intus glabra extus pubescente, stylo pubescente differt; a *M. glaberrima* Chodat foliis basi attenuatis, sepalo exterioro obtuso, carina extus pubescente, ovario puberulo distinguitur.

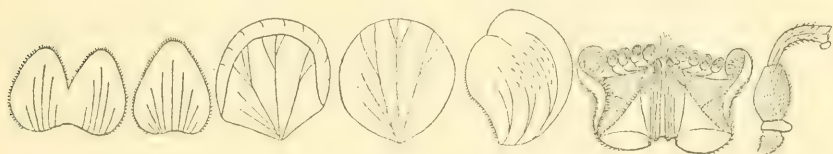


FIG. 4.—*Monnina cuatrecasasii*: Left to right, lower sepals, upper sepal, wing (inner), wing (outer), keel, upper petals and stamens, gynaecium. All  $\times 3$ .

Subscandent, branched, the branches 3.5–5 mm. in diameter, terete, glabrous; leaves coriaceous, elliptic-lanceolate, 44–130 mm. long, 17–52 mm. wide, acuminate, glabrous, entire, attenuate at base, the costa prominulous beneath, with 8 or 9 pairs of lateral veins; petioles 3–5 mm. long, 1–1.2 mm. in diameter, concave above, convex beneath, glabrescent; inflorescence paniculate, the axis 9–9.7 cm. long, 2–2.2 mm. in diameter, striate, glabrescent, the lateral branches more or less numerous, ascending, 3.5–6 cm. long, 10–12 mm. wide, acute at apex, pedunculate (peduncle 11–16 mm. long), bracteate, the bracts lanceolate, 3.2–4 mm. long, 1–1.2 mm. wide, acuminate, slightly pubescent beneath, ciliate, deciduous, 1-nerved; flowers 4.2–5 mm. long, the pedicels 1.5–3 mm. long, finely pubescent; outer sepals ovate, ciliate, obtuse, glabrous beneath, the two lower ones 3.5–3.8 mm. long, 2.2–2.5 mm. wide,  $\frac{1}{2}$  united, 5-nerved, the upper sepal 3.8–4 mm. long, 3.6–3.8 mm. wide, 7-nerved; wings blue, 5–6 mm. long, 5.2–6 mm. wide, fleshy, obovate, obtuse at base, 3-nerved, slightly pubescent beneath, eciliate; keel 4.8–6.5 mm. long, 3.4–5 mm. wide, orbicular, plicate, glabrescent within, more or less acute at base, 3- or 4-nerved, 3-lobed, the middle lobe obtuse-emarginate; upper petals elongate-

spatulate, pubescent; stamens 8, the filaments 3.2-4 mm. long, almost entirely united, the free part 0.6-1 mm. long, glabrous; ovary ellipsoid, 1.5-2.8 mm. long, 1-1.5 mm. wide, pubescent, the hairs conspicuous in the upper part; style 2.5-3 mm. long, geniculate above base, pubescent, more or less cylindric; stigma with 2 lobes, the lower one acute, the upper 1-tubercled, the tubercle papillose; drupe ovoid, 8-10 mm. long, 4-6 mm. wide, slightly pubescent, becoming glabrescent, reticulate.

Type in the herbarium of the Chicago Natural History Museum, Nos. 1367796 and 1367797, collected above Las Brisas, between El Tabor and Alto de Mira, Cordillera Occidental, Department of El Valle, alt. 2,200-2,300 meters, October 22-25, 1946, by J. Cuatrecasas (No. 22421).

DISTRIBUTION: Known only from the type collection.

The new species suggests *M. subscandens* Tr. & Pl., but the axis of its inflorescence is shorter (to 9.7 cm. long), the outer sepals are ovate, obtuse, the two lower ones  $\frac{1}{2}$  united and 5-nerved, the keel is pubescent beneath, the style pubescent, etc. It is also related to *M. glaberrima* Chodat, from which it differs in having the leaves attenuate at base, the lateral branches of panicles ascending, the outer sepals obtuse, the wings and keel pubescent beneath, and the ovary conspicuously pubescent.

5. *Monnina speciosa* Tr. & Pl. in Ann. Sci. Nat. IV. 17: 144. 1862.

Scandent, branched, the branches 25-97 cm. long, 2.5-5 mm. in diameter, pubescent, becoming glabrescent, striate; leaves ovate-ob lanceolate, 30-105 mm. long, 15-42 mm. wide, acuminate, conspicuously rounded at base, glabrescent above, pubescent beneath (hairs rigid, yellowish, more numerous on the nerves), entire, slightly revolute, the costa conspicuously prominulous beneath, with 8 or 9 pairs of lateral veins usually prominulous beneath; petioles 3-6 mm. long, concave above, convex beneath, pubescent; inflorescence paniculate, the axis 5-18 cm. long, 1.5-3 mm. in diameter, striate, finely pubescent, becoming glabrescent, the lateral branches (4-8) divaricate, 4.2-17.5 cm. long, 7-9 mm. wide, elongate-acuminate at apex, pedunculate (peduncle 6-20 mm. long), bracteate, the bracts linear, 3.5-5.5 mm. long, 0.6-1 mm. wide, acuminate, with a few hairs beneath, becoming glabrescent, ciliate, deciduous, 1-nerved; flowers 4.2-5.8 mm. long, the pedicels 2.4-3.2 mm. long, pubescent; outer sepals triangular, acute, ciliate, glabrescent beneath, the two lower ones 1.6-2 mm. long, 1-1.4 mm. wide,  $\frac{1}{2}$  or  $\frac{3}{4}$  united, usually 1-nerved, rarely 3-nerved, the upper sepal 2.5-2.8 mm. long, 1.8-2.6 mm. wide, usually 3-nerved, rarely 5-nerved; wings blue, 4.2-5.8 mm. long, 3.8-4.8 mm. wide,

obovate, obtuse at base, 3- or 4-nerved, glabrescent beneath, sometimes slightly pubescent, ciliate at base; keel 4.4–6 mm. long, 3.2–4 mm. wide, orbicular, plicate, glabrous within, obtuse at base, 3- or 4-nerved, 3-lobed, the middle lobe obtuse-emarginate, smaller; upper petals elongate-spatulate, pubescent; stamens 8, the filaments 3.2–4.2 mm. long, almost entirely united, the free part 0.8–1.4 mm. long, glabrous; ovary ellipsoid, 1.8–2.2 mm. long, 0.8–1.2 mm. wide, glabrous; style 2.2–2.8 mm. long, geniculate above base, glabrous, more or less cylindrical; stigma with 2 lobes, the lower one acute, the upper 1-tubercled, the tubercle papillose; drupe ellipsoid, 5.5–7 mm. long, 3–4 mm. wide, glabrous, reticulate.

DISTRIBUTION: From northern to southwestern Colombia, between 1,500 and 3,000 meters altitude.

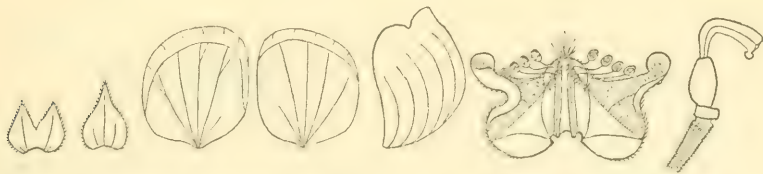


FIG. 5.—*Monnina speciosa*: Left to right, lower sepals, upper sepal, wings (inner), keel, upper petals and stamens, gynaecium. All  $\times 3$ .

HUILA: East of Neiva, Cordillera Oriental, *Rusby & Pennell* 663 (NY, US).

ANTIOQUIA: San Pedro, *Bro. Apollinaire-Marie* 268 (Ch); vicinity of Medellín, *Toro* 1262 (NY), *Gutiérrez & Delisle* 263 (US); Laguna de Guarna, *Bro. Daniel* 2762 (US); Santa Elena, *Archer* 1253 (NY, US).

NARIÑO: Trail from Mayasquer to Tambo, *Mexia* 7578a (US); Altaquer, *Triana* s. n. (fragments and photographs of type, GH, US).

This liana is characterized by its ovate-lanceolate leaves with conspicuously rounded bases, by having the lateral branches of the panicles divaricate, with linear bracts, and by the triangular-acute outer sepals.

#### 6. *Monnina colombiana* Ferreyra, sp. nov.

Frutex *M. glaberrima* Chodat affinis, foliis majoribus lamina spatulata acuminata ad 32 cm. longa, sepalo exteriori obtuso, sepalis duobus inferioribus breviter connatis, stylo glabro differt.

Branching shrub, the branches 4–5 mm. in diameter, more or less terete, hirsute, becoming glabrescent in the lower part; leaves almost spatulate, 260–320 mm. long, 90–115 mm. wide, acuminate, glabrescent above, slightly pubescent beneath, entire, attenuate at base, the costa prominulous beneath, with 10 or 12 pairs of lateral veins; petioles 5–8 mm. long, concave above, convex beneath, pubescent; inflorescence paniculate, the axis 14–16 cm. long, 2.5–3 mm. in diam-

eter, striate, hirsute, the lateral branches about 6, divaricate, 10–12 cm. long, 10–11 mm. wide, obtuse at apex, pedunculate (peduncle 6–14 mm. long), bracteate, the bracts lanceolate, 6–6.5 mm. long, 2–2.2 mm. wide, acute, pubescent beneath, ciliate, deciduous, 1-nerved; flowers 4.5–5 mm. long, the pedicels 1.5–2 mm. long, curved, pubescent; outer sepals ovate, obtuse, ciliate, slightly pubescent beneath, 3-nerved, the two lower ones 2–2.4 mm. long, 1.4–1.8 mm. wide, more or less united at base, sometimes free, the upper sepal 3–3.2 mm. long, 2–2.2 mm. wide; wings 4.5–4.8 mm. long, 3–3.2 mm. wide, obovate, obtuse at base, 3-nerved, ciliate; keel 4.4–5 mm. long, 3–3.6 mm. wide, orbicular, plicate, glabrous within, obtuse at base, 3- or 4-nerved, 3-lobed, the middle lobe obtuse-emarginate, larger; upper petals elongate-spatulate, pubescent; stamens 8, the filaments 3.2–3.6



FIG. 6.—*Monnina colombiana*: Left to right, lower sepals, upper sepal, wings (inner), keel, upper petals and stamens, gynaecium, bract. All  $\times 3$ .

mm. long, almost entirely united, the free part 0.6–1 mm. long, glabrous; ovary ellipsoid, 1.6–1.8 mm. long, 1–1.2 mm. wide, glabrous, the upper part slightly winged; style 1.8–2 mm. long, geniculate at base, glabrous, thicker toward apex; stigma with 2 lobes, the lower one acute, the upper 1-tubercled, the tubercle papillose; drupe samaroid, 9–11 mm. long, 5.5–6.5 mm. wide, glabrous, conspicuously reticulate, the upper part slightly winged.

Type in the U. S. National Herbarium, No. 1796574, collected below Gabinete, western slope, Cordillera Oriental, Department of Huila, alt. 1,900–2,100 meters, March 24, 1940, by J. Cuatrecasas (No. 8593).

DISTRIBUTION: Known only from the type collection.

This new species is distinguished by its large and more or less spatulate leaves, and by having the ovary slightly winged in the upper part. It resembles *M. glaberrima* Chodat but is quite distinct in its larger, spatulate, and acuminate leaves (to 32 cm. long), in the lower sepals being slightly united at base and obtuse, and in the winged ovary and glabrous style.

7. *Monnina chlamydantha* Ferreyra, sp. nov.

Frutex valde distinctus, bracteis magnis flores involucrantibus distinguendus; *M. parviflora* H.B.K. affinis, ramis teretibus glabris, bracteis florigeris majoribus extus glandulosis, stylo glabro differt.



Frutescent, branched, the branches 3.5–4.5 mm. in diameter, the lower part glabrescent, the upper finely pubescent, terete; leaves more or less elliptic, 50–162 mm. long, 21–67 mm. wide, elongate-acuminate, glabrous above, glabrescent beneath, entire, slightly revolute, attenuate at base, the costa strongly prominulous beneath, with 6 or 7 pairs of lateral veins; petioles 2.5–7 mm. long, concave above, convex beneath, finely pubescent, becoming glabrescent; inflorescence paniculate, the axis 19.8–21.8 cm. long, 2–2.5 mm. in diameter, striate, finely pubescent, the hairs strigose, the lateral branches ascending, obtuse at apex, 2–11 cm. long, 9–12 mm. wide, pedunculate (peduncle 25–60 mm. long), conspicuously bracteate, the bracts fanlike, 9.5–10.5 mm. long, 8.5–9.6 mm. wide, obtuse, slightly glandular beneath, ciliate, deciduous, 4-nerved, completely covering the flowers; flowers 5.2–



FIG. 7.—*Monnina chlamydantha*: Left to right, lower sepals, upper sepal, wings (inner), keel, upper petals and stamens, gynaeceum, all  $\times 3$ ; bract,  $\times 2$ .

6.5 mm. long, the pedicels 1.2–1.8 mm. long, pubescent; outer sepals ovate, ciliate, obtuse, glabrous beneath, concave, the two lower ones 2.4–2.8 mm. long, 1.8–2 mm. wide,  $\frac{2}{3}$  united, 3-nerved, the upper sepal 3–3.5 mm. long, 2.2–2.6 mm. wide, 5-nerved; wings dark blue, 5.5–6 mm. long, 5–5.5 mm. wide, obovate, obtuse at base, 3- or 4-nerved, glabrous beneath, eciliate; keel yellow, 6–7 mm. long, 4–5 mm. wide, orbicular, plicate, slightly pubescent within, obtuse at base, 3-nerved, 3-lobed, the middle lobe obtuse-emarginate, larger; upper petals almost spatulate, pubescent; stamens 8, the filaments 4.8–5 mm. long, unequally united, the free part 1–1.5 mm. long, glabrous; ovary ovoid, 2–2.2 mm. long, 1–1.2 mm. wide, glabrous; style 2.8–3 mm. long, geniculate above base, glabrous, thicker toward apex; stigma with 2 lobes, the lower one acute, the upper 1-tubercled, the tubercle papillose; drupe ellipsoid (immature), 5–6 mm. long, 2.5–3 mm. wide, glabrous, reticulate.

Type in the herbarium of the Chicago Natural History Museum, No. 1368044, collected in the region of Queremál, valley of Río Digua, western slope, Cordillera Occidental, Department of El Valle, alt. 1,540–1,650 meters, February 25, 1947, by J. Cuatrecasas (No. 23730).

DISTRIBUTION: Known only from the type collection.

The proposed entity is very distinct in its large and conspicuous

flower-subtending bracts and in its elliptic, acuminate, and glabrous leaves. It is related to *M. parviflora* H.B.K. but differs in having the branches terete and glabrescent, the flower-subtending bracts fanlike and glandular beneath, the flowers larger (to 6.5 mm. long), and the style glabrous.

8. *Monnina parviflora* H.B.K. Nov. Gen. & Sp. 5: 419. 1821.

Frutescent, branched, the branches 4-5 mm. in diameter, slightly tomentose, becoming glabrescent, striate; leaves lanceolate-elliptic, 80-230 mm. long, 20-64 mm. wide, acuminate, sometimes acute, finely pubescent above, becoming glabrescent, slightly pubescent beneath, entire, attenuate at base, the costa prominent beneath, with 10 or 11 pairs of lateral veins; petioles 3-5 mm. long, concave above, convex beneath, pubescent, slightly winged; inflorescence paniculate, the axis 23-25 cm. long, 3-4 mm. in diameter, striate, hirsute, the lateral



FIG. 8.—*Monnina parviflora*: Left to right, lower sepals, upper sepal, wing (outer), wing (inner), keel, upper petals and stamens, gynaecium, bract. All  $\times 3$ .

branches (3-10) 10.5-20 cm. long, 7-9 mm. wide, acuminate at apex, pedunculate (peduncle 12-23 mm. long), bracteate, the bracts linear, 6-7 mm. long, 0.8-1 mm. wide, acuminate, pubescent beneath, ciliate, deciduous, 1-nerved; flowers 3.5-3.8 mm. long, the pedicels 1.8-2 mm. long, finely pubescent; outer sepals almost lanceolate, acute, ciliate, pubescent beneath, 1-nerved, the two lower ones 2-2.2 mm. long, 0.8-1 mm. wide, nearly  $\frac{2}{3}$  united, the upper sepal 2.4-2.8 mm. long, 1-1.2 mm. wide; wings 3.4-3.6 mm. long, 2.8-2.9 mm. wide, obovate, acute at base, 3-nerved, pubescent beneath, eciliate; keel 3.6-3.8 mm. long, 2.5-2.7 mm. wide, orbicular, plicate, pubescent within, 3-nerved, 3-lobed, the middle lobe obtuse-subemarginate, smaller; upper petals short, spatulate, pubescent; stamens 8, the filaments 2.4-2.6 mm. long, almost entirely united, the free part 0.3-0.6 mm. long, glabrous; ovary ovoid, 1.4-1.5 mm. long, 0.6-0.8 mm. wide, glabrous; style 1.8-2 mm. long, geniculate at base, pubescent, more or less cylindrical; stigma with 2 lobes, the lower one acute, the upper 1-tubercled, the tubercle papillose; drupe ellipsoid, 7-8 mm. long, 4-4.5 mm. wide, glabrous, reticulate.

DISTRIBUTION: In the central part of the Colombian Andes, between 1,500 and 2,300 meters altitude.

TOLIMA: "Quindío," *Bonpland* s. n. (photographs of type, GH, Ch, US).

CALDAS: San Bernardino, Cordillera Central, *Pennell & Hazen* 10156 (US).

The conspicuously tomentose habit, the striate and hirsute lateral branches of the panicles, the small flowers, and the linear bracts characterize this species.

9. *Monnina glaberrima* Chodat in Bull. Soc. Bot. Genève II. 25: 215. 1934.

Frutescent, to 2 m. high, branched, the branches 3–6 mm. in diameter, terete, glabrescent; leaves ovate-oblong, sometimes ovate-lanceolate, 32–130 mm. long, 16–70 mm. wide, acuminate, rarely acute, glabrous above, glabrescent beneath, entire, usually rounded at base, the costa prominulous beneath, with 7 or 8 pairs of lateral veins, petioles 2–8 mm. long, 1–1.6 mm. wide, concave above, convex beneath, slightly pubescent, becoming glabrescent; inflorescence paniculate, the axis



FIG. 9.—*Monnina glaberrima*: Left to right, lower sepals, upper sepal, wings (inner), keel, upper petals and stamens, gynaecium. All  $\times 3$ .

6–14 cm. long, 1.8–3 mm. in diameter, striate, glabrescent, the lateral branches 5–14, divaricate, 2.4–9.5 cm. long, 8–10 mm. wide, more or less acute at apex, pedunculate (peduncle 5–15 mm. long), bracteate, the bracts linear-lanceolate, 2–3 mm. long, 0.8–1 mm. wide, deciduous; flowers 4–5 mm. long, the pedicels 1.5–2.2 mm. long, finely pubescent; outer sepals lanceolate, acute, ciliate, slightly pubescent beneath, becoming glabrescent, the two lower ones 1.8–2.8 mm. long, 1.5–2.2 mm. wide,  $\frac{1}{3}$  or  $\frac{2}{3}$  united, 1-nerved, rarely 3-nerved, the upper sepal 2.2–3 mm. long, 1–2 mm. wide, 1-nerved, sometimes 3–5-nerved; wings blue, 4.2–5 mm. long, 3–4.8 mm. wide, obovate, slightly acute at base, 3-nerved, ciliate, usually glabrous beneath, rarely pubescent; keel 4.2–5 mm. long, 2.8–3.4 mm. wide, orbicular, plicate, glabrous within, sometimes with a few hairs, obtuse at base, 3- or 4-nerved, 3-lobed, the middle lobe obtuse-emarginate, larger; upper petals elongate-spatulate, pubescent; stamens 8, the filaments 3–3.5 mm. long, almost entirely united, the free part 0.5–1.2 mm. long, glabrous; ovary ellipsoid, 1.2–1.8 mm. long, 0.8–1.4 mm. wide, glabrous; style 2.2–2.4 mm. long, geniculate above base, pubescent, cylindrical; stigma with 2 lobes,

the lower one acute, the upper 1-tubercled, the tubercle papillose; drupe ellipsoid, 6.2–8.5 mm. long, 4.8–5.5 mm. wide, glabrous, reticulate.

DISTRIBUTION: Central and southwestern parts of Colombia, between 1,400 and 3,300 meters altitude.

SANTANDER: Mountains east of Las Vegas, Eastern Cordillera, *Killip & Smith* 15863 (NY, US).

EL VALLE: La Cumbre, Cordillera Occidental, *Killip & Hazen* 11156 (type US, isotype NY); La Cumbre, Cordillera Occidental, *Pennell* 5724 (GH, NY, US).

CAUCA: "La Gallera," Micay Valley, Cordillera Occidental, *Killip* 7794 (US), 7923 (US); Cuesta de Tocoá, road from Buenaventura to Cali, Western Cordillera, *Pittier* 728 (US); without locality, *Triana* s. n. (US).

This species is closely related to *M. solandraefolia* Tr. & Pl., from which it differs in its glabrous habit, its panicle with fewer (rarely as many as 14) lateral branches, its ovate-oblong leaves, acute lower sepals, pubescent style, etc.



FIG. 10.—*Monnina solandraefolia*: Left to right, lower sepals, upper sepal, wings (inner), keel, upper petals and stamens, gynaecium, bract. All  $\times 3$ .

10. *Monnina solandraefolia* Tr. & Pl. in Ann. Sci. Nat. IV. 17: 138. 1862.

*Monnina platyphylla* Chodat in Bull. Herb. Boiss. 2: 170. 1894.

Shrub 1.6–3 m. high, branched, the branches 3–6 mm. in diameter, slightly hirsute, becoming glabrescent, striate; leaves conspicuously spatulate, 45–130 mm. long, 18–70 mm. wide, coriaceous, acute, mucronate, glabrous above, glabrescent beneath, sometimes with small hairs along the nerves, entire, slightly revolute, attenuate at base, the costa prominulous beneath, with 6 or 8 pairs of lateral veins; petioles 3–7 mm. long, concave above, convex beneath, more or less hirsute, becoming glabrescent; inflorescence paniculate, the axis 8.5–14.5 cm. long, 1–2.2 mm. in diameter, striate, hirsute, becoming glabrescent, the lateral branches lax, numerous, acute at apex, divaricate, 4–12 cm. long, 6–8 mm. wide, pedunculate (peduncle 5–15 mm. long), bracteate, the bracts almost acute-triangular, 3.2–5.5 mm. long, 2.6–3.5 mm. wide, deciduous, ciliate, usually 3-nerved, rarely 1- or 2-nerved, pubescent beneath, the base hood-shaped; flowers 4.5–5 mm. long, the pedicels 0.6–1 mm. long, finely pubescent; outer sepals ovate-triangu-

lar, ciliate, slightly pubescent beneath, becoming glabrescent, the two lower ones 2–2.4 mm. long, 0.9–1 mm. wide,  $\frac{1}{2}$  united, obtuse, 3-nerved, the upper sepal 2.2–2.8 mm. long, 2–2.2 mm. wide, acute, 5-nerved; wings blue, 4.2–4.8 mm. long, 3.8–4 mm. wide, obovate, obtuse at base, 3-nerved, glabrous, ciliate; keel 4.6–5 mm. long, 2.8–3 mm. wide, orbicular, plicate, glabrous within, rarely slightly pubescent, obtuse at base, 3-nerved, 3-lobed, the middle lobe obtuse-submarginate; upper petals elongate-spatulate, pubescent; stamens 8, the filaments 3–3.4 mm. long, almost entirely united, the free part 0.6–1.2 mm. long, glabrous; ovary ovoid, 1.6–2 mm. long, 0.8–1.2 mm. wide, glabrous; style 2–2.5 mm. long, geniculate above base, glabrous, thicker toward apex; stigma with 2 lobes, the lower one acute, the upper 1-tubercled, the tubercle papillose; drupe ellipsoid, 4.8–6.2 mm. long, 2.8–3.8 mm. wide, glabrous, reticulate.

DISTRIBUTION: Known only from the northern part of the Colombian Andes, between 2,000 and 2,700 meters altitude.

NORTE DE SANTANDER: Alto de Santa Inés, region of Sarare, Cordillera Oriental, *Cuatrecasas*, *Schultes*, & *E. Smith* 12503 (Ch, US).

ANTIOQUIA: Río Negro, *Archer* 469 (NY, US); between Valdivia and Yarumál, *Metcalf* & *Cuatrecasas* 30116 (US); "Monte Capiro de la Ceja," *Bro. Daniel* 2252 (US); Cocorná, *Bro. Daniel* 1783 (Ch, US); San Pedro, *Bros. Daniel* & *Tomás* 1569 (US); Cerro de la Vieja, *Bro. Daniel* 1691 (US); 1 kilometer south of Hoyo Rico, *Franco* & *Barkley* 18A187 (US); "Montagnes d'Herveo," *Linden* 742 (fragments of type US, photographs of type Ch, GH, US); "Montagnes d'Herveo," *Linden* 742 (photographs of type of *M. platyphylla*, Ch, US).

This shrub is distinguished by its spatulate and mucronate leaves, the numerous and lax lateral branches of its panicle, and by having the flower-subtending bracts conspicuously acute-triangular and hood-shaped at base.

In proposing *M. platyphylla*, Chodat inadvertently overlooked Triana and Planchon's species, for both entities are based upon the same collection number (*Linden* 742).

11. *Monnina subspeciosa* Chodat in Bull. Soc. Bot. Genève II. 25: 203. 1934.

Shrub 5 m. high, branched, the branches 3–6 mm. in diameter, slightly hirsute, becoming glabrescent, striate; leaves elliptic, sometimes oblong, 40–150 mm. long, 20–65 mm. wide, acute, mucronate, glabrous above, glabrescent beneath, sometimes more or less hirsute along the nerves, entire, attenuate at base, the costa prominulous beneath, with 7 or 8 pairs of lateral veins; petioles 3–15 mm. long, concave above, convex beneath, slightly hirsute, becoming glabrescent; inflorescence paniculate, the axis 7.5–18 cm. long, 1.5–2.8 mm. in

diameter, striate, usually slightly hirsute, rarely glabrescent, the lateral branches lax, numerous, acute at apex, 2.4–12 cm. long, 7–9 mm. wide, pedunculate (peduncle 6–12 mm. long), bracteate, the bracts linear-lanceolate, inconspicuous, acute, 1.8–2.2 mm. long, 1–1.2 mm. wide, slightly pubescent beneath, becoming glabrescent, finely pubescent within, 1-nerved, ciliate, deciduous; flowers 4–5 mm. long, the pedicels 0.8–1 mm. long, finely pubescent; outer sepals triangular, ciliate, glabrescent beneath, the two lower ones 1.2–1.8 mm. long, 0.9–1 mm. wide,  $\frac{1}{2}$  united, 1-nerved, rarely 3-nerved, more or less acute, the upper sepal 1.6–2 mm. long, 1–1.4 mm. wide, obtuse, 3-nerved, sometimes 5-nerved; wings 4–4.5 mm. long, 3–3.8 mm. wide, obovate, almost obtuse at base, 3-nerved, glabrous, usually ciliate; keel 4–5.5 mm. long, 2.2–3.8 mm. wide, orbicular, plicate, glabrous within, rarely



FIG. 11.—*Monnina subspiciosa*: Left to right, lower sepals, upper sepal, wings (inner), keel, upper petals and stamens, gynaecium, bract. All  $\times 3$ .

slightly pubescent, obtuse at base, 3-nerved, 3-lobed, the middle lobe obtuse-emarginate; upper petals elongate-spatulate, pubescent; stamens 8, the filaments 2.2–3.2 mm. long, almost entirely united, the free part 0.6–1 mm. long, glabrous; ovary ovoid, 1.2–1.8 mm. long, 0.5–1 mm. wide, glabrous; style 2–2.8 mm. long, geniculate above base, glabrous, thicker toward apex; stigma with 2 lobes, the lower one acute, the upper 1-tubercled, the tubercle papillose; drupe ellipsoid, 4–4.5 mm. long, 2–2.2 mm. wide, glabrous, reticulate.

DISTRIBUTION: From the Andes of central Colombia to northern Ecuador, between 1,000 and 3,200 meters altitude.

PUTUMAYO: Valle de Sibundoy, *Cuatrecasas* 11680 (Ch, US).

HUILA: East of Neiva, Cordillera Oriental, *Rusby & Pennell* 876 (GH, NY, US); between Gabinete and Andalucía, western slope, Cordillera Oriental, *Cuatrecasas* 8584 (Ch, US).

CALDAS: La Linea, Quindío, *Dryander* 2143 (US).

EL VALLE: Alto Mercedes, *Dryander* 351 (NY, US); La Cumbre, Cordillera Occidental, *Pennell & Killip* 5888 (type coll., GH, NY, US); Tareas, Río Pichindé, valley of Río Cali, eastern slope, Cordillera Occidental, *Cuatrecasas* 21589 (Ch); Cali, *Duque-Jaramillo* 1726a (US).

CAUCA: Eastern slope near crest, Cordillera Central, *Cuatrecasas* 23657 (Ch).

A close ally of *M. solandraefolia* Tr. & Pl., *M. subspeciosa* differs in its elliptic leaves and its linear and smaller flower-subtending bracts, as well as in its more southerly distribution.

12. *Monnina pilosa* H.B.K. Nov. Gen. & Sp. 5: 419. 1821.

*Monnina fastigiata* DC. Prodr. 1: 338. 1824.

*Monnina trianae* Chodat in Bull. Soc. Bot. Genève II. 25: 221. 1934.

Shrub or slender tree, 1.5–4 m. high, branched, the branches 3–15 mm. in diameter, conspicuously hirsute, more or less striate; leaves usually elliptic, rarely oblong, 48–220 mm. long, 22–100 mm. wide, usually acute, sometimes acuminate, rarely obtuse, slightly hirsute above, becoming glabrescent, canescent-hirsute beneath, entire, attenuate at base, the costa prominulous beneath, with 9 to 11 pairs of lateral veins; petioles 3–11 mm. long, concave above, convex beneath,



FIG. 12.—*Monnina pilosa*: Left to right, lower sepals, upper sepal, wings (inner), keel, upper petals and stamens, gynaecium, bract. All  $\times 3$ .

hirsute, inconspicuously winged; inflorescence paniculate, the axis 5.5–22 cm. long, 1.2–4 mm. in diameter, striate, hirsute, the lateral branches lax, acute at apex, 1.6–18 cm. long, 8–10 mm. wide, pedunculate (peduncle 4–14 mm. long), conspicuously bracteate, the bracts ovate, concave, acute, 3.5–6.2 mm. long, 2–4 mm. wide, the base hood-shaped, deciduous, ciliate, usually 1-nerved, sometimes 2- or 3-nerved, pubescent beneath, the hairs more conspicuous at base; flowers 4–5.5 mm. long, the pedicels 0.4–0.8 mm. long, finely pubescent; outer sepals free, ovate-triangular, obtuse, ciliate, slightly pubescent beneath, becoming glabrescent, the two lower ones 1.8–3 mm. long, 1.2–2 mm. wide, 3-nerved, the upper sepal 2.2–3.5 mm. long, 1.4–2.2 mm. wide, 5-nerved; wings deep blue, 4–5 mm. long, 3.4–4.2 mm. wide, obovate, obtuse at base, 3-nerved, glabrous; keel 4.4–5.5 mm. long, 2.6–3 mm. wide, orbicular, plicate, glabrous within, sometimes slightly pubescent, becoming glabrescent, obtuse at base, 3-nerved, 3-lobed, the middle lobe obtuse-submarginate, the lateral ones more or less acute; upper petals elongate-spatulate, pubescent; stamens 8, the filaments 2.8–3.8 mm. long, almost entirely united, the free part 0.5–1 mm. long, glabrous; ovary ovoid, 1.2–2.2 mm. long, 1–1.4 mm. wide, glabrous; style 2–2.5 mm. long, geniculate above base, glabrous, almost cylindrical;

stigma with 2 lobes, the lower one acute, the upper 1-tubercled, the tubercle papillose; drupe ellipsoid, 5-6 mm. long, 2.8-4 mm. wide, glabrous, reticulate.

DISTRIBUTION: Along the Andes from Colombia to Ecuador and northern Peru, between 1,400 and 2,500 meters altitude.

PUTUMAYO: Sibundoy, Valley of Sibundoy, *Schultes & Villarreal* 7671 (US), *García-Barriga* 4628 (US).

TOLIMA: "Quindio," *Triana* s. n. (authentic material of *M. fastigiata*, NY, US); "in mont. Quindiu," *Bonpland* s. n. (photographs of type of *M. fastigiata*, Ch, US).

HUILA: Resina, above Guadalupe, western slope, Cordillera Oriental, *Pérez-Arbeláez & Cuatrecasas* 8380 (Ch).

ANTIOQUIA: Fredonia, vicinity of Medellín, *Toro* 1040 (NY); Salgar, vicinity of Medellín, *Toro* 1046 (NY); vicinity of Medellín, *Toro* 1244 (NY); Valparaíso, vicinity of Medellín, *Toro* 1365 (NY); Cerro de La Vieja, *Bro. Daniel* 1714 (US); Río Negro, *Bro. Daniel* 421 (US).

CALDAS: Río Quindio, above Armenia, Cordillera Central, *Pennell, Killip, & Hazen* 8723 (type coll. of *M. trianae*, GH, NY, US); Salento, Cordillera Central, *Pennell* 8906 (GH, NY, US), *Pennell & Hazen* 10113 (US); Santuario, Cordillera Occidental, *Pennell* 10301 (US); San Clemente, Cordillera Occidental, *Pennell* 10663 (GH, US).

EL VALLE: "El Recuerdo," Valley of Río Cali, Cordillera Occidental, *Duque-Jaramillo* 1604 (US); north of Albán, western slope, Cordillera Occidental, *Dugand & Jaramillo* 3033 (US); Carrizales, north of Las Brisas, Cordillera Occidental, *Cuatrecasas* 22553 (Ch); Alto de Las Brisas, valley of Río Cali, eastern slope, Cordillera Occidental, *Cuatrecasas* 18221 (Ch, US).

CAUCA: Coconuco, Cordillera Central, *Killip* 6868 (GH, NY, US); San Antonio to "San José," Cordillera Occidental, *Pennell & Killip* 7269 (GH, NY, US); San Antonio to Río Ortega, Cordillera Occidental, *Pennell & Killip* 8020 (GH, NY, US); "San Isidro," Puracé, Cordillera Central, *Pennell & Killip* 6418 (US); Carpinterías, between Cerros de Munchique and Altamira, Cordillera Occidental, *Pérez-Arbeláez & Cuatrecasas* 6167 (Ch, US); highlands of Popayán, *Lehmann* 1083 (NY), 353 (Ch, GH, NY), 5524 (Ch, GH, NY); Popayán, *Cuatrecasas* 5759 (Ch, US); Quebrada de Cajibío, *Cuatrecasas* 23751 (Ch); without locality, western Cordillera, *Dryander* 2053 (NY, US).

NARIÑO: Pasto, *Jameson* 443 (US); without locality, *Triana* 298 (US), *Triana* s. n. (US).

This common species has a wide distribution along the Andes from Colombia to Ecuador and northern Peru. It is distinguished by having its branches conspicuously hirsute, its leaves oblong, and its flower-subtending bracts broadly acute-triangular and hood-shaped at base. *Monnina fastigiata* DC., so far as can be discerned from authentic material, including photographs of the type, is essentially identical with *M. pilosa*. The type collection of *M. trianae* Chodat has been examined, and one finds no reason either in this or in the original description to separate the concept from *M. pilosa*.



13. *Monnina arborescens* Ferreyra, sp. nov.

Arbor ad 10 m. alta, a *M. pilosa* H.B.K., cui affinis, habitu robusto, foliis lineari-lanceolatis conspicue angustioribus, bracteis florigeris linearibus, sepalo exteriori acuto differt.

Small tree to 10 m. high, branched, the branches 3–6 mm. in diameter, striate, more or less tomentose, becoming glabrescent; leaves narrowly lanceolate or linear, 60–160 mm. long, 15–40 mm. wide, usually acuminate, rarely acute, slightly pubescent above, becoming glabrescent, canescent-pubescent beneath, entire, attenuate at base, the costa prominulous beneath, with 7 to 9 pairs of lateral veins; petioles 3–7 mm. long, concave above, convex beneath, tomentose, rarely more or less glabrescent and slightly winged at base; inflorescence paniculate, the axis 6.5–15 cm. long, 1.5–2 mm. in diameter,



FIG. 13.—*Monnina arborescens*: Left to right, lower sepals, upper sepal, wings (inner), keel, upper petals and stamens, gynaecium, all  $\times 3$ ; bract (outer),  $\times 2$ .

striate, tomentose, the lateral branches numerous, 3–10.5 cm. long, 9–10 mm. wide, acute at apex, pedunculate (peduncle 6–14 mm. long), bracteate, the bracts linear-oblongate, 2.5–11.2 mm. long, 1–2.8 mm. wide, acuminate, densely pubescent beneath, ciliate, deciduous, 1-nerved, sometimes inconspicuously 3-nerved; flowers 4.5–5 mm. long, the pedicels 1–1.8 mm. long, finely pubescent; outer sepals free, triangular, acute, ciliate, slightly pubescent beneath, becoming glabrescent, 3-nerved, the two lower ones 1.8–4 mm. long, 1.2–1.8 mm. wide, the upper sepal 2.2–4.2 mm. long, 1.2–1.9 mm. wide; wings blue, 4.2–5 mm. long, 3.8–4.2 mm. wide, obovate, more or less acute at base, 3-nerved; keel 4.2–5.2 mm. long, 3–3.2 mm. wide, orbicular, plicate, pubescent within rarely with a few hairs, obtuse at base, 3-nerved, inconspicuously 3-lobed, the middle lobe obtuse-submarginate; upper petals elongate-spatulate, densely pubescent; stamens 8, the filaments 3–3.5 mm. long, almost entirely united, the free part 1–1.4 mm. long, glabrous; ovary elliptic, 1–1.8 mm. long, 0.6–1 mm. wide, glabrous; style 2.2–2.6 mm. long, geniculate in the middle part, glabrous, almost cylindric; stigma with 2 lobes, the lower one acute,

the upper 1-tubercled, the tubercle papillose; drupe ovoid, 4.8-5.8 mm. long, 2.2-3 mm. wide, glabrous, the base almost truncate, reticulate.

Type in the herbarium of the Chicago Natural History Museum, No. 1367341, collected along Quebrada de Santo Domingo, headwaters of Río Palo, western slope, Cordillera Central, Department of Cauca, alt. 2,700-2,800 m., Dec. 11-14, 1944, by J. Cuatrecasas (No. 19213). Duplicate in the U. S. National Herbarium.

ADDITIONAL SPECIMENS EXAMINED:

NORTE DE SANTANDER: Municipio de Toledo, valley of Samaria, Cordillera Oriental, *Cuatrecasas, Schultes, & E. Smith* 12799 (Ch, US).

PUTUMAYO: Hill north of valley, Sibundoy, *Schultes & Villarreal* 7517 (US); El Encano, *García-Barriga* 7852 (US).

CALDAS: Termales, southwest of Ruiz, western slope, Cordillera Central, *Cuatrecasas* 9236 (Ch, US).

EL VALLE: Almorzadero, eastern slope, Los Farallones, Cordillera Occidental, *Cuatrecasas* 21695 (Ch, US); La Palma, right side of Río Pichindé, valley of Río Cali, eastern slope, Cordillera Occidental, *Cuatrecasas* 21671 (Ch).

CAUCA: Alto del Duende, headwaters of Río Palo, western slope, Cordillera Central, *Cuatrecasas* 18907 (Ch, US); west of Tambo, Cordillera Occidental, *Haight* 5176 (US); Mount Santa Ana, Cordillera Occidental, *Pennell & Killip* 7390 (GH, NY, US); "San José," San Antonio, Cordillera Occidental, *Pennell & Killip* 7390 (GH, NY, US); between Jardín and San Rafael, Río Marcos, eastern slope, Cordillera Central, *Cuatrecasas* 14805 (Ch, US); Páramo de Puracé, Cordillera Central, *Cuatrecasas* 14683 (Ch, US); "Canaan," Mt. Puracé, Cordillera Central, *Pennell & Killip* 6598 (GH, NY, US); Puracé, *Pérez-Arbeláez & Cuatrecasas* 5915A (Ch, US).

NARIÑO: Near base of Volcán El Galeras, above Ibonuco, Pasto, *Schultes & Villarreal* 8009 (US); road from Ipiales to La Victoria, Páramo La Cortadera, *García-Barriga & Hawkes* 13085 (US); between Páramo del Tábano and Laguna, El Encano and Pasto, western slope of the Cordillera, *Cuatrecasas* 11948 (US); "Pasto et Popayán," *Triana* s. n. (NY); trail from Mayasquer to Tambo, *Mexia* 7578 (US).

DEPT. ? : Páramo Las Delicias, *Lehmann* 1051 (GH, NY).

DISTRIBUTION: Northern to southwestern parts of Colombia, between 2,000 and 3,400 meters altitude.

This new species has conspicuously lanceolate leaves and flower-subtending bracts which are linear-oblancoolate and densely pubescent without. It is a close relative of *M. pilosa* H.B.K., differing in its narrower, almost linear, leaves, its nearly filiform flower-subtending bracts, its acute outer sepals, etc.

14. *Monnina erecta* Ferreyra, sp. nov.

Frutex *M. arborcscenti* Ferreyra supra descriptae affinis, habitu plus minusve herbaceo, foliis majoribus lamina ad 22.5 cm. longa, bracteis florigeris angustioribus, carina intus glabra facile distinguitur.

Frutescent, erect, branched, the branches 2.5-5 mm. in diameter, terete, tomentose, becoming more or less glabrescent; leaves lanceolate,

67–225 mm. long, 10–40 mm. wide, acuminate, slightly pubescent above, becoming glabrescent, conspicuously tomentose beneath, entire, almost revolute, attenuate at base, the costa prominulous beneath, with 10 to 12 pairs of lateral veins; petioles 4–12 mm. long, concave above, convex beneath, inconspicuously winged, the wing 1–1.5 mm. wide, pubescent; inflorescence paniculate, the axis 12–17 cm. long, 1.8–3 mm. diameter, striate, tomentose, the lateral branches numerous, acute at apex, 3.5–12 cm. long, 7–10 mm. wide, pedunculate (peduncle 5–28 mm. long), bracteate, the bracts conspicuously linear, 5.5–7 mm. long, 0.6–0.8 mm. wide, acuminate, pubescent beneath, ciliate, deciduous, 1-nerved; flowers 4.5–5 mm. long, the pedicels 1.6–2 mm. long, pubescent; outer sepals free, triangular, acute, ciliate, slightly pubescent beneath, 3-nerved, the two lower ones 2.8–3 mm. long, 1–1.2 mm. wide, the upper sepal 3–3.2 mm. long, 1.2–1.8 mm. wide; wings blue,



FIG. 14.—*Monnina erecta*: Left to right, lower sepals, upper sepal, wings (inner), keel, upper petals and stamens, gynaeceum, bract (outer). All  $\times 3$ .

4.5–5 mm. long, 3.4–3.8 mm. wide, obovate, obtuse at base, 3-nerved, eciliate; keel 5–5.2 mm. long, 2.8–3 mm. wide, orbicular, plicate, glabrous within, obtuse at base, 3-nerved, ciliate, 3-lobed, the middle lobe obtuse-submarginate; upper petals spatulate, pubescent; stamens 8, the filaments 3.2–3.8 mm. long, almost entirely united, the free part 1–1.2 mm. long, glabrous; ovary ellipsoid, 1.4–1.6 mm. long, 0.9–1 mm. wide, glabrous; style 2.5–3 mm. long, geniculate in the middle part, glabrous, more or less cylindrical; stigma with 2 lobes, the lower one acute, the upper 1-tubercled, the tubercle papillose; drupe ellipsoid, 4.5–5 mm. long, 2.4–2.6 mm. wide, glabrous, reticulate.

Type in the herbarium of the Chicago Natural History Museum, No. 1366998, collected between Jardín and San Rafael, Quebrada del Río San Marcos, eastern slope, Cordillera Central, Department of Cauca, alt. 2,700–2,900 meters, July 25, 1943, by J. Cuatrecasas (No. 14802). Duplicate in the U. S. National Herbarium.

DISTRIBUTION: Known only from the type collection.

This new entity is near *M. arborescens* Ferreyra, from which it differs in its frutescent habit, its considerably longer leaves (to 225 mm. long), its very narrow flower-subtending bracts (8 times as long as wide), and in having its keel glabrous within.

15. *Monnina oblanceolata* Ferreyra, sp. nov.

Frutex, ramis glabris striatis, foliis oblanceolatis glabris revolutis, bracteis florigeris oblanceolatis, sepalo exteriori obtuso, sepalis duobus inferioribus breviter connatis distinguendus; a *M. chlamydantha* Ferreyra, cui affinis, racemis simplicibus, foliis minoribus, bracteis florigeris extus glabris, et characteribus supra enumeratis valde differt.

Branching shrub, the branches 2-3 mm. in diameter, glabrous, striate; leaves oblanceolate, 28-72 mm. long, 11-36 mm. wide, acute, glabrous, entire, revolute, attenuate at base, the costa prominulous beneath, with inconspicuous lateral veins; petioles 2-5 mm. long, concave above, convex beneath, glabrous; racemes elongate, obtuse, 8-10 mm. wide, simple, terminal or axillary, pedunculate (peduncle 5-20 mm. long), the axis 4.2-19 cm. long, glabrous, striate, conspicuously bracteate, the bracts broadly oblanceolate, 5-6.5 mm. long, 4.8-6.5 mm.



FIG. 15.—*Monnina oblanceolata*: Left to right, lower sepals, upper sepal, wings (inner), keel, upper petals and stamens, gynaecium, bract. All  $\times 3$ .

wide, more or less acute, hood-shaped, deciduous, ciliate, 3- or 4-nerved, glabrous beneath; flowers 4-4.8 mm. long, the pedicels 1.6-2 mm. long, finely pubescent; outer sepals ovate-triangular, obtuse, ciliate, glabrous beneath, the two lower ones 1.4-2 mm. long, 1-1.4 mm. wide, slightly united, usually 3-nerved, rarely 1-nerved, the upper sepal 1.6-2.4 mm. long, 1.2-2 mm. wide, 5-nerved; wings blue, 4-5 mm. long, 4-4.6 mm. wide, obovate, obtuse at base, 3-nerved, glabrous, ciliate; keel 4-5 mm. long, 3-3.2 mm. wide, orbicular, plicate, glabrous within, obtuse at base, 3-nerved, 3-lobed, the middle lobe obtuse-emarginate; upper petals elongate-spatulate, pubescent; stamens 8, the filaments 3-3.5 mm. long, almost entirely united, the free part 0.6-1.2 mm. long, glabrous; ovary ovoid, 1.4-1.6 mm. long, 0.8-1 mm. wide, glabrous; style 2-2.4 mm. long, geniculate above base, glabrous, more or less cylindrical; stigma with 2 lobes, the lower one acute, the upper 1-tubercled, the tubercle papillose; fruit unknown.

Type in the herbarium of the New York Botanical Garden, collected in forest, Cascada Chorrón, south of Antizales, Department of Bolívar, alt. 2,400-2,800 meters, February 25, 1918, by F. W. Pennell (No. 4387).

## ADDITIONAL SPECIMEN EXAMINED:

BOLÍVAR: Below Páramo de Chaquiro, Cordillera Occidental, Pennell 4298 (NY).

DISTRIBUTION: Andes of northwestern Colombia, between 2,400 and 3,100 meters altitude.

This new species is characterized by its glabrous habit, its oblanceolate, revolute leaves with inconspicuous lateral veins, its oblanceolate flower-subtending bracts, and by having its lower sepals slightly united. It is related to *M. chlamydantha* Ferreyra, from which it differs in its simple racemes, smaller leaves, glabrous flower-subtending bracts, etc.

16. *Monnina schultesii* Ferreyra, sp. nov.

Frutex *M. obtusifoliae* H.B.K. affinis, foliis conspicue majoribus lamina ad 13 cm. longa acuta, racemis obtusis rhachi elongata ad 29

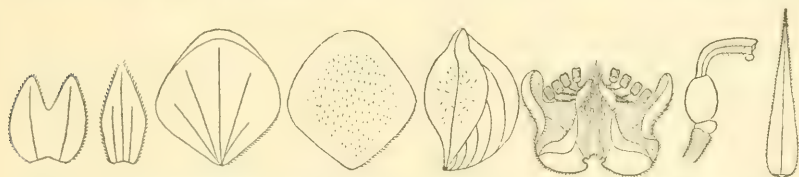


FIG. 16.—*Monnina schultesii*: Left to right, lower sepals, upper sepal, wing (inner), wing (outer), keel, upper petals and stamens, gynaecium, all  $\times 3$ ; bract,  $\times 2$ .

cm. longa, bracteis florigeris filiformibus ad 11.5 mm. longis, sepalo exteriore acuto, sepalis duobus inferioribus  $\frac{2}{3}$  connatis differt.

Frutescent, branched, the branches 23–36 cm. long, 3–8 mm. in diameter, terete, glabrescent; leaves lanceolate (upper) or ovate-lanceolate (lower), 30–130 mm. long, 12–60 mm. wide, acute, sometimes more or less acuminate, glabrous above, glabrescent beneath, entire, attenuate at base (upper) or almost truncate (lower), the costa prominent beneath, with 8 or 9 pairs of lateral veins; petioles 2–6 mm. long, 0.8–1.8 mm. in diameter, slightly concave above, convex beneath, glabrescent; racemes almost cylindrical, obtuse, 8–10 mm. wide, simple, terminal or axillary, pedunculate (peduncle 4–50 mm. long), the axis 3.5–29 cm. long, glabrescent, striate, bracteate, the bracts filiform, 7.2–11.5 mm. long, 1–1.8 mm. wide, acuminate, slightly puberulent beneath, becoming glabrescent, ciliate, deciduous, 1-nerved; flowers 5.2–6 mm. long, the pedicels 1.6–2 mm. long, puberulent; outer sepals lanceolate, ciliate, acute, finely puberulent beneath, the two lower ones 3.4–3.8 mm. long, 3–3.2 mm. wide,  $\frac{2}{3}$  united, 1-nerved, the upper sepal 4.2–4.5 mm. long, 2–2.2 mm. wide, 3-nerved; wings 5.5–6 mm. long,

5.2-5.5 mm. wide, obovate, almost acute at base (fleshy), 3- or 4-nerved, ciliate at base, strigose beneath; keel 5-6 mm. long, 4-4.2 mm. wide, orbicular, plicate, slightly puberulent within, obtuse at base, 3- or 4-nerved, 3-lobed, the middle lobe obtuse-emarginate, larger, with a few strigose hairs beneath; upper petals elongate-spatulate, pubescent; stamens 8, the filaments 4-4.2 mm. long, almost entirely united, the free part 0.6-1.2 mm. long, glabrous; ovary ellipsoid, 1.8-2 mm. long, 1.2-1.5 mm. wide, glabrous; style 3-3.4 mm. long, geniculate above base, pubescent, cylindrical; stigma with 2 lobes, the lower one inconspicuous, the upper 1-tubercled, the tubercle papillose; drupe ellipsoid, 7-9 mm. long, 4-6.5 mm. wide, glabrous, conspicuously reticulate.

Type in the herbarium of the Chicago Natural History Museum, No. 1241931, collected in the region of Sarare, between Ventanas and Bata, Cordillera Oriental, Department of Norte de Santander, alt. 1,400 meters, October 17, 1941, by J. Cuatrecasas, R. E. Schultes, and E. Smith (No. 12372).

ADDITIONAL SPECIMEN EXAMINED:

NORTE DE SANTANDER: El Amparo, headwaters of Río Negro, valley of Río Margua, region of Sarare, Cordillera Oriental, *Cuatrecasas* 12339 (US).

DISTRIBUTION: Known only from Norte de Santander.

This new species, from northern Colombia, has terete branches, leaves which are lanceolate (upper ones) or ovate-lanceolate (lower ones), and more or less cylindrical racemes which are conspicuously bracteate. It is closely related to *M. obtusifolia* H.B.K., of southern Colombia, differing in its larger leaves (to 130 mm. long) with acute apices, the elongate (to 29 cm. long) axis of its racemes, its filiform and larger (to 11.5 mm. long) bracts, etc.

17. *Monnina obtusifolia* H.B.K. Nov. Gen. & Sp. 5: 411. 1821.

Shrub to 2 m. high, branched, the branches 1.5-5 mm. in diameter, slightly pubescent, becoming glabrescent, striate; leaves oblong, 15-90 mm. long, 9-24 mm. wide, obtuse, mucronate, rarely more or less acute, glabrous above, glabrescent beneath, entire, revolute, coriaceous, attenuate at base, the costa prominulous beneath, with 5 to 7 pairs of lateral veins; petioles 1.2-3 mm. long, slightly concave above, convex beneath, glabrescent; racemes conical, acute, 8-10 mm. wide, simple, terminal or axillary, pedunculate (peduncle 2.5-19 mm. long), the axis 2-11.5 cm. long, strigose, striate, bracteate, the bracts acute-triangular, rarely obtuse, 1-2.2 mm. long, 1-1.2 mm. wide, inconspicuous, deciduous, ciliate, 1-nerved, finely pubescent beneath; flowers 4.2-6 mm. long, the pedicels 0.6-1.2 mm. long, finely pubescent; outer sepals ovate-triangular, ciliate, slightly pubescent beneath, the two

lower ones 1.4–3.2 mm. long, 1.2–1.9 mm. wide,  $\frac{1}{2}$  united, rarely only slightly united, obtuse, usually 3-nerved, rarely 5-nerved, the upper sepal 1.8–3.2 mm. long, 1.8–2.6 mm. wide, obtuse, sometimes more or less acute, 5- or 7-nerved; wings deep blue, 4.8–6 mm. long, 4–6 mm. wide, obovate, almost acute at base, 3-nerved, glabrous, rarely slightly pubescent beneath, ciliate; keel 4.2–6.5 mm. long, 2–4 mm. wide, orbicular, plicate, pubescent within, usually acute at base, sometimes obtuse, 3- or 4-nerved, 3-lobed, the lobes inconspicuous; upper petals more or less elongate-spatulate, pubescent; stamens 8, the filaments 3.2–4.2 mm. long, almost entirely united, the free part 0.5–1.5 mm. long, pubescent; ovary ovoid, 1.2–2.2 mm. long, 0.8–1.2 mm. wide, glabrous; style 2–3 mm. long, geniculate above base, pubescent, more or less cylindrical; stigma with 2 lobes, the lower one acute, the

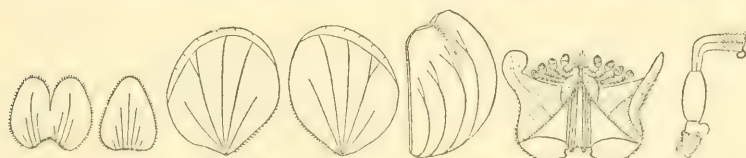


FIG. 17.—*Monnina obtusifolia*: Left to right, lower sepals, upper sepal, wings (inner), keel, upper petals and stamens, gynaeceum. All  $\times 3$ .

upper 1-tubercled, the tubercle papillose; drupe ellipsoid, 4.5–5.5 mm. long, 2.2–3.2 mm. wide, glabrous, reticulate.

DISTRIBUTION: The Central Cordillera of southwestern Colombia, between 2,600 and 3,600 meters altitude.

PUTUMAYO: Páramo de San Antonio del Bordoncillo, between El Encano and Sibundoy, *Cuatrecasas* 11694 (Ch, US).

EL VALLE: Barragán, Cerro de La Laguna, valley of Río Bugalagrande, western slope, Cordillera Central, *Cuatrecasas* 20839 (Ch), 20890 (Ch).

CAUCA: Mt. Pan de Azúcar, Cordillera Central, *Pennell* 7031 (Ch, NY, US); Páramo de Moras, between Mozoco and Pitayó, Tierra Adentro, *Pittier* 1405 (US); Alto del Duende, headwaters of Río Palo, western slope, Cordillera Central, *Cuatrecasas* 18844 (Ch, US); "road to east from Silva," Cordillera Central, *Haught* 5091 (US), 5091a (US); "Almaguer," Cordillera Central, *Bonpland* s. n. (photographs of type, Ch, US).

NARIÑO: Laguna de La Cocha, Isla La Corota, *García-Barriga, Hawkes, & Villarreal* 13056 (US); highway from Túquerres to Ipiales, *García-Barriga & Hawkes* 13063 (US), 13074 (US); region of Pasto, between Pasto and Anganoy, *Schultes & Villarreal* 7429 (US); region of Pasto, road to Arandá, *Schultes & Villarreal* 7467 (US); Túquerres, Pasto, *Triana* s. n. (NY); region of Pedregal, between Pasto and Túquerres, south of Yacuanquer, *Schultes & Villarreal* 7870 (US).

The type locality of this species is "Almaguer," Department of Cauca, in the southwestern part of Colombia. All the material studied

is distinguished by oblong and obtuse leaves and by the pubescent style, although this latter character is not mentioned by Bonpland in his original description.

18. *Monnina aestuans* (L. f.) DC. Prodr. 1: 338. 1824.

*Polygala aestuans* L. f. Suppl. 315. 1781.

*Monnina densa* Pl. & Lind. ex Wedd. Chlor. And. 2: 268. 1855.

Shrub 0.6-4 m. high, branched, the branches 2-8 mm. in diameter, slightly pubescent, becoming glabrescent, striate; leaves subcoriaceous, crowded, usually oblong-lanceolate, sometimes lanceolate, 18-72 mm. long, 4-24 mm. wide, obtuse, rarely acute, mucronate, strigose above, becoming glabrescent, canescent-strigose beneath, entire, slightly revolute, attenuate at base, the costa prominulous beneath, with 6 or 7 pairs of lateral veins; petioles 1.6-5 mm. long, concave above, convex be-



FIG. 18.—*Monnina aestuans*: Left to right, lower sepals, upper sepal, wings (inner), keel, upper petals and stamens, gynaecium, bract. All  $\times 3$ .

neath, articulate, strigose; racemes conical, acute, 8-10 mm. wide, simple, terminal or axillary, pedunculate (peduncle 2-23 mm. long), the axis 1.7-8.5 cm. long, finely pubescent, striate, bracteate, the bracts triangular, acuminate, 2.2-4 mm. long, 1.2-2 mm. wide, deciduous, ciliate, 1-nerved, hood-shaped at base, pubescent beneath; flowers 4.8-5.5 mm. long, the pedicels 0.8-2 mm. long, finely pubescent; outer sepals ovate-triangular, obtuse, ciliate, slightly pubescent beneath, the two lower ones 1.8-3 mm. long, 1.2-1.9 mm. wide, usually  $\frac{1}{2}$ , sometimes  $\frac{1}{3}$ , united, 1-nerved, rarely 3-nerved, the upper sepal 2-3.2 mm. long, 1.5-2.2 mm. wide, 3-nerved, rarely 5-nerved; wings blue, 4-5.4 mm. long, 3.2-5.2 mm. wide, obovate, obtuse at base, 3-nerved, glabrous, ciliate toward base; keel 4.6-6 mm. long, 3-4 mm. wide, orbicular, plicate, pubescent within, rarely glabrescent, obtuse at base, 3-nerved, 3-lobed, the middle lobe obtuse-emarginate; upper petals elongate-spatulate, pubescent; stamens 8, the filaments 3-3.8 mm. long, almost entirely united, the free part 0.6-1.2 mm. long, glabrous; ovary ovoid, 1.2-2 mm. long, 0.8-1.4 mm. wide, glabrous; style 2-3 mm. long, geniculate above base, glabrous, thicker toward apex; stigma with 2 lobes, the lower one acute, the upper 1-tubercled, the tubercle papillose; drupe ellipsoid, 5-6.5 mm. long, glabrous, reticulate.



DISTRIBUTION: Northern and central part of the Colombian Andes, and also in Venezuela and Ecuador, between 2,500 and 3,900 meters altitude.

MAGDALENA: Cerro Pintado, Sierra Perijá, *Carriker* 29 (US), 37 (US).

BOLÍVAR: Below Páramo de Chaquiro, Cordillera Occidental, *Pennell* 4311 (NY).

NORTE DE SANTANDER: Páramo de Santurbán enroute from Tona to Mutiscua, *Killip & Smith* 19570 (GH, NY, US); "Cordillères de la province d' Ocaña," *Schlim* 345 (fragments of cotype coll. of *M. densa*, Ch, US; photographs, Ch, US).

CUNDINAMARCA: Monserrate, near Bogotá, *Cuatrecasas* 268 (Ch, US); Salto de Tequendama, *Cuatrecasas* 106 (Ch, US); Guadalupe, Bogotá, *Haught* 5613 (Ch, US), 5623 (US), 5696 (US), 5697 (US); Bogotá, *Daive* 204 (US), *García-Barriga* 12644 (US); Macizo de Bogotá, *Cuatrecasas* 5050 (US), *Schultes* 7240 (US); above Bogotá, *Rusby & Pennell* 1290 (NY); Boquerón de Chipaque, *Killip* 34197 (NY, US); Ubate-Carupa highway, *Haught* 6175 (US); Páramo de Guasca, *Black* 46-663 (US); between Bogotá and La Calera, *Barkley, García-Barriga, & Vanegas* 17C740 (US); western slopes of Páramo de Cruz Verde, *Cuatrecasas* 328 (Ch).

TOLIMA: Along Quindío Highway, between Cajamarca and summit of the divide, *Killip & Varela* 34642 (NY, US).

DEPT. ? : Without locality, *Rodríguez* 29 (US); San Cristóbal, *Bros. Apollinaire & Arthur* 5 (US).

This species characteristically bears numerous, small, coriaceous, crowded, oblong-lanceolate, mucronate leaves on the upper parts of its branches; the bracts of its racemes are triangular, and the keel is pubescent within. The type was collected by Mutis, very probably in Cundinamarca; the original description agrees well with the cited material from Cundinamarca, and consequently I feel reasonably sure of the identity of the species. The cotype material of *M. densa*, from Norte de Santander, seems scarcely distinguishable from this concept.

19. *Monnina santamartensis* Ferreyra, sp. nov.

Herba annua a *M. rupestris* H.B.K., cui affinis, habitu herbaceo, racemis majoribus rachi ad 28 cm. longa, sepalo exteriori acuto facile distinguitur.

Herbaceous annual 1.1-1.6 m. high; root 11-12 cm. long, 7-8 mm. in diameter, branched, curved; stem erect, terete, glabrescent, branched in the upper part, the branches 15-27 cm. long, 1.5-4 mm. in diameter, striate, glabrous; leaves broadly lanceolate, 46-225 mm. long, 10-64 mm. wide, conspicuously acuminate, glabrescent, membranaceous, entire, attenuate at base, the costa prominulous beneath, with 8 to 10 pairs of lateral veins; petioles 1.5-10 mm. long, concave above, convex beneath, glabrescent; racemes elongate, acuminate, 8-11 mm. wide,

simple, terminal or axillary, pedunculate (peduncle 14-50 mm. long), the axis 7.2-28 cm. long, slightly canescent-pubescent, becoming glabrescent, striate, bractate, the bracts filiform, 4.2-6 mm. long, 0.9-1.6 mm. wide, deciduous, ciliate, 1-nerved, finely puberulent beneath; flowers 4.2-6 mm. long, the pedicels 1-1.8 mm. long, finely puberulent; outer sepals more or less lanceolate, acute, ciliate, glabrescent beneath, the two lower ones 1.8-3.2 mm. long, 1-3 mm. wide,  $\frac{1}{2}$  united, 3-nerved, the upper sepal 2.8-4.8 mm. long, 1.6-2 mm. wide, (apex more or less involute) 5-nerved; wings 4.2-5.2 mm. long, 3-4.2 mm. wide, obovate, obtuse at base, 3- or 4-nerved, glabrous, eciliate; keel 4.8-6 mm. long, 2.8-3 mm. wide, orbicular, plicate, glabrous within, rarely slightly pubescent, obtuse at base, 3- or 4-nerved, 3-lobed, the middle lobe obtuse-submarginate, larger; upper petals elongate-spatulate, pubescent; stamens 8, the filaments 2.6-3.5 mm. long, almost



FIG. 19.—*Monnina santamartensis*: Left to right, lower sepals, upper sepal, wings (inner), keel, upper petals and stamens, gynaeceum, bract. All  $\times 3$ .

entirely united, the free part 0.5-1.2 mm. long, glabrous; ovary ovoid, 1.5-2.2 mm. long, 1-1.4 mm. wide, glabrous; style 2.4-2.6 mm. long, geniculate above base, glabrous, more or less cylindrical; stigma with 2 lobes, the lower one acute, the upper 1-tubercled, the tubercle papillose; drupe (immature) 6-6.5 mm. long, 3.4-3.6 mm. wide, glabrous, reticulate.

Type in the herbarium of the New York Botanical Garden, collected in Sierra del Libano, region of Santa Marta, Department of Magdalena, alt. 1,935 meters, March 1898 or 1899, by H. H. Smith (No. 1480). Duplicates in the Gray Herbarium, the U. S. National Herbarium, and the Chicago Natural History Museum.

ADDITIONAL SPECIMENS EXAMINED:

MAGDALENA: Sierra del Libano, Santa Marta, *H. H. Smith* 1557 (GH, NY, US); San Lorenzo Mountains, Santa Marta, *Viereck* s. n. (US); Mount San Lorenzo, near Santa Marta, *Seifriz* 83 (US).

DISTRIBUTION: Northern Colombia, Department of Magdalena, between 1,900 and 2,400 meters altitude.

The proposed species is an herbaceous annual, with oblong-lanceolate, membranaceous, acuminate leaves, and apparently it is endemic to the Santa Marta region. From its close ally, *M. rupestris* H.B.K.,

it differs in its herbaceous habit, its racemes with a longer axis (to 28 cm. long), its larger (to 4.8 mm. long) and acute outer sepals, and its more northern distribution.

20. *Monnina rupestris* H.B.K. Nov. Gen. & Sp. 5: 415. 1821.

*Monnina tenuifolia* Chodat in Bull. Herb. Boiss. 3: 131. 1895.

*Monnina pulchra* Chodat in Bull. Herb. Boiss. 3: 133. 1895.

Shrub to 6 m. high, branched, the branches 1.8–7 mm. in diameter, strigose, becoming glabrescent, striate; leaves subherbaceous, lanceolate, rarely elliptic-lanceolate, 22–115 mm. long, 9–32 mm. wide, usually acuminate, sometimes obtuse or acute, strigose, becoming glabrescent, entire, attenuate at base, the costa prominulous beneath, with 7 or 8 pairs of lateral veins; petioles 2.5–7 mm. long, slightly winged, concave above, convex beneath, articulate, strigose; racemes conical, acute, 8–10 mm. wide, simple, terminal or axillary, pedunculate (peduncle 6–32 mm. long), the axis 2.6–9 cm. long, strigose, striate, bracteate, the bracts filiform, 2.2–3.5 mm. long, 1–1.2 mm. wide, deciduous, ciliate, 1-nerved, pubescent beneath; flowers 4.4–4.8 mm. long, the pedicels 1.8–2.8 mm. long, finely pubescent; outer sepals ovate-triangular, obtuse, rarely acute, ciliate, puberulent beneath, the two lower ones 1.4–1.8 mm. long, 1–1.4 mm. wide,  $\frac{1}{2}$  united, 3-nerved, the upper sepal 1.8–2.2 mm. long, 1.4–1.8 mm. wide, 5-nerved; wings blue, 4–5 mm. long, 3.6–5 mm. wide, obovate, acute at base, 3-nerved, ciliate; keel 4.2–5 mm. long, 2.6–3.2 mm. wide, orbicular, plicate, glabrous within, obtuse at base, 3-nerved, 3-lobed, the middle lobe more or less inconspicuous, emarginate; upper petals elongate-spatulate, pubescent; stamens 8, the filaments 3–3.8 mm. long, almost entirely united, the free part 0.8–1.2 mm. long, glabrous; ovary ovoid, 1.2–2.2 mm. long, 0.9–1.2 mm. wide, glabrous; style 2–3 mm. long, geniculate above base, glabrous, cylindrical; stigma with 2 lobes, the lower one acute, the upper 1-tubercled, the tubercle papillose; fruit samaroid or more or less drupaceous, ellipsoid, 5–10 mm. long, 3.2–5.2 mm. wide, glabrous, slightly winged, inconspicuously emarginate at apex, the body rugose, reticulate.

DISTRIBUTION: Along the Andes from Central Colombia to the northern part of Ecuador, between 1,300 and 3,000 meters altitude.

CUNDINAMARCA: Pacho-San Cayetano Highway, *Haught* 6022 (Ch, US); Bogotá, *Bro. Apollinaire* s. n. (US); above Bogotá, Río San Francisco, *Pennell* 1940 (GH, NY, US); Guadalupe, near Bogotá, *Bros. Apollinaire & Arthur* 22 (US), *Bro. Ariste-Joseph* A79 (GH, US); vicinity of Bogotá, *Schultze* 5 (US), *Bro. Ariste-Joseph* s. n. (US), *Holton* 23 (NY); Cordillera de Bogotá, *Triana* s. n. (NY); Cordillera Central, south of Bogotá, *Dugand* 3565 (US); Río del Arzobispo, *Herb. Bayon* s. n. (US); Salto de Tequendama, *Cuatrecasas* 65

(Ch, US), *Bro. Ariste-Joseph* s. n. (US); "Zipacón," *Poşenoe* 1141 (US); La Florida, *Pérez-Arbeláez* 2303 (US); without locality, *Bro. Ariste-Joseph* s. n. (US).

CAQUETÁ: Gabinete, Cordillera Oriental, *Cuatrecasas* 8411 (Ch, US), *Juzepczuk* 6616 (US).

PUTUMAYO: Highway from Sibundoy to Urcusique, Alto de la Cordillera, La Cabaña, *Cuatrecasas* 11526 (US); Portachuelo, valley of Sibundoy, *Schultes & Villarreal* 7728 (US); near Páramo de Bordoncillo, Laguna La Cocha, Ciudadela, above lake on road to Sibundoy, *Schultes & Villarreal* 7569 (US).

HUILA: Balsillas, on Río Balsillas, *Rusby & Pennell* 746 (GH, NY, US); valley of Río Cedro, southeast of Pitalito, *Schultes & Villarreal* 5215 (US); Santa Leticia, region of Moscopán, highway to La Plata, *García-Barriga & Hawkes* 12886 (US).

CAUCA: "La Gallera," Micay Valley, Cordillera Occidental, *Killip* 7964 (GH, NY, US).

NARIÑO: Pasto, *Jameson* 473 (type coll. of *M. pulchra* US, photograph of type US).



FIG. 20.—*Monnina rupestris*: Left to right, lower sepals, upper sepal, wings (inner), keel, upper petals and stamens, gynaecium, bract. All  $\times 3$ .

The type material of *M. rupestris* was obtained by Bonpland "in monte Saraguru," Ecuador. I have seen fragments and a photograph of the type, which agrees well with the specimens cited above. Chodat's description of *M. tenuifolia* does not disclose any differences from *M. rupestris*; its type locality is "prope San Pablo," in the Department of Nariño. *Monnina pulchra* was based by Chodat upon specimens reputedly collected by Jameson "in Andibus aequatorensis prope Patto." Doubtless this locality is to be transcribed as Pasto, in the Department of Nariño; an isotype of *M. pulchra*, cited above, can scarcely be separated from *M. pulchra*.

The species is characterized by its herbaceous and acuminate leaves, its simple, terminal or axillary racemes, the wings of its flowers being acute at base, and its more or less samaroid fruits.

21. *Monnina phytolaccaefolia* H.B.K. Nov. Gen. & Sp. 5: 419. 1821.

*Monnina floribunda* Tr. & Pl. in Ann. Sci. Nat. IV. 17: 139. 1862.

*Monnina comata* Chodat in Bull. Herb. Boiss. 2: 171. 1894.

*Monnina elliptica* Chodat in Bull. Herb. Boiss. 3: 134. 1895.

Shrub 0.5–3.8 m. high, branched, the branches 2–6 mm. in diameter, hirsute, becoming glabrescent, striate; leaves lanceolate, 4–15.5 cm. long, 1.4–5 cm. wide, almost coriaceous, usually acute, rarely more or

less obtuse, canescent-hirsute, becoming glabrescent, entire, attenuate at base, the costa prominulous beneath, with 7 to 9 pairs of lateral veins; petioles 1.5–6 mm. long, concave above, convex beneath, hirsute, sometimes becoming glabrescent, slightly winged; racemes almost conical, acute, 7–10 mm. wide, simple, terminal or axillary, pedunculate (peduncle 5–35 mm. long), the axis 2–15 cm. long, hirsute, rarely glabrescent, striate, bracteate, the bracts acute-triangular, hood-shaped at base, 2–4.2 mm. long, 1–2.5 mm. wide, deciduous, ciliate, 1-nerved, rarely 3-nerved, pubescent beneath; flowers 4.2–6 mm. long, the pedicels 0.8–1.2 mm. long, hirsute; outer sepals ovate-triangular, obtuse, ciliate, finely pubescent beneath, rarely glabrescent, the two lower ones 1.8–2.8 mm. long, 0.8–2 mm. wide, slightly united, 3-nerved, rarely 5-nerved, the upper sepal 2.2–3.2 mm. long, 1.5–2.4 mm. wide, usually 5-nerved, sometimes 3- or 7-nerved; wings blue, 4.5–6 mm.

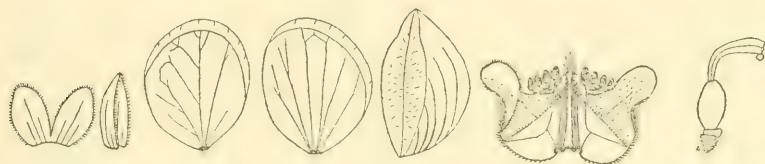


FIG. 21.—*Monnina phytolaccaefolia*: Left to right, lower sepals, upper sepal, wings (inner), keel, upper petals and stamens, gynaeceium. All  $\times 3$ .

long, 4–5.5 mm. wide, obovate, obtuse at base, 3-nerved, glabrous, rarely finely pubescent beneath; keel 4.6–6.5 mm. long, 2.8–4 mm. wide, orbicular, plicate, pubescent within, rarely glabrescent, obtuse at base, 3-nerved, 3-lobed, the middle lobe obtuse-emarginate, larger; upper petals elongate-spatulate, pubescent; stamens 8, the filaments 2.8–4.5 mm. long, almost entirely united, the free part 0.8–1.4 mm. long, glabrous; ovary ovoid, 1.2–2.2 mm. long, 0.8–1.4 mm. wide, glabrous; style 2.2–3.2 mm. long, geniculate above base, glabrous, rarely with a few hairs, thicker toward apex; stigma with 2 lobes, the lower one acute, the upper 1-tubercled, the tubercle papillose; drupe ellipsoid, 5–7.5 mm. long, 3–4.8 mm. wide, glabrous, sometimes slightly winged, reticulate.

DISTRIBUTION: Along the Andes from northern Colombia to Ecuador, between 1,040 and 3,300 meters altitude.

MAGDALENA: Cerro Quemado region, *Espina & Giacomello* A156 (Ch, NY, US).

BOLÍVAR: Antizales, *Pennell* 4439 (NY).

NORTE DE SANTANDER: Road from Pamplona to Toledo, *Killip & Smith* 19924 (GH, NY, US); vicinity of Chinácota, *Killip & Smith* 20779 (US).

SANTANDER: Vicinity of Charta, *Killip & Smith* 19043 (GH, NY, US); Río Suratá valley, between El Jaboncillo and Suratá, *Killip & Smith* 16449 (GH, NY, US); Mesa de los Santos, *Killip & Smith* 15077 (GH, NY, US); between Piedecuesta and Las Vegas, *Killip & Smith* 15515 (GH, NY, US); mountains east of Las Vegas, *Killip & Smith* 15862 (GH, NY, US); between El Roble and Tona, *Killip & Smith* 19396 (GH, NY, US); between Suratá and California, *Killip & Smith* 16796 (US).

BOYACÁ: Páramo de Santa Rosa, Cordillera Oriental, *Cuatrecasas* 10335 (US); region of Mount Chapón, *Lawrance* 16 (Ch, NY, US).

CUNDINAMARCA: Vicinity of San Bernardo, to Sasaima, *Cuatrecasas* 9577 (Ch, US); Sasaima, near San Bernardo, *García-Barriga* 12619 (US); Estación Santana, above Sasaima, *Dugand & Jaramillo* 3827 (US); Sasaima, *García-Barriga* 11584 (US); El Colegio, *Bro. Ariste-Joseph* 1049 (US); between El Salto and El Colegio, *Cuatrecasas* 8249 (Ch, US); "Susumuco," southeast of Quetamé, *Pennell* 1736 (GH, NY, US); La Vega, *Pérez-Arbeláez & Cuatrecasas* 5338 (Ch, US); San Antonio de Tena, western slope, Cordillera Oriental, *Dugand & Jaramillo* 2944 (US); Caparrapi, *García-Barriga* 7674 (US); La Palma, highway to Pacho, Río Murca, *García-Barriga* 12402 (US); highway between San Francisco and La Vega, *García-Barriga* 10951 (US); Hacienda Paramillo, west of Guaduas, *García-Barriga* 12325 (US); Macizo de Bogotá, Cerro El Retiro, *Schultes* 7023 (US); Ubalá, Bogotá, *Triana* s. n. (type coll. of *M. floribunda*, NY; photographs of type, Ch, US).

TOLIMA: "La Virginia," Líbano, *Pennell* 3288 (GH, NY, US); "Icononzo" to "Boca de Monte," highway to Melgar, *García-Barriga* 12015 (US); El Líbano, *García-Barriga* 12234 (US); "Mariquita," *Bonpland* s. n. (fragments of type, US; photographs of type, Ch, US).

ANTIOQUIA: Medellín, *Archer* 79 (US); vicinity of Medellín, *Toro* 88 (NY, US); vicinity of Bocana, east of Medellín, *Araque & Barkley* 19A054 (US); "Sonson," *Archer & López* 402 (NY, US); Santa Bárbara, Cauca Valley, *Pennell* 10922 (US); Heliconia, *Bro. Daniel* 3987 (US); Cordillera Central, *Correa* 28 (US).

CALDAS: Salento, Cordillera Central, *Pennell, Killip, & Hazen* 8740 (GH, NY, US), 8741 (GH, NY, US); Santuario, Cordillera Occidental, *Pennell* 10303 (GH, US); near Victoria, *Haught* 2151 (US); "La Palmita," west of Armenia, Cauca Valley, *Pennell, Killip, & Hazen* 8595 (NY, US); Pereira, Cordillera Central, *Killip & Hazen* 11008 (US); "Chinchina," *Cuatrecasas* 23380 (Ch); La Selva, Cordillera Occidental, western slope, *von Suedern* 5540 (US).

CHOCO: "La Mansa," *Araque & Barkley* 19Ch012 (US).

EL VALLE: La Cumbre, Cordillera Occidental, *Pennell* 5171 (GH, NY, US); Naranjal, valley of Río Sanquinini, western slope, Cordillera Occidental, *Cuatrecasas* 15373 (Ch, US); Morro Pelado, Pichindé, valley of Río Cali, eastern slope, Cordillera Occidental, *Cuatrecasas* 18137 (Ch, US); La Tulia, valley of Río Cali, eastern slope, Cordillera Occidental, *Cuatrecasas* 18529 (Ch); kilometer 54 on Cali-Buenaventura highway, *Haught* 5313 (US); Ciclito, Western Cordillera, *Dryander* 1977 (US); Versalles, Western Cordillera, *Dawe* 832 (NY, US); hills near Alcalá, *Cuatrecasas* 22849 (Ch); Las Neives, west of Cali, Western Cordillera, *Killip, Cuatrecasas, & Dryander* 39208 (Ch, US).

CAUCA: Popayán, *Yepez* 133 (Ch, US), *von Suedern* 5602 (US); highlands of Popayán, *Lehmann* 360 (NY), 361 (Ch, GH, NY); Tambo, *Haught* 5279

(US); "Timbio-Paispampa" highway, *Haught* 5297 (US); between Popayán and Cajeti, toward Tambo, *Cuatrecasas* 13822 (Ch, US).

DEPT. ? : Without locality, *Rodriguez* 5 (US); La Esperanza, *García-Barriga* 3062 (US); San Antonio, *Langlassé* 31 (GH); above Palmira, Cordillera Central, *Pittier* 903 (US); Río Ortega to San Antonio, Cordillera Occidental, *Pennell & Killip* 7261 (NY, US); Estación Uribe, *Bro. Ariste-Joseph*, s. n. (US).

This is a common species of the Andes of Colombia and Ecuador. It is related to *M. rupestris* H.B.K., but is distinct in the more or less coriaceous and acute leaves, the racemes with longer axes (to 15 cm. long), the triangular flower-subtending bracts, the two lower sepals being inconspicuously united at base, and the keel being pubescent within. The type collection of *M. floribunda* Tr. & Pl. shows the same characters, and a comparison of it with fragments and photographs of the type of *M. phytolaccaefolia* demonstrates that only one species is concerned. Moreover, numerous specimens from essentially the type locality of *M. floribunda* (near Bogotá) have been found to be identical with the Bonpland collection. *Monnina comata* Chodat was founded on material collected by André at Salento, Department of El Valle. The type of this species is not now available at Geneva; Professor Baehni informs me that it may have been destroyed in a fire at the University of Genève at the time Chodat was working on this family. However, examination of the original description of *M. comata* shows no reason to consider it a distinct species, and the numerous specimens from El Valle agreeing with Bonpland's material bear out this reduction. The same disposition has been made of the binomial *M. elliptica*, based on material from near Cartago, El Valle, in spite of the fact that Chodat placed this species in a group marked by "ovarium pilosum." No other characters separate Chodat's species, and his characterization of the ovary as pilose has been questionable in other species, i. e., in *M. mathusiana*, from northern Peru.

22. *Monnina revoluta* H.B.K. Nov. Gen. & Sp. 5: 412. 1821.

Shrub, 1-2 m. high, the stem erect, glabrescent, branched, the branches 12-32 cm. long, 2-9 mm. in diameter, slightly pubescent, corymbose; leaves crowded, linear-elliptic, 14-50 mm. long, 3.5-9 mm. wide, obtuse, glabrescent above, finely pubescent beneath, entire, conspicuously revolute, the costa prominulous beneath, with inconspicuous lateral veins; petioles 1.5-2 mm. long, concave above, convex beneath, puberulent; racemes conical, acute, 8-10 mm. wide, simple, terminal, pedunculate (peduncle 3-4 mm. long), the axis 1.6-2.5 cm. long, slightly pubescent, bracteate, the bracts triangular, acute, 1-1.5

mm. long, 1–1.2 mm. wide, pubescent beneath, ciliate, 1-nerved, inconspicuous; flowers 4–5 mm. long, the pedicels 0.8–1 mm. long, finely pubescent; outer sepals free, ovate-triangular, obtuse, ciliate, the two lower ones 1.4–3 mm. long, 1.2–2 mm. wide, usually 1-nerved, rarely 3-nerved, the upper sepal 2–3.2 mm. long, 1.6–2 mm. wide, 3- or 5-nerved; wings deep blue, 4.2–5 mm. long, 3.5–4 mm. wide, obovate, more or less acute at base, 3- or 4-nerved, ciliate, glabrous on both sides; keel 4.2–5.2 mm. long, 2.5–3 mm. wide, orbicular, plicate, glabrous within, sometimes slightly pubescent, obtuse at base, 4-nerved, 3-lobed, the middle lobe obtuse-emarginate, larger; upper petals spatulate, pubescent; stamens 8, the filaments 2.8–4 mm. long, almost entirely united, the free part 0.8–1.5 mm. long, glabrous; ovary ovoid, 1.8–2 mm. long, 1–1.2 mm. wide, glabrous; style 2.2–2.6 mm. long, geniculate near its base, glabrous, cylindrical; stigma with 2 lobes, the



FIG. 22.—*Monnina revoluta*: Left to right, lower sepals, upper sepal, wings (inner), keel, upper petals and stamens, gynaecium. All  $\times 3$ .

lower one acute, the upper 1-tubercled, the tubercle papillose; drupe ellipsoid, 6–6.5 mm. long, 2.8–3 mm. wide, glabrous, reticulate.

DISTRIBUTION: Central and southwestern parts of Colombia, between 3,250 and 4,200 meters altitude, and also in Ecuador.

CUNDINAMARCA: Páramo de Guasca, Cordillera Oriental, *Hodge* 6478 (Ch).

PUTUMAYO: Between El Encano and Sibundoy, Páramo de San Antonio del Bordoncillo, *Cuatrecasas* 11752 (US).

TOLIMA: Páramo de Ruiz, *Pennell* 3083 (NY); "Mariquita," *Linden* 955 (fragments of authentic material, US).

CALDAS: Above El Bosque, Río Otún, western slope, Cordillera Central, *Cuatrecasas* 23169 (Ch); Páramos de la Laguna del Mosquito, Río Otún, western slope, Cordillera Central, *Cuatrecasas* 23249 (Ch); Páramo del Quindío, Cordillera Central, *Pennell & Hazen* 9986 (GH, NY, US).

CAUCA: Mount Pan de Azúcar, Cordillera Central, *Pennell* 7045 (GH, NY, US); San Francisco, Páramo del Puracé, Cordillera Central, *Cuatrecasas* 14576 (Ch, US), 14576A (Ch); Las Casitas, Río Palo, western slope, Cordillera Central, *Cuatrecasas* 18994 (Ch, US); Puracé, Cordillera Central, *von Suedern* 1815 (NY).

NARIÑO: Pasto, *Bonpland* s. n. (fragments of type Ch, photographs of type, GH, US).

DEPT. ?: *Holton* 829 (GH, NY).

This species, characterized by more or less corymbose branches and conspicuously small, crowded, linear-elliptic, revolute leaves, is typified



by a collection from Pasto, Department of Nariño, of which fragments and photographs have been seen.

23. *Monnina elongata* Pl. & Lind. in Ann. Sci. Nat. IV. 17: 137. 1862.

Frutescent, to 1.6 m. high, branched, the branches 12–24 cm. long, 1.5–2 mm. in diameter, canescent-pubescent, becoming more or less glabrescent; leaves lanceolate, 34–80 mm. long, 12–23 mm. wide, acuminate, rarely acute, pubescent above, becoming almost glabrescent, canescent-pubescent beneath, entire, attenuate at base, the costa slightly prominulous beneath, with 8 or 9 pairs of lateral veins; petioles 2–6 mm. long, concave above, convex beneath, pubescent; racemes more or less conical, obtuse, 8–10 mm. wide, simple, terminal or axillary, pedunculate (peduncle 7–18 mm. long), the axis 2.2–11 cm. long, canescent-pubescent, striate, bracteate, the bracts oblance-



FIG. 23.—*Monnina elongata*: Left to right, lower sepals, upper sepal, wings (inner), keel, upper petals and stamens, gynaecium, bract. All  $\times 3$ .

olate, 6–7 mm. long, 2–2.6 mm. wide, acuminate, 1-nerved, slightly pubescent beneath, becoming glabrescent, deciduous, ciliate; flowers 4–4.5 mm. long, the pedicels 1–1.2 mm. long, finely pubescent; outer sepals free, ovate-triangular, obtuse, ciliate, the two lower ones 2–2.4 mm. long, 1.2–1.5 mm. wide, usually 1-nerved, rarely 2-nerved, glabrous beneath, the upper sepal 2.8–3 mm. long, 1.8–2 mm. wide, 3-nerved, glabrescent beneath; wings deep blue, 4–4.5 mm. long, 3.5–3.8 mm. wide, obovate, obtuse at base, 3-nerved, glabrous beneath, glabrescent within, sometimes with a few hairs at base; keel 4.5–5 mm. long, 2.3–2.8 mm. wide, orbicular, plicate, glabrous within, obtuse at base, 3-nerved, 3-lobed, the middle lobe obtuse-submarginate; upper petals elongate-spatulate, pubescent; stamens 8, the filaments 2.8–3.2 mm. long, almost entirely united, the free part 0.8–1.2 mm. long, glabrous; ovary ovoid, 1.6–2 mm. long, 0.9–1 mm. wide, slightly pubescent, becoming glabrescent, the hairs more conspicuous in the upper part; style 2–2.2 mm. long, geniculate above base, glabrous, cylindrical; stigma with 2 lobes, the lower one acute, the upper 1-tubercled, the tubercle papillose; drupe ellipsoid, 5–5.5 mm. long, 3–3.2 mm. wide, slightly pubescent, becoming glabrescent, reticulate.

DISTRIBUTION: Northern part of Colombia, between 1,500 and 3,300 meters altitude.

NORTE DE SANTANDER: Ocaña, *Schlim* 674, 1137 (photographs of cotypes, Ch, GH, US).

SANTANDER: Eastern slope of Páramo de las Coloradas, above La Baja, *Killip & Smith* 18381 (GH, NY, US); without locality, *Linden* 375 (fragments of authentic material, US).

The canescent-pubescent habit, the lanceolate and acuminate leaves, and the obtuse racemes with conspicuous oblanceolate bracts characterize this species.

24. *Monnina andreana* Chodat in Bull. Herb. Boiss. 3: 134. 1895.

*Monnina lehmanniana* Chodat in Bull. Herb. Boiss. 3: 542. 1895.

Frutescent, branched, the branches 1.6–3.8 mm. in diameter, conspicuously hirsute, terete; leaves lanceolate, 18–65 mm. long, 5.5–15 mm. wide, acute, glabrescent above, slightly pubescent beneath, entire,



FIG. 24.—*Monnina andreana*: Left to right, lower sepals, upper sepal, wings (inner), keel, upper petals and stamens, gynaecium, bract. All  $\times 3$ .

attenuate at base, the costa prominulous beneath, with 4 or 5 pairs of lateral veins; petioles 2.5–5.5 mm. long, concave above, convex beneath, pubescent; racemes elongate, acute, 8–10 mm. wide, simple, terminal or axillary, pedunculate (peduncle 3–10 mm.), the axis 2.2–6 cm. long, hirsute, striate, bracteate, the bracts linear or narrowly triangular, 1.8–3 mm. long, 0.5–0.8 mm. wide, deciduous, ciliate, 1-nerved, finely pubescent beneath; flowers 3.8–4 mm. long, the pedicels 1.2–1.4 mm. long, slightly pubescent; outer sepals free, triangular, acute, ciliate, finely pubescent beneath, becoming glabrescent, the two lower ones 2.2–2.5 mm. long, 0.9–1.2 mm. wide, 1-nerved, rarely 3-nerved, the upper sepal 2.6–3.2 mm. long, 1–1.2 mm. wide, 3-nerved; wings 4–4.4 mm. long, 3–3.8 mm. wide, obovate, acute at base, 3-nerved, glabrous beneath, ciliate at base; keel 3.8–5 mm. long, 2.6–3 mm. wide, orbicular, plicate, glabrous within, obtuse at base, 3-nerved, inconspicuously 3-lobed, the middle lobe obtuse-subemarginate; upper petals elongate-spatulate, pubescent; stamens 8, the filaments 3.2–3.8 mm. long, almost entirely united, the free part 0.8–1.5 mm. long, glabrous; ovary ovoid, 1–1.8 mm. long, 0.7–1 mm. wide, pubescent;

style 2.5–3 mm. long, geniculate in the middle part, glabrous, more or less cylindrical; stigma with 2 lobes, the lower one conspicuously acute, the upper 1-tubercled, the tubercle papillose; drupe ellipsoid, 5–6 mm. long, 2.4–3 mm. wide, pubescent, becoming glabrescent, reticulate.

DISTRIBUTION: Central and southwestern Colombia, between 2,700 and 3,450 meters altitude.

CUNDINAMARCA: Facatativa, *André* 558 (type, in Conservatoire Botanique, Genève).

CAUCA: Páramos near Laguna del Paez, headwaters of Río Paez, western slope, Cordillera Central, *Cuatrecasas* 19047 (Ch, US); Páramo de Guanacas, *Lehmann* 2129 (type coll. of *M. lehmanniana*, US; photographs, GH, US).

This species seems closely related to *M. elongata* Pl. & Lind. but, unlike that species, it has conspicuously hirsute branches, acute leaves with 4 or 5 pairs of lateral veins, racemes with a shorter axis (to 6 cm. long) and with linear or narrowly triangular bracts, acute outer sepals, etc. Direct comparison of type material of the two binomials concerned indicates that they cannot both be maintained, the only apparent difference being the somewhat glabrescent ovary in the type of *M. andreana*. Through the kindness of Professor Bachni, Director of the Conservatoire Botanique, Genève, it has been possible for me to borrow the actual type of *M. andreana*.

25. *Monnina involuta* Ferreyra, sp. nov.

Frutex ad 1 m. altus *M. latifoliae* (Bonpl.) DC. affinis, foliis minoribus lamina ad 5 cm. longa, racemis minoribus rhachi ad 4.5 cm. longa, sepalo exteriore conspicue involuto, stylo glabro differt.

Frutescent, to 1 m. high, branched, the branches 16.5–26.5 cm. long, 2.6–3 mm. in diameter, nodose, glabrescent, striate; leaves lanceolate, 22–50 mm. long, 9–16 mm. wide, acute, glabrescent above, finely pubescent beneath, entire, slightly revolute, attenuate at base, the costa prominulous beneath, with 4 or 5 pairs of lateral veins; petioles 2–2.5 mm. long, concave above, convex beneath, finely pubescent; racemes conical, acute, 7–9 mm. wide, simple, terminal or axillary, pedunculate (peduncle 5–8 mm. long), the axis 2.8–4.5 cm. long, pubescent, striate, bracteate, the bracts inconspicuous; flowers 4.8–5.4 mm. long, the pedicels 1.6–2.2 mm. long, slightly pubescent; outer sepals free, lanceolate, acute, the apex conspicuously involute, ciliate, glabrous beneath, 3-nerved, the two lower ones 4–4.8 mm. long, 1.2–1.6 mm. wide, the upper sepal 4.2–5 mm. long, 1.6–1.8 mm. wide; wings blue, 4–4.6 mm. long, 3.5–4 mm. wide, obovate, obtuse at base, 3- or 4-nerved, glabrous beneath, eciliate; keel 4.5–5.2 mm. long, 2.4–2.8 mm. wide,

orbicular, plicate, glabrous within, obtuse at base, 3- or 4-nerved, subemarginate at apex, inconspicuously 3-lobed; upper petals short, spatulate, pubescent; stamens 8, the filaments 3.2-4 mm. long, almost entirely united, the free part 0.5-1 mm. long, glabrous; ovary ellipsoid, 1-1.4 mm. long, 0.6-0.8 mm. wide, glabrous; style 2-2.2 mm. long, more or less geniculate in the middle part, glabrous, almost cylindrical; stigma with 2 lobes, the lower one acute, the upper 1-tubercled, the tubercle papillose; drupe ellipsoid, 4-5 mm. long, 2.2-2.8 mm. wide, glabrous, reticulate.

Type in the herbarium of the Chicago Natural History Museum, No. 1366909, collected on Los Farallones, in thickets on Páramo of Cerro La Torre, Cordillera Occidental, Department of El Valle, alt. 3,750 meters, October 10, 1941, by J. Cuatrecasas (No. 17862).



FIG. 25.—*Monnina involuta*: Left to right, lower sepals, upper sepal, wings (inner), keel, upper petals and stamens, gynaecium. All  $\times 3$ .

DISTRIBUTION: Known only from the type collection.

The new entity has small, lanceolate, acute leaves (to 50 mm. long), the apex of the outer sepals being strongly involute. It is related to *M. latifolia* (Bonpl.) DC., but has smaller leaves, the axis of racemes shorter (to 4.5 cm. long), the outer sepals involute, the keel and style glabrous, etc.

26. *Monnina latifolia* (Bonpl.) DC. Prodr. 1: 338. 1824.

*Hebandra latifolia* Bonpl. in Ges. Naturf. Freund. Berlin Mag. 2: 43. 1808.

Frutescent to 1 m. high, branched, the branches 3.5-5 mm. in diameter, slightly canescent-pubescent, striate; leaves elliptic-lanceolate, 68-215 mm. long, 19-85 mm. wide, usually acuminate, rarely acute, glabrescent above, finely pubescent beneath, entire, attenuate at base, the costa prominulous beneath, with 8 or 9 pairs of lateral veins; petioles 2-3 mm. long, concave above, convex beneath, finely pubescent; racemes elongate, obtuse, 10-12 mm. wide, simple, terminal or axillary, sometimes inconspicuously aggregate in groups of 2-4, pedunculate (peduncle 16-32 mm. long), the axis 5.8-30 cm. long, canescent-pubescent, striate, bracteate, the bracts linear, 6-7.2 mm. long, 1-1.2 mm. wide, deciduous, ciliate, 1-nerved, finely pubescent beneath; flowers 4.5-5.5 mm. long, the pedicels 1.5-2.5 mm. long, finely pubescent; outer sepals free, ovate, acute, ciliate, pubescent

beneath, the two lower ones 4.8–5.2 mm. long, 2.8–3 mm. wide, 3-nerved, the upper sepal 5–6 mm. long, 3.2–3.9 mm. wide, 5-nerved; wings deep blue, 4.5–5.2 mm. long, 4.6–5.2 mm. wide, obovate, obtuse at base, 3- or 4-nerved, strongly pubescent beneath, the hairs more or less rigid, ascending, glabrous within, eciliate; keel 4.8–5.5 mm. long, 3–3.5 mm. wide, orbicular, plicate, pubescent within, obtuse at base, 3- or 4-nerved, 3-lobed, the middle lobe obtuse-emarginate; upper petals slightly elongate-spatulate, pubescent; stamens 8, the filaments 3.2–4 mm. long, almost entirely united, the free part 0.6–1 mm. long, glabrous; ovary ovoid, 2–2.2 mm. long, 1.2–1.4 mm. wide, glabrous; style 2–2.5 mm. long, conspicuously geniculate at base, pubescent, cylindric; stigma with 2 lobes, the lower one acute, the upper 1-tubercled, the tubercle papillose; drupe ellipsoid, 7–8 mm. long, 4–4.5 mm. wide, glabrous, reticulate.



FIG. 26.—*Monnina latifolia*: Left to right, lower sepals, upper sepal, wing (inner), wing (outer), keel, upper petals and stamens, gynaecium, bract. All  $\times 3$ .

**DISTRIBUTION:** Confined to the Andes of Central Colombia, between 2,000 and 2,100 meters altitude.

**CUNDINAMARCA:** Pacho-Paime Highway, *Haught* 6073 (US).

**TOLIMA:** "Quindio," *Goudot* s. n. (US), *Bonpland* s. n. (photograph of type, US).

This small shrub is readily distinguished by its large, acuminate, elliptic-lanceolate leaves, its racemes with elongate axes (to 30 cm. long) and conspicuous linear bracts (to 7.2 mm. long), and by having its outer sepals larger than the wings, its wings strongly pubescent, and its style also pubescent.

27. *Monnina bracteata* Chodat in Bull. Herb. Boiss. 3: 133. 1895.

*Monnina multicomata* Chodat in Bull. Soc. Bot. Genève II. 25: 211. 1934.

Slender tree, branched, the branches 1.8–3 mm. in diameter, striate, hirsute; leaves lanceolate, 38–155 mm. long, 10–55 mm. wide, acuminate, rarely acute, finely pubescent above, becoming glabrescent, canescent-hirsute beneath, entire, attenuate at base, the costa prominent beneath, with 7 to 9 pairs of lateral veins; petioles 1.8–8 mm. long, concave above, convex beneath, articulate, pubescent; racemes

more or less conical, acute, 8–10 mm. wide, simple, terminal or axillary, pedunculate (peduncle 8–20 mm. long), the axis 1.8–9.5 cm. long, hirsute, striate, bracteate, the bracts conspicuously filiform, 6–11.6 mm. long, 1–3.5 mm. wide, deciduous, ciliate, 1-nerved, puberulous beneath; flowers 3.8–5 mm. long, the pedicels 1–1.2 mm. long, finely puberulent; outer sepals free, lanceolate, ciliate, acute (apex involute), pubescent beneath, the two lower ones 3.8–5.5 mm. long, 1.8–3 mm. wide, 5-nerved, rarely 3-nerved, the upper sepal 3.8–6 mm. long, 1.8–3.8 mm. wide, 7-nerved, sometimes 5-nerved; wings blue, 4–4.5 mm. long, 3–4 mm. wide, obovate, obtuse at base, 3-nerved, slightly pubescent beneath, rarely glabrescent, glabrous within, usually eciliate; keel 4–5 mm. long, 2.8–3.2 mm. wide, orbicular, plicate, slightly pubescent within, rarely glabrescent, obtuse at base, 3-nerved, 3-lobed, the middle



FIG. 27.—*Monnina bracteata*: Left to right, lower sepals, upper sepal, wing (inner), wing (outer), keel, upper petals and stamens, gynaecium, all  $\times 3$ ; bract,  $\times 2$ .

lobe inconspicuous, obtuse-subemarginate; upper petals elongate-spatulate, pubescent; stamens 8, the filaments 3–3.2 mm. long, almost entirely united, the free part 0.4–0.8 mm. long, glabrous; ovary ovoid, 1.2–2.2 mm. long, 0.8–1.4 mm. wide, glabrous; style 2–2.4 mm. long, geniculate above base, glabrescent, rarely with a few inconspicuous hairs, more or less cylindrical; stigma with 2 lobes, the lower one acute, the upper 1-tubercled, the tubercle papillose; drupe ellipsoid, 5.2–7 mm. long, 3.2–4.4 mm. wide, glabrous, reticulate.

DISTRIBUTION: In the Andes of central and northern Colombia, and the southwestern part of Venezuela, between 2,000 and 3,400 meters altitude.

NORTE DE SANTANDER: Pica-Pica Valley, above Tapatá, north of Toledo, Killip & Smith 20029 (NY, US).

CALDAS: Salento, Cordillera Central, Pennell 8917 (GH, NY, US); "Alaska," above Salento, Pennell 9382 (GH, US); Salento to "Laguneta," Old Quindío Trail, Killip & Hazen 9116 (GH, NY, US); Cerro Tatamá, Cordillera Occidental, Pennell 10500 (US); Río San Rafael, below Cerro Tatamá, Pennell 10386 (type of *M. multicomata* US, isotype GH, NY).

This species was established by Chodat in 1895 from material collected by Moritz in "Truxillo et Mérida," in southwestern Venezuela. The original description and photographs of the type agree well with the specimens here cited and also with the type of *M. multicomata* Chodat. The species suggests *M. latifolia* (Bonpl.) DC. but differs in its smaller and lanceolate leaves (to 155 mm. long), the axes of the racemes being shorter (to 9.5 cm. long), the apex of outer sepals slightly involute, etc.

In connection with my reduction of *M. multicomata* to Chodat's earlier binomial, the following Venezuelan material of *M. bracteata* may be cited: "Truxillo et Mérida," Moritz 1267 (photographs of type, Ch, US); Mérida: Tabay, Gehriger 390 (US), 558 (US); Palmira, Jahn 602 (US).

28. *Monnina pennellii* Ferreyra, sp. nov.

Frutex *M. salicifoliae* R. & P. valde affinis, foliis majoribus lamina ad 14.5 cm. longa, sepalis duobus inferioribus 5-nerviis, stylo pubescente facile distinguendus.



FIG. 28.—*Monnina pennellii*: Left to right, lower sepals, upper sepal, wings (inner), keel, upper petals and stamens, gynaecium. All  $\times 3$ .

Suffrutescent, branched, the branches 3–5 mm. in diameter, striate, slightly pubescent; leaves subcoriaceous, elliptic, 55–145 mm. long, 22–92 mm. wide, acute, finely strigose-pubescent, becoming glabrescent, entire, attenuate at base, the costa prominulous beneath, with 9 or 10 pairs of lateral veins; petioles 2.5–5 mm. long, concave above, convex beneath, finely pubescent; racemes conical, acute, 8–10 mm. wide, simple, terminal or axillary, pedunculate (peduncle 17–24 mm. long), the axis 5.2–6.5 cm. long, finely pubescent, striate, bracteate, the bracts oblanceolate or triangular, acute, 2–2.5 mm. long, 1.2–1.5 mm. wide, deciduous, ciliate, 1-nerved, pubescent beneath; flowers 4.5–5.2 mm. long, the pedicels inconspicuous, 0.4–0.6 mm. long, finely pubescent; outer sepals free, ovate-lanceolate, obtuse, ciliate, slightly pubescent beneath, becoming glabrescent, the two lower ones 1.8–2.2 mm. long, 1.6–1.8 mm. wide, usually 5-nerved (3 nerves conspicuous), rarely 3-nerved, the upper sepal 2.5–2.8 mm. long, 1.6–2 mm. wide, 5-nerved; wings violet-blue, 4.2–5.2 mm. long, 3.6–4.8 mm. wide, obovate, obtuse at base, 3- or 4-nerved, glabrous beneath, with few

hairs within, ciliate at base; keel 5-5.8 mm. long, 3-3.8 mm. wide, orbicular, plicate, pubescent within, obtuse at base, 3- or 4-nerved, 3-lobed, the middle lobe obtuse-subemarginate, larger; upper petals elongate-spatulate, densely pubescent; stamens 8, the filaments 3.8-4 mm. long, almost entirely united, the free part 1-1.5 mm. long, glabrous; ovary ovoid, 1.2-2 mm. long, 0.8-1.4 mm. wide, glabrous; style 2.5-3 mm. long, geniculate above base, pubescent, more or less cylindrical; stigma with 2 lobes, the lower one acute, the upper 1-tubercled, the tubercle papillose; drupe ellipsoid, 5.5-7 mm. long, 3-4 mm. wide, glabrous, reticulate.

Type in U. S. National Herbarium, No. 1141652, collected at San José, Cauca Valley, Department of Caldas, alt. 1,400-1,800 meters, September 3, 1922, by F. W. Pennell (No. 10247). Duplicate in the Gray Herbarium.

DISTRIBUTION: Known only from the type collection.

The new species seems closely related to *M. salicifolia* R. & P., from which it differs in its larger, acute leaves (to 145 mm. long) with 9 or 10 pairs of lateral nerves, and in having its lower sepals 5-nerved and its upper petals and style pubescent.

29. *Monnina salicifolia* R. & P. Syst. Veg. 172. 1798.

*Monnina cestrifolia* H.B.K. Nov. Gen. & Sp. 5: 413. t. 502. 1821.

Shrub 0.4-3 m. high, branched, the branches 2-8 mm. in diameter, nodose, pubescent, becoming glabrescent, striate; leaves usually elliptic, rarely lanceolate, 15-75 mm. long, 5-35 mm. wide, obtuse, sometimes acute, finely canescent-pubescent; becoming more or less glabrescent, entire, slightly revolute, attenuate at base, the costa prominent beneath, with 5 or 6 pairs of lateral veins; petioles 1.5-3 mm. long, concave above, convex beneath, articulate, pubescent; racemes conical, acute, 9-12 mm. wide, simple, terminal, pedunculate (peduncle 8-14 mm. long), the axis 2-9 cm. long, pubescent, striate, bracteate, the bracts acute-triangular, 1.4-4 mm. long, 1.4-1.8 mm. wide, deciduous, ciliate, 1-nerved, finely pubescent beneath, becoming glabrescent; flowers 4.2-6.5 mm. long, the pedicels 0.8-1.4 mm. long, pubescent; outer sepals free, ovate-triangular, obtuse, ciliate, slightly pubescent beneath, rarely glabrescent, the two lower ones 1.4-2.5 mm. long, 1.2-2 mm. wide, 3-nerved, the upper sepal 2-3 mm. long, 1.6-2.4 mm. wide, 5-nerved; wings deep blue, 4-6.5 mm. long, 3.6-6 mm. wide, obovate, obtuse at base, 3-nerved, ciliate; keel 4.2-6.8 mm. long, 2.8-4 mm. wide, orbicular, plicate, pubescent within, obtuse at base, 3-nerved, 3-lobed, the middle lobe obtuse-emarginate; upper petals elongate-spatulate, slightly pubescent; stamens 8, the filaments 3-4



mm. long, almost entirely united, the free part 0.8–1.4 mm. long, glabrous; ovary ovoid, 1.2–2.5 mm. long, 0.8–1.5 mm. wide, glabrous; style 2–3 mm. long, geniculate above base, glabrous, thicker toward apex; stigma with 2 lobes, the lower one acute, the upper 1-tubercled, the tubercle papillose; drupe ellipsoid, 5.5–7 mm. long, 3.6–4 mm. wide, glabrous, reticulate.

DISTRIBUTION: Along the Andes from northern Colombia to Ecuador, Peru, and Bolivia, between 1,200 and 3,700 meters altitude.

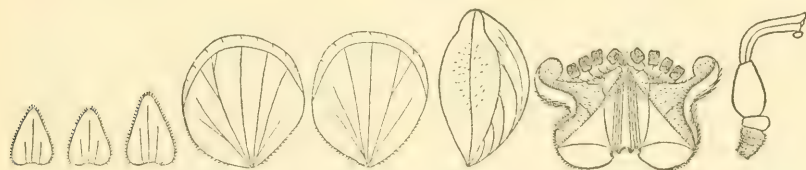


FIG. 29.—*Monnina salicifolia*: Left to right, lower sepals, upper sepal, wings (inner), keel, upper petals and stamens, gynaecium. All  $\times 3$ .

NORTE DE SANTANDER: Páramo de Tamá, above La Cueva, *Cuatrecasas*, *Schultes & E. Smith* 12649 (Ch, US).

SANTANDER: Vicinity of Charta, *Killip & Smith* 19080 (GH, NY, US), 19231 (GH, NY, US); Páramo de Vetas, *Killip & Smith* 17420 (GH, NY, US); vicinity of Tona, *Killip & Smith* 19476 (GH, NY, US); edge of Páramo de Santurbán, *Killip & Smith* 17927 (Ch, NY, US); vicinity of La Baja, *Killip & Smith* 18746 (GH, NY, US), 18137 (US); western slope of Páramo de las Puentes, above La Baja, *Killip & Smith* 18156 (GH, NY, US).

BOYACÁ: Northeast of Duitama, Quebrada de Becerra, Cordillera Oriental, *Cuatrecasas* 10379 (Ch, US).

CUNDINAMARCA: Bogotá and immediate vicinity, *Bequaert* 2 (Ch, GH, US), *Bro. Ariste-Joseph* A103 (GH, US), A238 (US), *Juzepczuk* 5040 (US), *Schiefer* 532 (GH), *Holton* 830 (GH, NY), *Triana* s. n. (NY); cerro above La Cita, Bogotá, *Schultes* 7119 (US); between El Delirio and Guadalupe, Macizo de Bogotá, *Cuatrecasas* 5166 (US); Guadalupe, near Bogotá, *Haught* 5045 (US), 5046 (US), 5698 (US); Páramo de Guasca, *Balls* 5707 (US), *García-Barriga* 11640 (US); Guasca, *Grant* 7377 (US); road to east from Guasca, *Haught* 5813 (US); Venecia-Pandi, *Herb. Nac. Colomb.* 478 (US); Páramo de Zipaquirá, *Cuatrecasas* 9559 (Ch, US); Páramo de Chocontá, *Cuatrecasas* 9655 (Ch, US); Sopó, *García-Barriga* 13354 (US), 13373 (US); near Sutatausa, *Haught* 6168 (Ch, US); Río Negro valley, between Quetamé and Piperal, *Killip* 34223 (NY, US).

PUTUMAYO: Road between Laguna La Cocha and Páramo de Tábano, *Schultes & Villarreal* 7833q (US).

ANTIOQUIA: Jerico, *Bros. Daniel & Tomás* 3499 (US); between Medellín and Palmitas, Cordillera Central, *Hodge* 6610 (US); north of Santa Rosa de Osos, *Rivera, Franco, & Barkley* 18A048 (US).

CALDAS: Páramos between El Bosque and Plan del Villar, western slope, Cordillera Central, *Cuatrecasas* 23267 (Ch).

EL VALLE: Páramo de Bavaya, valley of Río Bugalagrande, western slope, Cordillera Central, *Cuatrecasas* 20061 (Ch).

CAUCA: Tablón, near Puracé, western slope, Cordillera Central, *Cuatrecasas* 14558 (Ch, US); "San Isidro," Puracé, Cordillera Central, *Pennell & Killip* 6465 (US); San Pedro, *Bro. Daniel* 1363 (Ch); without locality, *Dryander* 1058 (US).

NARIÑO: Pasto, *Bonpland* s. n. (fragments and photograph of type of *M. cestrifolia*, US); "isla Tuquerre," *Herb. Nac. Colomb.* 86 (US).

DEPT. ? : Without locality, *Linden* 781 (GH, US); without locality, *Holton* 831 (NY); without locality, *Triana* 414 (US), 415 (US).

*Monnina salicifolia* is very abundant in the Andes of northwestern South America, its distribution extending from Colombia southward into Bolivia. It was based upon material from central Peru (for a discussion of the Peruvian distribution, see *Journ. Arn. Arb.* 27: 157-158. 1946). The species is characterized by elliptic leaves, racemes which are simple, terminal, conical, and acute, completely free lower sepals, and by the keel being pubescent within.

*Monnina cestrifolia* was described from material collected at Pasto, Department of Nariño, of which fragments and a photograph are available. Although the type specimen of the binomial was sterile, I have no doubt of its identity with *M. salicifolia*.

30. *Monnina mollis* Pl. & Lind. ex Tr. & Pl. in *Ann. Sci. Nat.* IV. 17: 139. 1862.

Frutescent, or slender tree to 6 m. high, branched, the branches 2-7 mm. in diameter, conspicuously hirsute, sometimes becoming more or less glabrescent, striate; leaves oblong, 35-130 mm. long, 14-47 mm. wide, usually obtuse, rarely acute or acuminate, mucronate, slightly hirsute above, becoming glabrescent, hirsute beneath, entire, attenuate at base, the costa prominulous beneath, with 7 or 8 pairs of lateral veins; petioles 4-7 mm. long, concave above, convex beneath, hirsute; racemes conical, acute, 7-9 mm. wide, simple, terminal or axillary, pedunculate (peduncle 8-30 mm. long), the axis 2.5-10.5 cm. long, conspicuously hirsute, striate, bracteate, the bracts hood-shaped, acute, concave, 3.6-6.2 mm. long, 2-2.1 mm. wide, deciduous, ciliate, 1-nerved, densely pubescent beneath; flowers 4.2-5 mm. long, the pedicels 0.6-1 mm. long, finely pubescent; outer sepals free, ovate-triangular, obtuse, ciliate, slightly pubescent beneath, becoming glabrescent, finely puberulent within, the two lower ones 1.8-2.8 mm. long, 1.6-2 mm. wide, 3-nerved, the upper sepal 2-3 mm. long, 1.8-2.4 mm. wide, 5-nerved; wings deep blue, 4.4-5 mm. long, 4.4-5 mm. wide, obovate, obtuse at base, 3-nerved, glabrous, ciliate; keel 4.8-5.4 mm. long, 3.2-4 mm. wide, orbicular, plicate, pubescent within, obtuse

at base, 3-nerved, 3-lobed, the middle lobe obtuse-emarginate; upper petals elongate-spatulate, pubescent; stamens 8, the filaments 2.8–3.2 mm. long, almost entirely united, the free part 0.8–1.2 mm. long, glabrous; ovary ovoid, 1.2–1.4 mm. long, 0.8–1 mm. wide, glabrous; style 2.2–2.5 mm. long, geniculate above base, glabrous, thicker toward apex; stigma with 2 lobes, the lower one acute, the upper 1-tubercled, the tubercle papillose; drupe ellipsoid, 5–5.5 mm. long, 3–4 mm. wide, glabrous, reticulate.

DISTRIBUTION: Andes of northern and central Colombia, between 1,500 and 3,300 meters altitude.

MAGDALENA: Hillside at "Africa," Sierra Perija, *Haught* 4392 (US), 4520 (US); Sierra Nevada de Santa Marta, *Schlim* 819 (fragments of type, US; photographs of type, Ch, GH, US).



FIG. 30.—*Monnina mollis*: Left to right, lower sepals, upper sepal, wings (inner), keel, upper petals and stamens, gynaecium, bract. All  $\times 3$ .

NORTE DE SANTANDER: Páramo de Fontibón, *Cuatrecasas, Schultes, & E. Smith* 12330 (Ch, US); La Cabuya, valley of Río Chitagá, region of Sarare, *Cuatrecasas, Schultes, & E. Smith* 12175 (US); between Pamplona and La Isla, *Killip & Smith* 19800 (GH, NY, US); between Toledo and Pamplona, *Killip & Smith* 20555 (GH, NY, US); vicinity of Toledo, *Killip & Smith* 20048 (GH, NY, US).

SANTANDER: Vicinity of Vetas, *Killip & Smith* 17890 (Ch, GH, NY, US); mountains east of Las Vegas, *Killip & Smith* 15575 (GH, NY, US); Río Suratá Valley, above Suratá, *Killip & Smith* 16625 (GH, NY, US); vicinity of California, *Killip & Smith* 17008 (GH, US).

CUNDINAMARCA: Vicinity of Fusagasugá, *García-Barriga* 11978 (US), *Jucep-czuk* 5347 (US); Salto de Tequendama, *Cuatrecasas* 98 (Ch, US), *Killip* 34001 (NY, US), *Bro. Ariste-Joseph* A113 (GH, US), *Bros. Apollinaire & Arthur* 80 (US), *Schiefer* 491 (GH); Puente de Seviz, eastern slope, Cordillera Oriental, *Cuatrecasas* 7933 (Ch, US); "Gachetá," *Haught* 5853 (US), 5886 (US).

This slender tree has conspicuously hirsute branches, oblong, obtuse, and mucronate leaves, and the bracts of the racemes are large (to 6.2 mm. long), hood-shaped, and densely pubescent beneath.

31. *Monnina smithii* Chodat in Bull. Soc. Bot. Genève II. 25: 216. 1934.

Frutescent, 1–1.8 m. high, branched, the branches 1.5–5 mm. in diameter, finely canescent-pubescent, becoming more or less glabres-

cent, striate: leaves lanceolate, herbaceous, 35–170 mm. long, 8–47 mm. wide, conspicuously acuminate, slightly pubescent above, becoming glabrescent, finely canescent-pubescent beneath, entire, attenuate at base, the costa prominulous beneath, with 8 or 9 pairs of lateral veins; petioles 1.5–8 mm. long, concave above, convex beneath, slightly winged, canescent-pubescent; racemes elongate, acuminate, 8–10 mm. wide, simple, terminal, pedunculate (peduncle 6–35 mm. long), the axis 2–23 cm. long, canescent-pubescent, striate, bracteate, the bracts linear, acuminate, 7–14 mm. long, 1.6–2 mm. wide, deciduous, ciliate, 1-nerved, slightly puberulent beneath; flowers 4.6–5 mm. long, the pedicels 1.2–2 mm. long, finely puberulent; outer sepals free, triangular, acute, ciliate, glabrous beneath, the two lower ones 2–3.8 mm. long, 1.8–2.5 mm. wide, usually 3-nerved, rarely 5-nerved, the upper sepal 2.2–4 mm. long, 1.8–2.8 mm. wide, usually 5-nerved, sometimes 7-

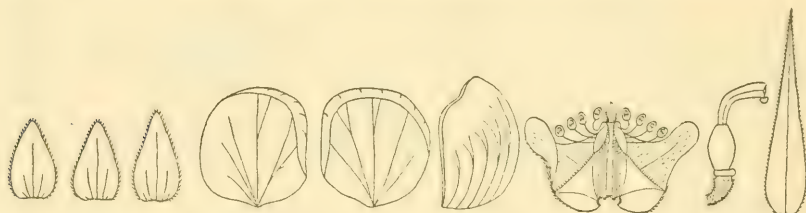


FIG. 31.—*Monnina smithii*: Left to right, lower sepals, upper sepal, wings (inner), keel, upper petals and stamens, gynaecium, all  $\times 3$ ; bract,  $\times 2$ .

nerved; wings deep blue, 4–5 mm. long, 3.5–5.2 mm. wide, obovate, obtuse at base, 3-nerved, glabrous, eciliate; keel 4.8–6 mm. long, 2.8–3.2 mm. wide, orbicular, plicate, glabrous within, obtuse at base, 3-nerved, 3-lobed, the middle lobe inconspicuous, obtuse-subemarginate; upper petals short, spatulate, pubescent; stamens 8, the filaments 3–3.5 mm. long, almost entirely united, the free part 0.5–1 mm. long, glabrous; ovary ovoid, 1.8–2 mm. long, 1.2–1.4 mm. wide, glabrous; style 2.2–2.4 mm. long, geniculate above base, glabrous, more or less cylindrical; stigma with 2 lobes, the lower one acute, the upper 1-tubercled, the tubercle papillose; drupe ellipsoid, 5.5–9 mm. long, 3.8–5.5 mm. wide, glabrous, reticulate.

DISTRIBUTION: In the Andes of northern Colombia, between 1,400 and 2,500 meters altitude.

NORTE DE SANTANDER: Vicinity of Toledo, Killip & Smith 20081 (GH, NY, US); between El Amparo and La Mesa, valley of Río Margua, region of Sarare, Cuatrecasas 12868 (Ch, US); Ventanas, valley of Río Chitagá, region of Sarare, Cuatrecasas 12354 (Ch, US); between Ventanas and Bata, valley of Río Chitagá, region of Sarare, Cuatrecasas, Schultes, & E. Smith 12372a (US).

SANTANDER: Between Piedecuesta and Las Vegas, *Killip & Smith* 15568 (type US 1351426, isotypes GH, NY), 15533 (US).

COLOMBIA?: Without locality, *Moritz* s. n. (US).

The present species is a relative of *M. angustata* Tr. & Pl., from which it differs in its finely pubescent branches, its racemes with longer axes (to 23 cm. long) and with lax elongate bracts (to 14 mm. long), its obtuse outer sepals, and its keel being glabrous within. It also shows a relationship to *M. mollis* Pl. & Lind., differing in its lanceolate and acuminate leaves, its longer and slightly winged petioles, and the linear bracts of its racemes.

32. *Monnina angustata* Tr. & Pl. in Ann. Sci. Nat. IV. 17: 140. 1862.

Frutescent, branched, the branches 2–5 mm. in diameter, conspicuously hirsute, becoming glabrescent, striate; leaves lanceolate, 30–110 mm. long, 10–25 mm. wide, usually acuminate, rarely acute, finely pubescent above, becoming glabrescent, more or less hirsute beneath,

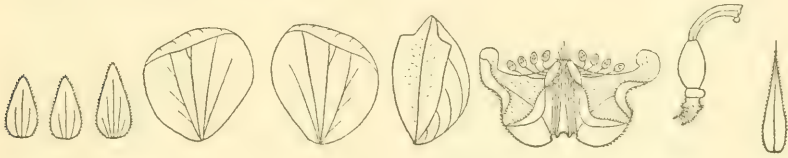


FIG. 32.—*Monnina angustata*: Left to right, lower sepals, upper sepal, wings (inner), keel, upper petals and stamens, gynaecium, bract. All  $\times 3$ .

the hairs more numerous at the nerves, entire, attenuate at base, the costa prominulous beneath, with 7 or 8 pairs of lateral veins; petioles 2–5 mm. long, concave above, convex beneath, hirsute; racemes elongate, acuminate, 7–9 mm. wide, simple, terminal or axillary, pedunculate (peduncle 9–29 mm. long), the axis 2.2–11.5 cm. long, hirsute, striate, bracteate, the bracts linear, acuminate, 3–5 mm. long, 1–1.2 mm. wide, deciduous, ciliate, 1-nerved, finely puberulent beneath; flowers 3.8–5 mm. long, the pedicels 0.6–2 mm. long, finely pubescent, curved; outer sepals free, triangular, acute, ciliate, finely pubescent beneath, the two lower ones 2–2.8 mm. long, 1–1.8 mm. wide, 3-nerved, sometimes 1- or 2-nerved, the upper sepal 2.4–3.2 mm. long, 1.4–2 mm. wide, usually 5-nerved, rarely 3-nerved; wings blue, 3.8–5.5 mm. long, 3–5 mm. wide, obovate, obtuse at base, 3-nerved, glabrous, eciliate, sometimes ciliate at base; keel 4–5.2 mm. long, 2.4–3.4 mm. wide, orbicular, plicate, pubescent within, obtuse at base, 3-nerved, inconspicuously 3-lobed, the middle lobe obtuse-submarginate; upper petals elongate-spatulate, pubescent; stamens 8, the filaments 2.8–3.2 mm. long, almost entirely united, the free part 0.4–1 mm. long, glabrous;

ovary ovoid, 1.2–2 mm. long, 0.8–1.2 mm. wide, glabrous; style 2.2–2.5 mm. long, geniculate above base, glabrous, thicker toward apex; stigma with 2 lobes, the lower one acute, the upper 1-tubercled, the tubercle papillose; drupe ellipsoid, 4.2–6.2 mm. long, 2–3.4 mm. wide, glabrous, reticulate.

DISTRIBUTION: Central to southwestern Colombia, between 1,800 and 3,500 meters altitude.

NORTE DE SANTANDER: Western side of Culagá Valley, north of Toledo, *Killip & Smith* 20283 (GH, NY, US).

BOYACÁ: Sierra del Cocuy, Cordillera Oriental, *Cuatrecasas* 1657 (Ch, US).

TOLIMA: Between Buenavista and Azufra, Old Quindio Trail, Cordillera Central, *Killip & Hazen* 9578 (GH, NY, US).

ANTIOQUIA: San Pedro, *Bro. Tomás* 114 (US); Cerro de La Vieja, *Bro. Daniel* 1698 (US); Santa Elena, *Archer* 1177 (US); Las Minitas, south of Caldas, Cauca Valley, *Pennell* 10956 (GH, US); Río Negro, *Triana* s. n. (fragments and photographs of type, Ch, US).

CALDAS: San Clemente, Cordillera Occidental, *Pennell* 10664 (NY, US).

EL VALLE: Valley of Bugalagrande, between Las Azules and Las Violetas, western slope, Cordillera Central, *Cuatrecasas* 20783 (Ch); Los Farallones, between Alto del Buey and Quebrada de los Ramos, *Cuatrecasas* 18024 (Ch).

CAUCA: Mount El Trueno, Cordillera Occidental, *Pennell* 7537 (GH, NY, US); "Los Volcancitos," *Linden* 1104 (fragments of authentic material US); central Andes of Popayán, *Lehmann* 6664 (Ch); Alto del Duende, western slope, Cordillera Central, *Cuatrecasas* 18838 (Ch); "Calaguala," Coconuco, Cordillera Central, *Pennell* 7144 (GH, US); Popayán, *Lehmann* 4747 (Ch, GH, US); Río Paez Valley, Tierra Adentro, *Pittier* 1225 (US); Río Vinagre, Puracé, *Dryander* 1841 (US).

From *M. mollis* Pl. & Lind., apparently its closest ally, *M. angustata* differs in its narrowly lanceolate and acuminate leaves, its racemes with linear and extrorsely slightly pubescent bracts, its acute-triangular outer sepals, etc.

#### INDEX TO NUMBERED SPECIMENS

The following list includes the numbered specimens studied.

<p>ANDRÉ, E. F.</p> <p>558. <i>andrea</i></p> <p>APOLLINAIRE-MARIE, BROTHER</p> <p>268. <i>speciosa</i></p> <p>523. <i>subscandens</i></p> <p>APOLLINAIRE-MARIE, BROTHER, and ARTHUR, BROTHER</p> <p>5. <i>aestuans</i></p> <p>22. <i>rupestris</i></p> <p>80. <i>mollis</i></p>	<p>ARAQUE-M., J., and BARKLEY, F. A.</p> <p>19An054. <i>phytolaccaefolia</i></p> <p>19Cho12. <i>phytolaccaefolia</i></p> <p>ARCHER, W. A.</p> <p>79. <i>phytolaccaefolia</i></p> <p>469. <i>solandraefolia</i></p> <p>1253. <i>speciosa</i></p> <p>ARCHER, W. A., and LÓPEZ, A.</p> <p>402. <i>phytolaccaefolia</i></p>
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## ARISTE-JOSEPH, BROTHER

- A79. rupestris  
A103. salicifolia  
A113. mollis  
A238. salicifolia

## BALLS, E. K.

5707. salicifolia

BARKLEY, F. A., GARCÍA-BARRIGA, H.,  
and VANEGAS, R.

- 17C740. aestuans

## BEQUAERT, J.

2. salicifolia

## BLACK, G.

- 46-663. aestuans

## CARRIKER, M. A.

29. aestuans

## CORREA, J.

28. phytolaccaefolia

## CUATRECASAS, J.

65. rupestris  
98. mollis  
106. aestuans  
268. aestuans  
328. aestuans  
1657. angustata  
5050. aestuans  
5166. salicifolia  
5759. pilosa  
7933. mollis  
8249. phytolaccaefolia  
8411. rupestris  
8584. subspiciosa  
8593. colombiana  
9236. arborescens  
9559. salicifolia  
9577. phytolaccaefolia  
9655. salicifolia  
10335. phytolaccaefolia  
10379. salicifolia  
11526. rupestris  
11680. subspiciosa  
11694. obtusifolia  
11752. revoluta  
11948. arborescens

12354. smithii  
12839. schultesii  
12868. smithii  
13822. phytolaccaefolia  
14558. salicifolia  
14576. revoluta  
14683. arborescens  
14802. erecta  
14805. arborescens  
15373. phytolaccaefolia  
17862. involuta  
18024. angustata  
18137. phytolaccaefolia  
18221. pilosa  
18529. phytolaccaefolia  
18836. angustata  
18844. obtusifolia  
18907. arborescens  
18994. revoluta  
19047. andreana  
19213. arborescens  
20061. salicifolia  
20783. angustata  
20839. obtusifolia  
20887. chodatiana  
20890. obtusifolia  
20920. chodatiana  
21589. subspiciosa  
21616. subscandens  
21671. arborescens  
21695. arborescens  
21973. subscandens  
22316. subscandens  
22421. cuatrecasarii  
22553. pilosa  
22849. phytolaccaefolia  
23169. revoluta  
23249. revoluta  
23267. salicifolia  
23380. phytolaccaefolia  
23518. subscandens  
23657. subspiciosa  
23730. chlamydantha  
23751. pilosa  
23907. subscandens

CUATRECASAS, J., SCHULTES, R. E.,  
and SMITH, E.

12175. mollis  
12330. mollis

12372. schultesii  
 12372a. smithii  
 12503. solandraefolia  
 12649. salicifolia  
 12799. arborescens

DANIEL, BROTHER

421. pilosa  
 1363. salicifolia  
 1691. solandraefolia  
 1698. angustata  
 1714. pilosa  
 1783. solandraefolia  
 2252. solandraefolia  
 2762. speciosa  
 3987. phytolaccaefolia

DANIEL, BROTHER, and TOMÁS,  
 BROTHER

1569. solandraefolia  
 3499. salicifolia

DAWE, M. T.

204. aestuans  
 832. phytolaccaefolia

DRYANDER, E.

351. subspeciosa  
 1058. salicifolia  
 1841. angustata  
 1977. phytolaccaefolia  
 2053. pilosa  
 2143. subspeciosa

DUGAND, A.

3565. rupestris

DUGAND, A., and JARAMILLO, R.

2944. phytolaccaefolia  
 2996. subscandens  
 3033. pilosa  
 3827. phytolaccaefolia

DUQUE-JARAMILLO, J. M.

1604. pilosa  
 1726. subspeciosa

ESPINA, R., and GIACOMETTO, J.

A156. phytolaccaefolia

FRANCO, A., and BARKLEY, F. A.

18A187. solandraefolia

GARCÍA-BARRIGA, H.

4628. pilosa  
 7674. phytolaccaefolia  
 7852. arborescens  
 10951. phytolaccaefolia  
 11584. phytolaccaefolia  
 11640. salicifolia  
 11978. mollis  
 12015. phytolaccaefolia  
 12234. phytolaccaefolia  
 12325. phytolaccaefolia  
 12402. phytolaccaefolia  
 12619. phytolaccaefolia  
 12644. aestuans  
 13354. salicifolia

GARCÍA-BARRIGA, H., and HAWKES,  
 J. G.

12886. rupestris  
 13063. obtusifolia  
 13074. obtusifolia  
 13085. arborescens

GARCÍA-BARRIGA, H., HAWKES,  
 J. G., and VILLARREAL, M.

13056. obtusifolia

GRANT, V.

7377. salicifolia

GUTIÉRREZ, G., and DELISLE, A. L.

263. speciosa

HAUGHT, O. L.

2151. phytolaccaefolia  
 4492. mollis  
 4520. mollis  
 5045. salicifolia  
 5046. salicifolia  
 5091. obtusifolia  
 5091a. obtusifolia  
 5176. arborescens  
 5279. phytolaccaefolia  
 5297. phytolaccaefolia  
 5313. phytolaccaefolia  
 5613. aestuans



5623. *aestuans*  
 5697. *aestuans*  
 5698. *salicifolia*  
 5813. *salicifolia*  
 5853. *mollis*  
 5886. *mollis*  
 6022. *rupestris*  
 6073. *latifolia*  
 6168. *salicifolia*  
 6175. *aestuans*  
 6221. *subscandens*

## HERBARIO NACIONAL COLOMBIANO

86. *salicifolia*  
 478. *salicifolia*

## HODGE, W. H.

6478. *revoluta*  
 6610. *salicifolia*

## HOLTON, I.

23. *rupestris*  
 829. *revoluta*  
 830. *salicifolia*

## JAMESON, W.

443. *pilosa*  
 473. *rupestris*

## JUZEPCZUK, S.

5040. *salicifolia*  
 5347. *mollis*  
 6616. *rupestris*

## KILLIP, E. P.

6868. *pilosa*  
 7794. *glaberrima*  
 7923. *glaberrima*  
 7964. *rupestris*  
 34001. *mollis*  
 34197. *aestuans*  
 34223. *salicifolia*

KILLIP, E. P., CUATRECASAS, J., and  
DRYANDER, E.

39208. *phytolaccaefolia*

## KILLIP, E. P., and HAZEN, T. E.

9116. *bracteata*  
 9578. *angustata*

11008. *phytolaccaefolia*  
 11156. *glaberrima*

## KILLIP, E. P., and SMITH, A. C.

15077. *phytolaccaefolia*  
 15515. *phytolaccaefolia*  
 15533. *smithii*  
 15568. *smithii*  
 15575. *mollis*  
 15862. *phytolaccaefolia*  
 15863. *glaberrima*  
 16449. *phytolaccaefolia*  
 16625. *mollis*  
 16796. *phytolaccaefolia*  
 17008. *mollis*  
 17420. *salicifolia*  
 17890. *mollis*  
 17927. *salicifolia*  
 18137. *salicifolia*  
 18156. *salicifolia*  
 18381. *elongata*  
 18746. *salicifolia*  
 19043. *phytolaccaefolia*  
 19080. *salicifolia*  
 19396. *phytolaccaefolia*  
 19476. *salicifolia*  
 19570. *aestuans*  
 19800. *mollis*  
 19924. *phytolaccaefolia*  
 20029. *bracteata*  
 20048. *mollis*  
 20081. *smithii*  
 20283. *angustata*  
 20555. *mollis*  
 20779. *phytolaccaefolia*

## KILLIP, E. P., and VARELA, G.

34642. *aestuans*

## LANGLASSÉ, E.

31. *phytolaccaefolia*

## LAWRANCE, A. E.

16. *phytolaccaefolia*

## LEHMANN, F. C.

353. *pilosa*  
 360. *phytolaccaefolia*  
 361. *phytolaccaefolia*  
 1051. *arborescens*

1083. pilosa  
2129. andreana  
4747. angustata  
5524. pilosa  
6664. angustata

LINDEN, J.

375. elongata  
742. solandraefolia  
781. salicifolia  
955. revoluta  
1104. angustata

METCALF, R. D., and CUATRECASAS, J.

30116. solandraefolia

MEXIA, Y.

7578. arborescens  
7578a. speciosa

PENNELL, F. W.

1736. phytolaccaefolia  
1940. rupestris  
3083. revoluta  
3288. phytolaccaefolia  
4298. oblanceolata  
4311. aestuans  
4387. oblanceolata  
4439. phytolaccaefolia  
5171. phytolaccaefolia  
5724. glaberrima  
7031. obtusifolia  
7045. revoluta  
7144. angustata  
7470. arborescens  
7537. angustata  
8906. pilosa  
8917. bracteata  
9382. bracteata  
9395. subscandens  
10247. pennellii  
10301. pilosa  
10303. phytolaccaefolia  
10335. subscandens  
10386. bracteata  
10500. bracteata  
10663. pilosa  
10664. angustata  
10922. phytolaccaefolia  
10956. angustata

PENNELL, F. W., and HAZEN, T. E.

9986. revoluta  
10113. pilosa  
10156. parviflora

PENNELL, F. W., and KILLIP, E. P.

5888. subspeciosa  
6418. pilosa  
6465. salicifolia  
6598. arborescens  
7261. phytolaccaefolia  
7269. pilosa  
7390. arborescens  
8020. pilosa

PENNELL, F. W., KILLIP, E. P., and  
HAZEN, T. E.

8595. phytolaccaefolia  
8723. pilosa  
8740. phytolaccaefolia  
8741. phytolaccaefolia

PÉREZ-ARBELÁEZ, E.

2303. rupestris

PÉREZ-ARBELÁEZ, E., and  
CUATRECASAS, J.

5915A. arborescens  
6167. pilosa  
8380. pilosa

PITTIER, H.

728. glaberrima  
903. phytolaccaefolia  
1225. angustata  
1405. obtusifolia  
1477. subscandens

POPENOE, W.

1141. rupestris

RIVERA, F., FRANCO, B., and  
BARKLEY, F. A.

18A048. salicifolia

RODRIGUEZ, S.

5. phytolaccaefolia  
29. aestuans

RUSBY, H. H., and PENNELL, F. W.

663. *speciosa*  
 746. *rupestris*  
 876. *subspeciosa*  
 1290. *aestuans*

SCHIEFER, H.

491. *mollis*  
 532. *salicifolia*

SCHLIM, L.

345. *aestuans*  
 674. *elongata*  
 819. *mollis*  
 1137. *elongata*

SCHULTES, R. E.

7023. *phytolaccaefolia*  
 7119. *salicifolia*  
 7240. *aestuans*

SCHULTES, R. E., and VILLARREAL, M.

5215. *rupestris*  
 7429. *obtusifolia*  
 7467. *obtusifolia*  
 7517. *arborescens*  
 7569. *rupestris*  
 7671. *pilosa*  
 7728. *rupestris*  
 7833q. *salicifolia*  
 7870. *obtusifolia*  
 8009. *arborescens*

SCHULTZE, A.

5. *rupestris*

SEIFRIZ, W.

83. *santamartensis*

SMITH, H. H.

1480. *santamartensis*  
 1557. *santamartensis*

SNEIDERN, K. VON

1815. *revoluta*  
 5540. *phytolaccaefolia*  
 5602. *phytolaccaefolia*

TOMÁS, BROTHER

114. *angustata*

TORO, R. A.

88. *phytolaccaefolia*  
 1040. *pilosa*  
 1046. *pilosa*  
 1244. *pilosa*  
 1262. *speciosa*  
 1365. *pilosa*

TRIANA, J. J.

298. *pilosa*  
 414. *salicifolia*  
 415. *salicifolia*

YEPES, S.

133. *phytolaccaefolia*













SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 121, NUMBER 4

STRUCTURE AND FUNCTION OF THE  
GENITALIA IN SOME AMERICAN  
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ROBERT L. GERING

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North Newton, Kans.



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CITY OF WASHINGTON  
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BALTIMORE, MD., U. S. A.

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# STRUCTURE AND FUNCTION OF THE GENITALIA IN SOME AMERICAN AGELENID SPIDERS

By ROBERT L. GERING

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## INTRODUCTION

References to the sexual biology of spiders are numerous in the literature. This is not surprising in view of the unique morphological modifications of the genitalia of these animals. There is virtually no information, however, pertaining to one of the most fundamental phases of the sexual biology of spiders, viz, the actual mechanics of copulation. This paper deals with the problem of copulatory mechanics and its implications.

The following objectives were formulated for this investigation:

1. To determine the structure and function of each part of both the male and female genitalia; particularly of those structures directly involved in copulation.
2. To study in detail the process of copulation with correlations to mechanical structures.
3. To determine, if possible, the correlations between structural mechanics and certain patterns of copulatory behavior.
4. To determine, if possible, the validity of the lock-and-key concept in a representative group of agelenid spiders found in North America.
5. To investigate the mechanical feasibility of copulation between representatives of closely related species of agelenids.

The work herein considered was confined primarily to the agelenid genus *Agelenopsis* Giebel, 1869. Spiders of additional genera in the Agelenidae and other families of Entelegynae were used to a limited extent for determining whether certain features exist exclusively in this genus.

The males of several unrelated groups of animals display the curious condition in which ambulatory or tactile appendages, widely separated from the genital aperture, are modified for the purpose of transferring sperms to the female. Similar modified appendages are to be found in representatives of the common squid (*Loligo*, Mollusca),

of the insect order Odonata, and of the arachnid orders Ricinulida, Araneida, and probably the Solpugida. The decapod Crustacea, the Chelonethida, and some of the Acarina also utilize a method of sperm transference somewhat analogous to that of the spiders but are excluded here because they apparently lack the modified appendages for effecting this transfer.

The evolutionary factors involved in the origin of this separation of the sperm-transferring structures from the immediate vicinity of the genital apertures of the males, and the phylogenetic significance of this separation are still unknown. Several facts become evident when reviewing the groups in which this morphological phenomenon is manifest. Geologically speaking, all these animals originated in the Paleozoic. The cephalopods are known at least from early Silurian. The Araneida have been traced back to the Devonian, the Ricinulida and the Solpugida to the early Carboniferous, and the Odonata to the early Permian. A study of fossils of the aforementioned arachnids shows that all three orders were already well established and discrete at the time of the earliest known specimens of each. Furthermore, it is evident that this separation of the sperm-transferring organs from the primary genitalic structures is no recent caprice of nature. Fossil evidence indicates that this separation was completed in the spiders long before the Permian. Petrunkevitch (1925, p. 559) stated that "the study of coenozoic spiders, the tertiary spiders of North America and especially the amber species of the Baltic, has revealed the presence of external reproductive organs of as great complexity as in recent forms." The fact that this genitalic separation appears in only certain groups of animals while not appearing in closely related forms indicates that this phenomenon arose independently in each of the groups considered.

Behavior patterns play a paramount role in the life of spiders. As one of the objectives of this paper is an evaluation of certain behaviors, it is desirable to review this subject briefly. A reflex is a motor response to stimulation (Wigglesworth, 1947, p. 99). Such reflexes typically serve some useful function under normal conditions (Wigglesworth, *op. cit.*, p. 100). Responses which orient the animal relative to the source of stimulation are referred to as topotaxes. A specific topotaxis which "implies that the muscular tone on the two sides of the body is proportional to the intensity of stimulus received in bilaterally symmetrical sense organs" (Wigglesworth, *op. cit.*, p. 162) is called a tropotaxis. The animal thus turns toward the side which is most strongly stimulated until the sense organs are equally stimulated, thereby orienting itself relative to the source of stimulation.



One of the functions of the sense organs of insects is to increase the nerve tone of the central nervous system. This results in a responsive state during which reflexes may occur in a definite sequence. It appears that each reflex is instrumental in initiating a subsequent reflex. This self-perpetuating sequence constitutes a chain reflex (Wigglesworth, *op. cit.*, p. 101). Probably most of the activities of spiders similarly result from such chain reflexes. The behavior patterns herein considered are interpreted on this basis. The writings of Hanstroem (1941), Wigglesworth (1947), Scheer (1948), and Prosser (1950) indicate that the fundamental physiology of the nervous system appears to be essentially the same, qualitatively, throughout at least most of the Animal Kingdom. Hence it is necessary, in animals, to interpret and evaluate qualitatively the effect of sensory stimulation. Such evaluations must be interpreted in terms of the responses evolving from such stimulation. That the male becomes aware of the female indicates that the presence of the female impinges upon the nervous system of the male, and that he then responds in a characteristic manner.

The inability of animals to mate because of the physical incompatibility of their genital structures is called mechanical isolation. Dufour formulated the lock-and-key concept as a result of his study of the close correlations existing between the morphological configurations of the male and female genitalia of insects. This concept advanced the idea that the configuration of the female genitalia was such as to preclude the possibility of introducing any intromittent organ except that of a male belonging to the same species as the female. Araneologists had long been aware of the elaborate development of the male intromittent organs, and the complex configuration of the female copulatory structures. The lock-and-key concept was readily accepted by many araneologists. Other araneologists endorsed the concept in essence, if not in fact.

Subsequently, however, the lock-and-key concept was challenged and attacked repeatedly. Berland (1932) suggested that the isolating factor in the spiders is physiological rather than mechanical. Petrunkevitch (1942, p. 177) and Kaston (1948, p. 16) concurred with Berland on this point. Gertsch (1949, p. 98) pointed out that while interspecific copulation was precluded by "fundamental instinctive patterns probably based on chemical stimuli, it must be admitted that in spiders the differences between the genitalia of allied groups are usually sufficiently great to make pairing impossible—in effect a 'lock and key' presenting an impassable barrier to all but the most closely related species." Few, if any, araneologists still hold that morpho-

logical incompatibility of the genitalia constitutes the sole factor precluding mating between spiders of different species.

The term "intraspecific copulation" is used hereafter in reference to matings involving two spiders belonging to the same species. The somewhat ambiguous term "interspecific copulation" is used as a matter of convenience, to indicate matings involving two spiders belonging to two morphologically distinct groups of animals that are generally accepted as being distinct species.

### ACKNOWLEDGMENTS

Correspondence and personal interviews with Dr. W. J. Gertsch contributed materially to this investigation from its inception to the reading of the final manuscript. Dr. R. V. Chamberlin generously placed all material in the Institute of Arachnology (University of Utah) as well as his personal library at my disposal. Dr. Chamberlin was a challenging teacher and an inspiring friend throughout the entire study. I owe a special debt of gratitude to my wife for her active assistance in all phases of this study. To these people and the many others who contributed directly and indirectly to my work, I acknowledge my indebtedness and proffer my thanks.

### REVIEW OF LITERATURE

The literature pertaining to the sexual biology of spiders, and its ramifications, is voluminous. Specific literature relevant to each phase of this study is reviewed in the text.

Blackwall (1843) was one of the first to write specifically of the palpi of spiders. Later (1844, 1873) he wrote of both the structure and the function of these appendages. Westring (1861), Menge (1866), Emerton (1875, 1878, 1889), Bertkau (1875, 1876, 1878, 1884), and van Hasselt (1876, 1877, 1886, 1888, 1889) wrote extensively on this subject. In 1882, Karpinski reported on the structure of the copulatory apparatus of both male and female spiders, including the mechanics of copulation. His work was limited to specimens of *Dictyna benigna* Walckenaer. Wagner (1886) considered both the morphological features and the development of the copulatory organs of spiders, and later (1887) strongly advocated the use of the palpi as systematic criteria. Chamberlin (1904, 1908) pointed out the significance of employing the female genitalia as well as the male palpus as taxonomic criteria. Comstock (1910) brought all this information together, added the results of his own studies, and produced a com-

prehensive treatise on the palpi of male spiders which is still the basic reference on this subject.

Subsequent work was done on the structural and functional aspects of the palpus by Szombathy (1913, 1915), Gerhardt (1921a, 1921b), Gassman (1925), and Harm (1931, 1934). Osterloh's work (1922) included an analysis of the mechanics of copulation as well as a study of the morphology of the copulatory structures. He worked with specimens of *Linyphia triangularis* Clerck, *Lycosa amentata* Clerck, *Agelena similis* Keyserling, and *Meta segmentata* Clerck. Petrunkevitch (1925) pioneered the detailed study of the copulatory apparatus of agelenid spiders in America. Working specifically with *Agelenopsis naevia* (Walckenaer) and *Agelena labyrinthica* Walckenaer, he considered both male and female structures. Seyler (1941) extended Petrunkevitch's work by studying the copulatory structures, particularly those of the female, in three additional species of agelenopsids. Homann's work (1935) with hydraulic inflation of the palpus marked a major technical advance in the comprehension of the mechanism of palpal activation and thus of copulation. Blauvelt (1936) made a critical comparative study of the copulatory structures of spiders belonging to *Linyphia* and other related genera. She based her revision of these genera on this study. The revision of the genus *Cicurina* by Chamberlin and Ivie (1940) similarly was based, to a large extent, on a detailed comparative study of the genital structures. Gertsch (1949) added important information pertaining to the structure and, particularly, to the function of the palpus during copulation.

Literature pertaining specifically to the female copulatory structures is much more limited. No general study, comparable to that of the male palpi by Comstock, is known for the female structures. Van Hasselt (1892a, 1892b) studied the epigyna of female spiders in considerable detail. The work of Jaervi (1905, 1908, 1912, 1914) on the "Vaginalorgane" of the lycosids and sparassids was outstanding. Engelhardt's (1910) study involved eight families of spiders. The only agelenid included was *Agelena labyrinthica*. The investigations of Chamberlin and Ivie (1940), Blauvelt (1936), Petrunkevitch (1925), and Osterloh (1922) upon the epigyna have already been mentioned. In 1938, Kolosvary presented the first extensive study of variation found in the epigyna of females (*Argyope lobata* Pallas). Further studies of this nature are essential for a better understanding of female structures.

The study of courtship and mating has been popular with araneologists. Menge reported on the courtship of *A. labyrinthica* as early as 1843, but the first detailed studies of courtship and mating were made

by Peckham and Peckham (1889, 1890). Their classical work with the Salticidae (formerly known as Attidae) continues to exert considerable influence on investigations of all phases of sexual biology. Montgomery reported on the mating habits of spiders (1903) and upon the secondary sexual characteristics (1910).

Outstanding work has been done on the sexual biology of spiders since 1910. In Germany, Gerhardt limited himself primarily to this field of investigation, and published numerous papers (1911-1938) pertaining to various phases of sexual biology. In England, Bristowe (1926, 1929, 1930) made many contributions to this subject, as did Locket (1923, 1926, 1927). In 1926 Bristowe and Locket considered the courtship of British Lycosidae. In France, Bonnet (1924, 1929, 1930a, 1930b, 1932, 1933a, 1933b, 1935, 1937, 1938) wrote extensively on all phases of sexual biology. In the United States, Kaston (1936) greatly extended courtship and copulation records during his study of the senses involved in courtship. Kaston (1948, pp. 31-34) included a concise summary of sexual biology in his "Spiders of Connecticut." Gertsch (1941) gave an excellent description of copulation in his revision of the Misumeninae. Gertsch (1949) and Savory (1928) devoted several sections in their books to this subject. Crane (1948-1950) added materially to our understanding of display in the courtship of the Salticidae.

Gerhardt's technical section on the sexual biology of spiders in Araneae (Gerhardt and Kaestner, 1937-1938, pp. 530-560) probably is the most comprehensive treatment available on this subject. With the active cooperation of many of his colleagues, Gerhardt integrated and systematized the preponderance of relevant information from the widely scattered literature.

A number of papers pertaining to the systematics of the Agelenidae were used extensively during this investigation. These included the series of generic revisions by Chamberlin and Ivie (1932, 1933, 1937, 1940, 1941, 1942), the papers of Exline (1935, 1936, 1938), and the generic reviews of Muma (1946, 1947).

One additional paper warrants special mention. Ellis (1944) established the fact that haemolymphatic pressure is a major factor in the extension of the legs. This mechanism appears to be equally functional in the male pedipalpus.

## MATERIALS AND METHODS

While spiders of the genus *Agelenopsis* were used almost exclusively for the detailed portion of this study, the genital structures of

representatives of the following agelenid genera were also cleared and examined during the investigation: *Agelena*, *Blabomma*, *Calilena*, *Calymnaria*, *Chorizomma*, *Cicurina*, *Coelotes* (Old World genus), *Coras*, *Cryphocca*, *Cybaeina* (males only), *Cybaeota*, *Cybaeus*, *Hololena*, *Novalena*, *Ritalena* (males unknown), *Rualena*, *Tegenaria*, and *Wadotes*. As only type specimens of the following genera were available, the copulatory structures were studied without subjecting them to KOH treatment: *Chorizommoides* (males unknown), *Cybaeosyga*, *Ethobuella*, *Melpomene*, and *Tortolena*. The copulation of representatives of *Chiracanthium inclusum* Hentz (Clubionidae) and of *Misumenacalycina* (Linnaeus) (Thomisidae) was subjected to detailed scrutiny both in the field and in the laboratory.

A total of 618 living specimens of *Agelenopsis aperta* (Gertsch), *A. oklahoma* (Gertsch), and *A. pennsylvanica* (C. Koch) were collected in Kansas and Utah for this investigation. Representatives of 13 additional species were used for detailed studies in vitro: *A. actuosa* (Gertsch and Ivie), *A. aleenae* Chamberlin and Ivie, *A. aperta guttata* Chamberlin and Ivie, *A. emertoni* (Chamberlin and Ivie), *A. kastoni* Chamberlin and Ivie, *A. longistylus* (Banks), *A. naevia* (Walckenaer), *A. oregonensis* Chamberlin and Ivie, *A. potteri* (Blackwall), *A. spatula* Chamberlin and Ivie, *A. utahana* (Chamberlin and Ivie), *A. texana* (Gertsch), and *A. barrowsi* (Gertsch). The last two species belong to the subgenus *Barronopsis* Chamberlin and Ivie. It should be noted, however, that the genital bulbs of the barronopsids differ so radically from those of the other agelenopsids that the term agelenopsid is used, in this paper only, in reference to the genus *Agelenopsis* exclusive of the subgenus *Barronopsis*. All known species of *Agelenopsis*, except *A. (Barronopsis) jeffersi* Muma (1945), have been included in this investigation. All specimens used are now at the Institute of Arachnology of the University of Utah.

The living spiders were collected directly into large shell vials. A separate vial was used for each specimen. Each vial was numbered to facilitate recording data pertaining to the specimen contained therein. As spiders are sensitive to low humidity, a few drops of water were added periodically to a thin layer of cotton on the bottom of each vial.

Transparent plastic gelatine molds with lids were used when studying the behavior of the spiders. A white cardboard disk was placed on the bottom of each of these mating cases. The disks not only increased the ease of observation but provided a suitable surface on which the spiders moved naturally and mated readily. Once copula-

tion was initiated, the lid was removed and the spiders were studied in detail with the aid of a wide field binocular microscope. A magnification of 20 diameters was sufficient for most observations.

A wire recorder was used extensively during the studies of copulation. This permitted the recording of detailed, uninterrupted observations over long periods of time. By replaying each recording any necessary number of times, it was possible to obtain a most detailed account of each mating.

The pedipalpi of the male spiders were cleared and the genital bulbs were simultaneously expanded by boiling them in KOH. The pedipalpi were then washed in several changes of water, and transferred to glycerin for preservation and study. The copulatory structures of the females were treated in the same manner.

The mechanics of the palpus were hypothesized on the basis of observations of the palpus during copulation, and with the assistance of scale models. These hypotheses were then checked by a study of the palpus *in vitro*, and finally verified by additional observations of the palpus during copulation.

Hypotheses pertaining to the mechanical functions of the various parts of the genital bulb were further tested by means of artificial inflation of the bulb. This was accomplished by placing the palpus in a concentrated solution of KOH for several minutes, and then transferring it into distilled water. Osmotic pressure inflated the genital bulb. By alternately placing the palpus in distilled water and absolute alcohol the genital bulb was inflated and deflated at will. The mechanical results of this artificial inflation were checked against those of normal inflation. The two were found to agree well.

Little use was made of histological sectioning in this study. Where such sectioning was done, standard histological procedures for sclerotized material were followed.

Most of the figures were made with the aid of a camera lucida. The angles of articulation were measured by means of a grid ocular and a large-scale model of the grid superimposed on a protractor.

## MORPHOLOGY AND FUNCTION OF REPRODUCTIVE ORGANS

Spiders are dioecious. Their gonads, and associated ducts leading to the external surface of the body, are relatively constant in basic organization throughout the order. This paper deals with the specialized copulatory apparatus of both sexes.

## REPRODUCTIVE ORGANS OF THE MALE

The reproductive organs of the male consist of the internal testes and associated ducts, and the external pedipalpi. The pedipalpi are the first pair of leglike appendages of the prosoma (figs. 1, 2).

## TESTES AND ASSOCIATED INTERNAL STRUCTURES

The testes of the spider are paired organs lying in the lower portion of the abdomen (fig. 50). They are elongated, and extend caudally from the epigastric furrow. These organs are simple and tubular. Each testis continues cephalically as a long, coiled vas deferens. These paired, tubular structures open into a common seminal vesicle, which in turn opens to the outside through the seminal aperture on the midline of the cephalic margin of the epigastric furrow.

## PEDIPALPUS

Each pedipalpus consists of a coxa, trochanter, femur, patella, tibia, and tarsus. The segments distal to, and exclusive of, the coxa are referred to collectively as the palpus or palp. Systematists have long utilized the great variety of modifications of the palpi of male spiders in classification.

*Coxa*.—The coxa (*c*) is a large structure located between the chelicerae (*cl*) and the cephalic margin of the sternum (*sm*) (figs. 1, 3). The labrum (*lb*) separates the two coxae. Ventrally each coxa is produced into an endite (*en*), the distal margin of which is inclined sharply toward the chelicerae. In the agelenopsids the ectoventral margin of the endite bears a heavily pigmented carinate ridge (*cr*), and a scopula consisting of setae (not shown in figures). Laterally the coxa articulates with the small trochanter. The articulation of the coxa with the body is largely membranous; while the coxa-trochanteral articulation is entirely membranous.

The function of the coxa is twofold: (1) The endite endows it with a masticatory function; and (2) it serves as the basal segment of the pedipalpus.

*Trochanter*.—The trochanter is a small segment, subrectangular when viewed in profile, articulating with the lateral margin of the coxa (figs. 1, 3, *tr*). Within the agelenopsids, the trochanteral proportions range from 0.67 times as long as broad in *A. longistylus* to 0.91 times as long as broad in *A. oklahoma*, with the typical proportion being 0.82 times as long as broad as found in *A. potteri* and *A. utahana*. There is no marked variation in the trochanteral facies. The

ectodistal margin is somewhat more heavily sclerotized and pigmented than the remainder of the segment. The ventral margin of the distal end is produced into a strong condyle. The trochantero-femoral articulation is dicondylar.

The trochanter is the basal segment of the palpus. Its importance in palpal movement is indicated by the size and number of muscles which insert on it, and the great degree of vertical and horizontal flexibility afforded by the membranous coxal articulation (figs. 9, 10).

*Femur.*—The femur is an elongated, parallel-sided structure (figs. 1, 2, *f*). Femoral proportions range from 4.1 times as long as broad in *A. pennsylvanica* and *A. actuosa* to 5.2 times as long as broad in *A. potteri*. The typical proportion is 4.5 times as long as broad as found in *A. kastoni* and *A. oklahoma*. The femoral facies are relatively constant. The proximal end of the femur is dicondylar.

The femoropatellar articulation is also dicondylar. The upper margins of both femur and patella are strongly sclerotized, and the fact that they impinge upon each other is the limiting factor in maximum extension. Maximum flexure likewise obtains when the sclerotized ventral portions of both segments impinge upon each other (figs. 9, 10).

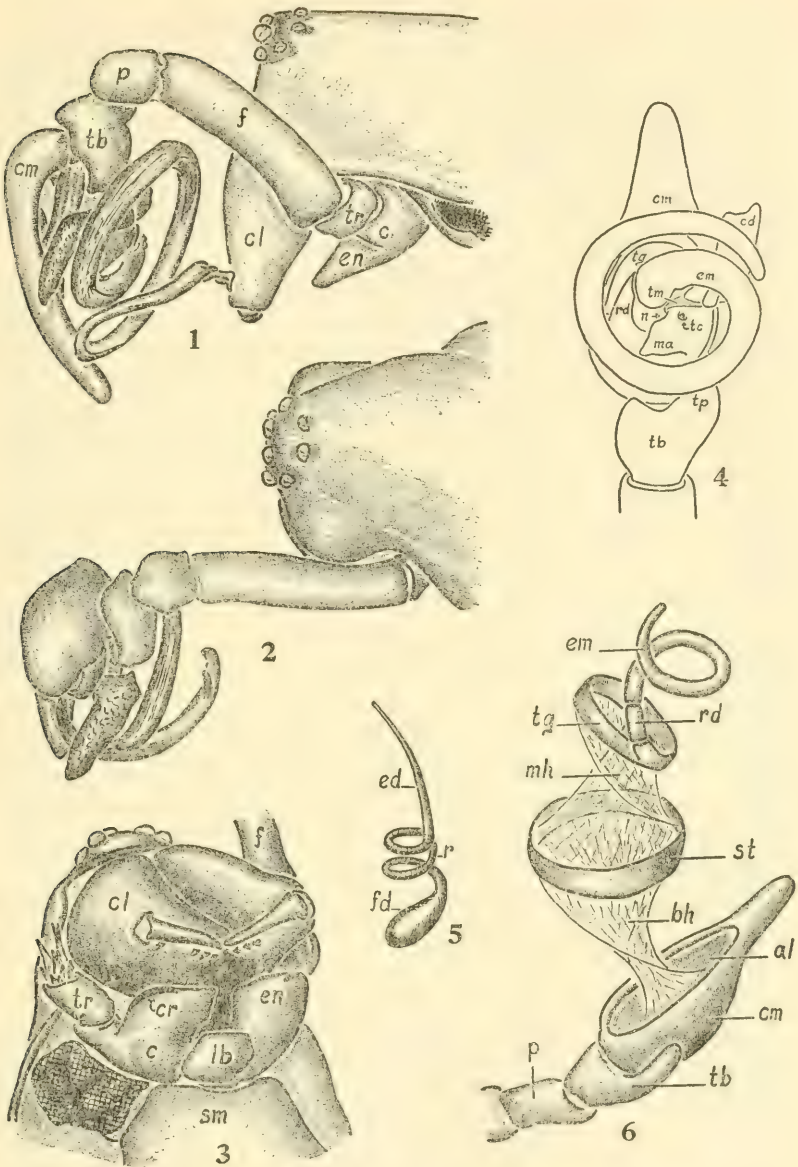
A small chitinous plate is located ventrally in the membrane between the femur and patella. This plate was first described by Gaubert (1892) in the legs of spiders. Ellis (1944) showed that this plate normally lies in a horizontal position. A special muscle, the levator,

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EXPLANATION OF LETTERING ON FIGURES

<i>al</i>	alveolus.	<i>g</i>	guide.
<i>an</i>	anelli.	<i>lb</i>	labrum.
<i>at</i>	atrium.	<i>lp</i>	lunate plate.
<i>bc</i>	bursa copulatrix.	<i>ma</i>	median apophysis.
<i>bd</i>	blind tube of diverticle.	<i>mh</i>	middle haematodocha.
<i>bh</i>	basal haematodocha.	<i>n</i>	notch of median apophysis.
<i>bs</i>	blind tube of spermathecum.	<i>p</i>	patella.
<i>c</i>	coxa.	<i>pm</i>	posterior median sclerite.
<i>cc</i>	coupling cavity.	<i>pt</i>	petiole.
<i>cd</i>	conductor.	<i>r</i>	reservoir.
<i>cl</i>	chelicera.	<i>rd</i>	radix.
<i>cm</i>	cymbium.	<i>sm</i>	sternum.
<i>cr</i>	carinate ridge of chelicera.	<i>sp</i>	spermathecum.
<i>ct</i>	connecting tube.	<i>st</i>	subtegulum.
<i>dv</i>	diverticle.	<i>tb</i>	tibia.
<i>ed</i>	ejaculatory duct.	<i>tc</i>	tubercle.
<i>ef</i>	epigastric furrow.	<i>tg</i>	tegulum.
<i>em</i>	embolus.	<i>tgr</i>	tegular ridge.
<i>en</i>	endite of coxa.	<i>tm</i>	tethering membrane.
<i>f</i>	femur.	<i>tp</i>	tibial process.
<i>fd</i>	fundus.	<i>tr</i>	trochanter.
<i>ft</i>	fertilization tube.	<i>u</i>	uterus.
		<i>v</i>	vagina.





FIGS. 1-6

1, Pedipalpus, left, ectal aspect, *Agelenopsis aperta* (Gertsch). 2, Pedipalpus, left, dorsal aspect, *A. aperta*. 3, Mouth region, subventral aspect, *A. aperta*. 4, Genital bulb, left, unexpanded, frontal aspect, diagrammatic, genus *Agelenopsis*. 5, Receptaculum seminis, diagrammatic. 6, Genital bulb, left, expanded, subpectal aspect, diagrammatic, genus *Agelenopsis*. (For explanation of lettering see p. 10.)

of the chitinous plate (Ellis, op. cit., p. 47) can draw the plate into a vertical position, and thus largely limit the increased haemolymphatic pressure, with its resultant extension, to the femur, trochanter, and coxa of the leg. The writer's observations and dissections indicate that a chitinous plate plays a similar role in the pedipalpi.

Being the longest single segment of the pedipalpus, the femur plays a major role in palpal movements and general orientation of the more distal genital bulb.

*Patella*.—The patella articulates proximally with the femur. It is subtriangular in outline when viewed ectally (figs. 1, 2, 6, *p*). Patellar proportions range from 1.5 times as long as broad in *A. pennsylvanica* to 2.0 times as long as broad in *A. aperta* and *A. kastoni*, with the typical proportion being 1.7 times as long as broad as found in *A. spatula* and *A. longistylus*. The patellar facies are relatively constant in the agelenopsids. Distally there is a small ectal process on the ventral apex of the patella. This is slightly more heavily sclerotized than the remainder of the patella. This process limits patellar-tibial flexure. The patellar-tibial articulation is monocondylar, and thus is not limited to a single plane of movement. This versatility of movement is important to the agelenopsids in the proper orientation of the genital bulb during copulation. Extension of the tibia appears to be limited by the impingement of the sclerotized dorsal portions of the patella and tibia and, more probably, by the extent of elasticity of the ventral intersegmental membrane. The morphological limits of maximum extension and flexure and of lateral articulation are shown in figures 9 and 10. Lateral articulation also appears to be limited by the segments themselves, and by the intersegmental membrane.

The patella is particularly important because of its monocondylar articulations with the tibia, and the lateral tibial movement which is thus permitted.

*Tibia*.—The tibia (*tb*) is roughly subtriangular in shape, with a pronounced ectal tibial process (*tp*) extending distally along the side of the cymbium (figs. 1, 2, 4, 6). Kaston (1948, p. 15) stated that this process was called the "carpoblem" by Hull. The tibial proportions range from 1.3 times as long as broad in *A. aperta* to 1.9 times as long as broad in *A. longistylus*, while the most frequent proportion is 1.5 times as long as broad as found in *A. actinosa*. The variability in the configuration of the tibial process in the agelenopsids is shown in figures 11-13. The tibiotarsal articulation is dicondylar. The ectal condyle, located approximately midway between the tibia proper and the distal end of the tibial process, is weakly developed. The mesal

condyle is actually a condylar area. The limits of articulation are shown in figures 9 and 10. The writer has been unable to demonstrate the existence of a chitinous plate in the palpus comparable to that found by Ellis (1944) between the tibia and the metatarsus in the ambulatory legs of spiders. As will be shown later, however, the mechanical aspects of the genital bulb are such that extension of the distal palpal segments can be achieved without the chitinous plates.

The tibia serves as a base for the cymbium. The tibial process serves to limit the extent of cymbial flexure.

*Tarsus.*—The tarsus of the mature female spider retains the unmodified appearance of the tarsi of the ambulatory legs, even to the point of bearing a small, terminal claw. The tarsus of the mature male, however, is highly specialized into the copulatory organ consisting of (1) the cymbium and (2) the genital bulb.

1. Cymbium. Westring (1861) used the term "lamina" for this structure. Comstock (1910, p. 165), however, adopted Menge's (1866) term "cymbium," because of general usage. The body of the cymbium is oval when viewed from frontal aspect, with a short, heavy, distal extension (figs. 4, 6, 39, *cm*). Cymbial proportions range from 1.9 times as long as deep in *A. utahana* to 3.3 times as long as deep in *A. oklahoma*, with the typical proportion being 2.0 times as long as deep as found in *A. emertoni*, *A. potteri*, and *A. spatula*. The alveolus is the concavity in the frontal portion of the cymbium (figs. 6, 39, *al*). Comstock (op. cit., p. 163) adopted this term from Menge (1866). Usually the genital bulb lies almost wholly within the alveolus.

The ectoproximal margin of the cymbium has a weakly produced depression, which normally is somewhat more heavily pigmented and sclerotized than the surrounding area (figs. 11-12, 39). The tibial process rests in this depression when the palpus is locked.

The cymbium consists of a thin, sclerotized material and is abundantly covered with short and variously developed setae. Some of these setae are distinctly longer than others, and generally are much heavier. This vestiture has been omitted from all drawings to emphasize the morphological configurations.

The cymbium, with its alveolus, appears to serve a dual purpose: (1) It is the foundation for the genital bulb and the bulb's activity during copulation, and (2) it is a protection for the delicate membranes of the unexpanded genital bulb.

2. Genital bulb. The genital bulb includes all portions of the copulatory apparatus of the male arising from within the alveolus of the cymbium (fig. 6). The receptaculum seminis (fig. 5), consisting of

the fundus, reservoir, and the ejaculatory duct, is the only internal structure found in the genital bulb. Comstock (1910, p. 171) stated that there is no muscle tissue within the genital bulb. The writer's studies verify this in the agelenopsids. Osterloh (1922) presented evidence of the role of a hydraulic mechanism in the movements of the copulatory apparatus. Homann (1935) utilized hydraulic pressure to activate the genital bulb. Osmotic pressure was used for the same purpose in the study herein reported.

Wagner (1887, p. 64) introduced the term "receptaculum seminis." The fundus forms the proximal end of the receptaculum seminis (fig. 5, *fd*). This saclike structure is enclosed within the subtegulum in the agelenopsids. In some specimens (e.g., *A. oklahoma*) the fundus extends upward into the sclerotized lunate plate of the subtegulum. Distally the fundus opens into the reservoir, which can be seen distinctly through the walls of the tegulum following KOH treatment. Comstock (1910, p. 174) was unable to demonstrate taenidia in the intima of the fundus, and inferred that this structure serves as a compressible bulb when subjected to the increased haemolymphatic pressures found in the genital bulb during copulation. The total absence of muscles within the genital bulb strengthens this hypothesis. The fact that the distal end of the fundus bridges the articulation of the tegulum and the subtegulum in many of the agelenopsids, might indicate that some of the force needed for ejaculation may stem from this source.

The reservoir constitutes the middle portion of the receptaculum seminis (fig. 5, *r*). It is a heavily sclerotized, darkly pigmented tube which is in intimate contact with the wall of the tegulum. This tube is characterized by the presence of taenidia. The reservoir gradually narrows distally and merges with the ejaculatory duct near the base of the radix.

The ejaculatory duct (*ed*) is the terminal portion of the receptaculum seminis. It consists of a slender tube traversing the radix and the embolus. Because of its dark color, the ejaculatory duct is easy to trace, especially in expanded bulbs. Distally the duct opens at or near the embolic terminus.

Seminal fluid passes through the ejaculatory duct and the reservoir, and is stored in the fundus. Sperm induction is considered later. Subsequently this fluid is driven out of the receptaculum seminis during ejaculation by the collapse of the fundus. This probably is due to increased haemolymphatic pressure within the genital bulb and, possi-

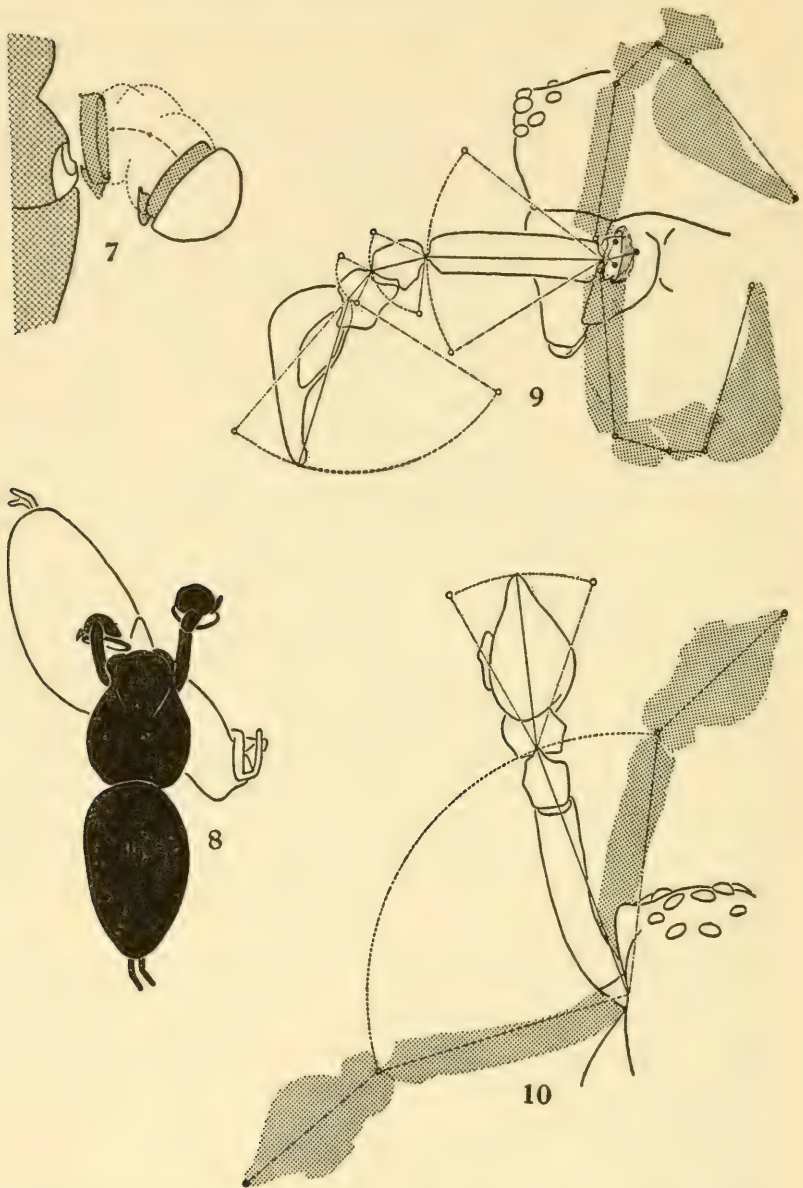
bly, in part, to a folding of the fundus at the tegular-subtegular articulation.

The basal haematodocha, petiole, and subtegulum are referred to collectively as the basal division of the genital bulb. Wagner (1887, pp. 64, 65) first used the term "haematodocha" because this structure was distended with "blood" during copulation. Comstock (1910, p. 171) showed that Menge's term "spiral muscle" was inappropriate for the basal haematodocha because of the total absence of muscles from the genital bulb. The agelenopsid haematodocha is membranous, with its proximal end connected to the cymbium inside of the alveolus, and its distal end connected to the subtegulum (fig. 6, *bh*). The alveolar wall is incomplete ectally (fig. 39), permitting the haematodochal lumen to communicate with the cymbial lumen, and thus, ultimately, with the body cavity through the segments of the pedipalpus. Distally the basal haematodocha is attached to the subtegulum (fig. 6). When not expanded, this membranous tube is folded and twisted upon itself, typically to the extent of approximately  $500^\circ$  (fig. 38).

Haemolymphatic activation of the genital bulb is the only hypothesis that is supported by both morphological and experimental investigation. This activation includes distention, rotation, and extension of articulated segments. Homann (1935) found that the genital bulb could be inflated with water under 1.5 atmospheres of pressure. He stated that the action thus induced closely approximated normal inflation of the haematodocha during copulation. The writer found that artificially induced osmotic pressures elicited the same response. Normal and artificial inflations of the genital bulb were compared. Artificial inflation was found to duplicate the normal sequence with accuracy.

Contraction of body muscles, particularly of the abdominal muscles, probably is responsible for increasing the haemolymphatic pressures, although experimental evidence to support this hypothesis is lacking. Gertsch (1949, pp. 93-94) also held this view. The increased haemolymphatic pressure inflates the basal haematodocha, and subsequently the middle haematodocha.

Expanding, the basal haematodocha unfolds and uncoils from its normal resting position within the alveolus. In so doing, two distinct operations are performed: (1) The genital bulb is forced outward and ectad from the alveolus, permitting unrestricted movement and rotation of the distal portions of the bulb (fig. 7). (2) The subtegulum and the more distal parts of the genital bulb are rotated (figs. 44, 45). This specific rotation is an integral part of the mechanics of copulation.



FIGS. 7-10

7, Mechanics of genital bulb displacement, right palpus, dorsal aspect, diagrammatic, genus *Agelenopsis*. 8, Copulatory stance, dorsal aspect, genus *Agelenopsis*. [Male black, female white.] 9, Limits of pedipalpal articulation, ectal aspect, semidiagrammatic, based on *Agelenopsis aperta* (Gertsch). Extreme total extension and flexion indicated by stippled structures. 10, Limits of pedipalpal articulation, dorsal aspect, semidiagrammatic, based on *A. aperta*. Extreme total extension and flexion indicated by stippled structures.

The term "petiole" was proposed by Chamberlin (1904, p. 174). The petiole is a straplike, sclerotized segment found within the alveolus, and closely associated with the proximal end of the basal haematodocha (figs. 27, 39, *pt*). It is located on the ectal side of the alveolus.

Comstock (1910, p. 166) indicated that the petiole is located in the articulating membrane connecting the genital bulb and the cymbium, and further stated (*op. cit.*, p. 182) that in *A. naevia* it articulated with a condyle found at the proximal end of the lunate plate of the subtegulum. Using cleared, unexpanded genital bulbs from specimens of *A. naevia* and 10 other species of *Agelenopsis*, the writer found that the proximal part of the subtegulum lies in juxtaposition with the distal end of the petiole, but the evidence of articulation is inconclusive. In expanding these bulbs, the petiole appeared to serve as a lever in the ectal displacement of the basal haematodocha. Even in partially inflated bulbs the petiole was found to be widely separated from the subtegulum (fig. 27). During deflation the petiole appeared to exert a weak, though distinct, retracting influence on the remainder of the genital bulb, tending to draw it back toward the alveolus. Osterloh (1922) also attributed a retractor function to the petiole. The primary function of the petiole appears to be that of facilitating ectal displacement of the genital bulb during inflation, and probably that of actively assisting in retraction of the deflating genital bulb back into its normal position within the alveolus. This latter action, however, is also assisted by the natural elasticity of the membranes comprising the basal haematodocha.

Wagner (1887) used the legend "S. teg." to indicate the subtegulum in his figures, but failed to mention anything pertaining to the subtegulum in his paper. In fact, he stated (*op. cit.*, p. 64) that the haematodocha ends in the tegulum. Comstock (1910, p. 171) corrected this statement, and named this structure the subtegulum. The subtegulum constitutes the distal portion of the basal division of the genital bulb (fig. 6, *st*). Typically, the subtegulum is ringlike in configuration. In the agelenopsids this ring configuration is not strongly developed. The mesal margin of the subtegulum forms the sclerotized lunate plate which terminates in a condyle. This condyle articulates with the proximal end of the tegulum, whereas the proximal end of the subtegulum is subcontiguous with the petiole in the unexpanded genital bulb. The remainder of the subtegular margin consists of a slightly sclerotized tubular structure. The anelli (*an*) are also a part of the subtegulum. The proximal end of the middle haematodocha has its origin on the subtegulum (fig. 6, *mh*).

The term "lunate plate" was introduced by Chamberlin (1904, p. 174). It applies to that portion of the subtegulum which is sclerotized (fig. 31, *lp*). The lunate plate frequently is the only visible portion of the subtegulum in the unexpanded bulbs (figs. 25, 33, 34, 37, 38). In some agelenopsids, the distal end of the fundus of the receptaculum seminis terminates within the lunate plate. In the agelenopsids, the lunate plate varies considerably in the extent of its sclerotization, but the articulation condyle remains the same in basic position and configuration.

While the lunate plate forms a heavily sclerotized section on one side of the subtegulum, the opposite side is made up of a series of parallel, incompletely ringlike sclerites which are called anelli. The anelli are distinctly sclerotized and pigmented in most, but not all, agelenopsids, e.g., *A. naevia* (fig. 38). Comstock (1910, p. 182) suggested that there may be characteristics of taxonomic value and importance in the anelli. Figures 27, 28, 31, and 35-38 indicate the range of variability found in agelenopsid anelli.

The several parts of the subtegulum have their own specific functions: (1) The semirigid tubular rim of the subtegulum serves as a region of attachment for the basal and middle haematodochae. (2) The subtegulum contains the fundus, and consequently plays a major role in ejaculation. (3) The lunate plate furnishes a sufficiently solid structure to be rotated as a discrete unit, and thus forms the base for rotation of all the more distal parts of the genital bulb. (4) The lunate plate further furnishes a condyle for articulation with the tegulum. (5) The anelli probably serve to strengthen the subtegulum. (6) The writer's earlier investigations indicated a major role for the anelli in retraction of the genital bulb. Subsequent studies of agelenopsids having weakly developed anelli indicate that while the hypothesis of this role of retraction is probably correct, its degree of function is highly variable in the different species, and in individuals of the same species.

The middle haematodocha, the tegulum, and the median apophysis of the tegulum make up the middle division of the genital bulb. In the agelenopsids, the middle haematodocha is the membranous bulb found between the subtegulum and the tegulum (fig. 6, *mh*). It resembles the basal haematodocha physically, and, like it, is somewhat twisted and folded upon itself. In the unexpanded bulb, the middle haematodocha is entirely hidden between the subtegulum and the tegulum. The proximal end of the middle haematodocha opens directly into the distal end of the basal haematodocha. The mechanism for inflation is the same in both.



As the middle haematodocha is inflated, the tegulum rotates on its articulation with the lunate plate (figs. 31, 36, 38). This rotation is in the same direction as that of the basal haematodocha. The rotation serves two functions: (1) The embolus is oriented parallel to the long axis of the bursa copulatrix of the female, permitting maximum total insertion of the embolus; and (2) it gives the embolus an additional rotation needed to insure maximum total insertion during copulation.

Wagner (1887, p. 64) applied the term "tegulum" to all the heavily sclerotized portions of the genital bulb. Comstock (1910, pp. 171-172) indicated the desirability for having distinctive names for each sclerite, and restricted this term to "the sclerite that forms the wall of the middle division." Petrunkevitch (1925, pp. 569-571) referred to the "thread" of *A. naevia*, and to "two sclerites" which are "limited to the ventral portion of the thread." This is obviously in reference to the tegulum. Blauvelt's description (1936, p. 82) of the tegulum of *Linyphia*, particularly of the basic tegular configuration, agrees well with that found in the agelenopsids. The tegulum is a ringlike sclerotized structure in which the distal end slightly overlaps the proximal end when seen in frontal aspect (figs. 6, 31, *tg*). The distal portion of the tegulum is expanded into a wide tegular plate which incompletely covers the frontal face of the tegulum. This plate is the "bezel" of Crosby and Bishop. The median apophysis arises from this plate. The outer margin of the tegulum forms a narrow, heavy tegular ridge (fig. 31, *tgr*). This ridge is most strongly developed at the proximal end of the tegulum, but is entirely wanting from the distal half. The tegulum is basically U-shaped in cross section, with the closed portion being peripherally located. The distal portion of the fundus and all of the reservoir of the receptaculum seminis are enclosed within the tegulum. Distally, the tegulum articulates synarthrodially with the radix. The nature of this articulation largely eliminates movement between the two structures.

The function of the tegulum in final orientation of the embolus, after it is already in the bursa copulatrix of the female, and the additional rotation which it imparts to the embolus during copulation has already been mentioned in connection with the middle haematodocha. It further serves to protect the portion of the receptaculum seminis which it contains and serves as a solid base for supporting and activating the embolus.

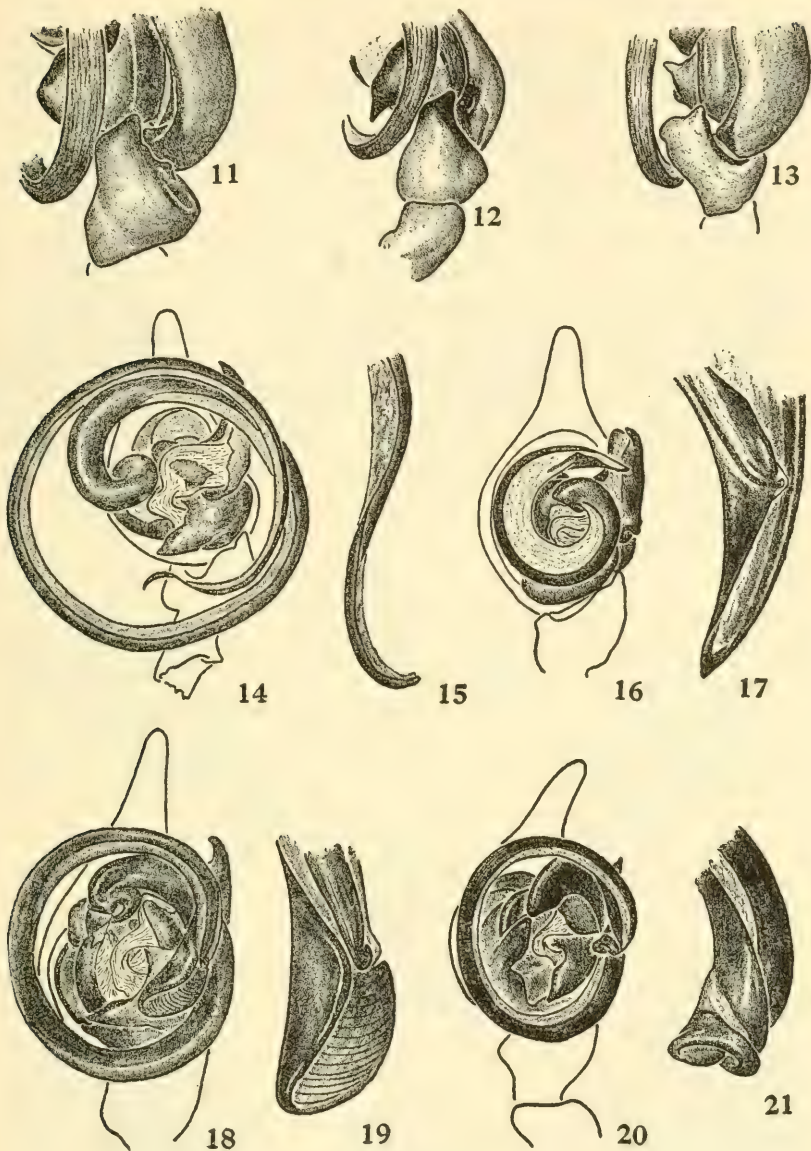
The median apophysis is an appendage arising from the distal margin of the tegulum. Chyzer and Kulczynski (1891, 1894, 1897) used the terms "lamella characteristic" and "apophysis mediana" for

this structure. F. O. Pickard-Cambridge (1897) used the terms "clavis" and "unca" respectively, while Chamberlin (1904) used the term "scopus." Comstock (1910, p. 172) urged the continued use of the term "median apophysis" on the basis of priority and general usage. Petrunkevitch (1925, pp. 569, 570) referred to this structure as the "ventral apophysis" and stated that it "marks the end of the haematodocha." The median apophysis of the agelenopsids is a plate-like structure arising from the tegular plate (fig. 4, *ma*). It is usually heavily sclerotized. The ectal margin and the proximal end of this apophysis are fused with the tegulum and tegular plate respectively, making it an integral part of the tegulum. The mesal margin of the median apophysis is free, and in most species is strongly and distinctively developed (figs. 14, 18, 20, 22-25). Near its ectodistal margin, the median apophysis is strongly sclerotized, and forms the outer rim of a groove found between the apophysis and the tegulum (figs. 36, 38, 41, 42). There is a distinct notch in the mesal margin (fig. 4, *n*). The portion of the tegulum lying behind (when viewing the genital bulb in frontal aspect) the median apophysis is weakly sclerotized, or may even be membranous.

Near the proximal end of the median apophysis is found a small, mammae-like tubercle (fig. 4, *tc*). This may be homologous to the distal haematodocha described by Comstock (1910, p. 177) in the aranea-type genital bulb. This tubercle was figured but not otherwise considered by Chamberlin and Ivie (1941, pp. 620-622).

There is still some question as to the complete role of the median apophysis in copulation. Some functions, however, are obvious. Because of its size, position, and sclerotic nature, it increases both the strength and rigidity of the tegulum, and aids in protecting the receptaculum seminis. The role of the apophysis in the process of locking the genital bulb during maximum insertion is considered later, as is the role of the mesal notch of the apophysis.

Comstock (1910, p. 169) adopted the term "conductor" in preference to Menge's (1866) term "spermaphorum" because the former term was already in general usage, and because the latter term, suggested by a misconception of function, was inappropriate. Petrunkevitch (1925, pp. 569-570) figured and briefly described the conductor. Seyler (1941) utilized the conductor and the embolus extensively in his study of the agelenopsids. The conductor of the agelenopsids is a heavily sclerotized segment (fig. 4, *cd*). It occupies a prominent position ectal to the main portion of the genital bulb. This segment is subrectangular in outline, with the ectodistal margin produced into a



FIGS. 11-21

11, Tibial apophysis, left, ectal aspect, *Agelenopsis naevia* (Walckenaer). 12, Tibial apophysis, left, ectal aspect, *Agelenopsis actuosa* (Gertsch and Ivie). 13, Tibial apophysis, left, subectal aspect, *Agelenopsis oklahoma* (Gertsch). 14, Genital bulb, left, frontal aspect, *A. oklahoma*. 15, Embolic terminus, left, frontal aspect, *A. oklahoma*. 16, Genital bulb, left, frontal aspect, *Agelenopsis pennsylvanica* (C. Koch). 17, Embolic terminus, left, frontal aspect, *A. pennsylvanica*. 18, Genital bulb, left, frontal aspect, *Agelenopsis spatula* Chamberlin and Ivie. 19, Embolic terminus, left, frontal aspect, *A. spatula*. 20, Genital bulb, left, sub-frontal aspect, *Agelenopsis actuosa* (Gertsch and Ivie). 21, Embolic terminus, left, frontal aspect, *A. actuosa*.

toothlike process. In cross section, the conductor is somewhat U-shaped, with the open portion visible in frontal aspect. The range of variability in the configuration of the agelenopsid conductor is shown in figures 22-25. An elongated process is found near the proximal end of the conductor. This process and a somewhat smaller process from the proximal end of the conductor are directed mesally toward the base of the embolus (fig. 40). The outline of the concavity formed by the mesal margin of the conductor and the large mesal process are shown in figures 22-25. This concavity plays an important role in the locking mechanism which is considered later.

The proximal end of the conductor is connected to the genital bulb by means of a cordlike tethering membrane. This membrane has its origin in the membranous region of the tegulum immediately behind (when viewed in frontal aspect) the median apophysis (fig. 4, *tm*). The tethering membrane was figured by Seyler (1941, p. 69) and by Chamberlin and Ivie (1941, pp. 620-622). Blauvelt (1936, p. 83), however, appears to have been the first to mention it. She described this structure as a "membrane from the lamellar arm of the radix" which connects with the lateral process in the genus *Linyphia*.

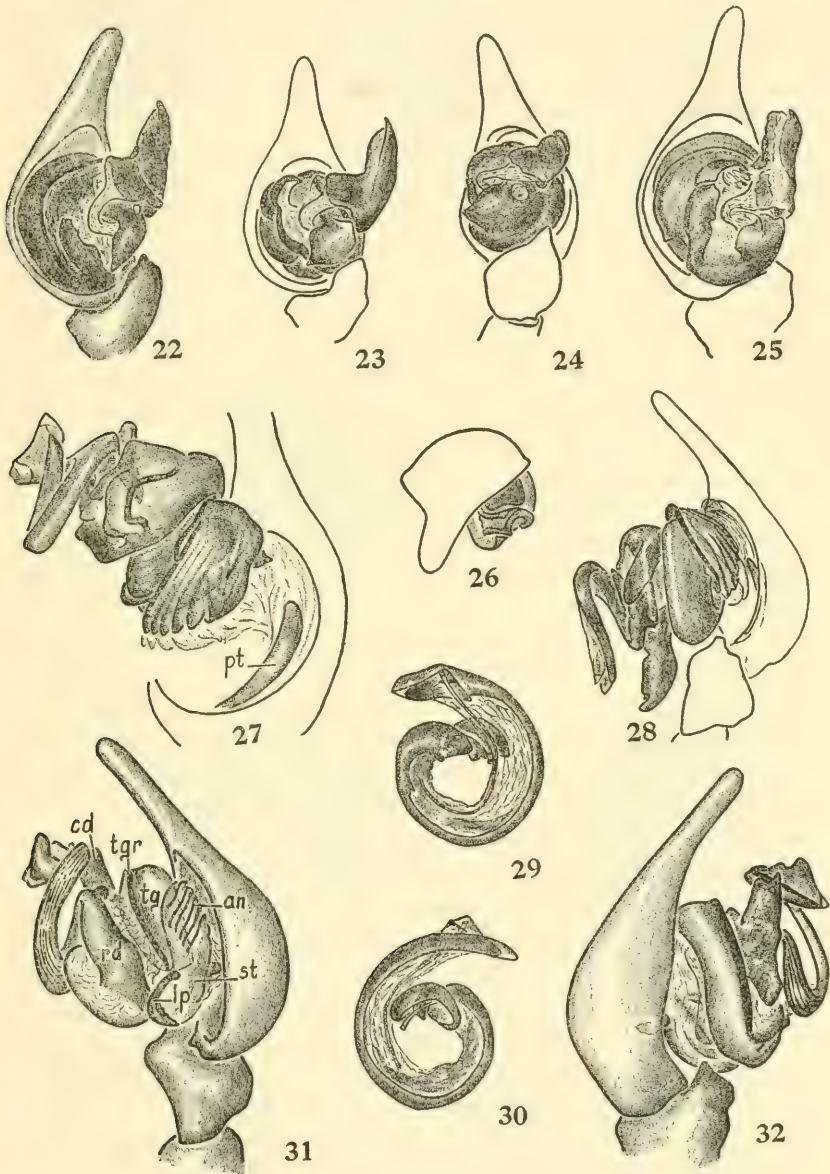
Comstock (1910, p. 172) stated that "in every case the embolus in the unexpanded bulb occupies such a position that its tip is protected by the conductor." This is probably in reference to *Linyphia*. Petrunkevitch (1925, p. 570) stated that the function of the conductor (in males of *A. naevia*) "remains uncertain." Gerhardt (Gerhardt and Kaestner, 1937-1938, p. 533) divided conductors into three basic types on the basis of their fundamental configurations, and supported the theory of protection or support as their function. While this protective function undoubtedly is correct for many groups of spiders, the conductor of the agelenopsids has a radically different and more vital function in the process of copulation.

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FIGS. 22-32

22, Genital bulb with embolus removed, left, subfrontal aspect, *Agelenopsis actiuosa* (Gertsch and Ivie). 23, Genital bulb with embolus removed, left, subfrontal aspect, *Agelenopsis longistylus* (Banks). 24, Genital bulb with embolus removed, left, frontal aspect, *Agelenopsis utahana* (Chamberlin and Ivie). 25, Genital bulb with embolus removed, left, frontal aspect, *Agelenopsis pennsylvanica* (C. Koch). 26, Genital bulb, left, as seen from apex of cymbium, *A. utahana*, showing configuration of conductor. 27, Genital bulb, left, expanded and displaced mesad, subfrontal aspect, *A. pennsylvanica*. 28, Genital bulb, left, partially expanded, subectal aspect, *A. pennsylvanica*. 29, Embolus, right, disarticulated, frontal aspect, *A. pennsylvanica*. 30, Embolus, right, disarticulated, reverse side of fig. 29, *A. pennsylvanica*. 31, Genital bulb, right, slightly expanded, mesal aspect, *A. pennsylvanica*. 32, Genital bulb, right, slightly expanded, ectal aspect, *A. pennsylvanica*. (For explanation of lettering see p. 10.)

The most important function of the conductor is that of coupling during copulation. The protective function, if it persists at all in the agelenopsids, is negligible. As the haematodocha expands during the initiation of copulation, the genital bulb is forced out of the alveolus.



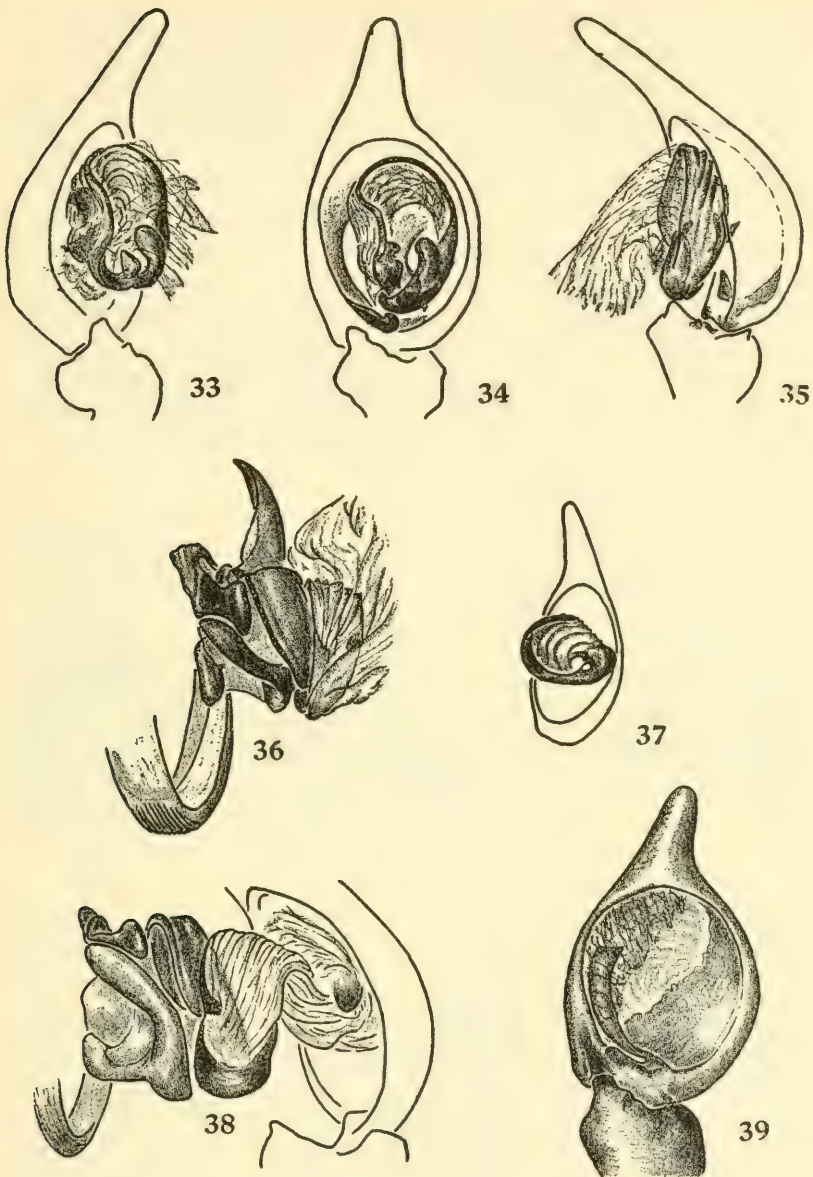
FIGS. 22-32.—See opposite page for legend.

The initial engagement of the embolic terminus in the female's atrium places the conductor directly above the coupling cavity in the caudal margin of the epigynum. It is shown later that the coupling of the conductor with this cavity is one of the most crucial events in agelenopsid copulation. Continued rotation of the genital bulb apparently results in a locking of the entire male palpus to the epigynum because of the tethering membrane, and of the mechanical configurations of the conductor, the embolic base, the tegulum, and the median apophysis.

The radix and the embolus make up the embolic subdivision of the genital bulb. Comstock (1910, p. 173) introduced the terms "radix" and "stipes" respectively for the proximal and distal segments connecting the embolus to the tegulum. He noted (op. cit., p. 181), however, that in the pisaurid type of palpus "the radix and stipes are not developed as distinct segments." In her study of *Pityohyphantes*, Blauvelt (1936, p. 87) found that the palpus of *P. phrygiana*, when treated with caustic potash, appeared to have these two discrete segments, but that "examination of an untreated specimen, and the comparative study of *Linyphia* palpi make certain that these two pieces are parts of a single sclerite." She used the term radix for this single structure. Osterloh (1922) found only a single structure, and called it the "Stuetzapparat." Neither Petrunkevitch (1925) nor Seyler (1941) mentioned the radix in their studies of agelenopsids. The agelenopsid radix is the segment that appears to be a distal prolongation of the tegulum (figs. 4, 6, *rd*). It is the heavily sclerotized portion into which the distal end of the fundus of the receptaculum seminis disappears (fig. 27). While the radix is synarthrodially articulated with the tegulum, on the bases of sclerotization, pigmentation, and function it appears to be a distinct segment (figs. 25, 31, 38). Distally the radix articulates diarthrodially with the embolus (figs. 36, 38, 41). Like the tegulum, the radix is roughly U-shaped in cross section, with the closed portion being peripherally located.

The radix apparently serves as a passive link between the tegulum and the embolus, imparting the thrust and rotation of the tegulum to the embolus. While the evidence in the agelenopsids is indirect, it appears that the base of the embolus folds up under the radix as a result of the diagonal radix-embolic articulation. This would place the outer, convex portion of the embolic base in the notch in the mesal margin of the median apophysis (figs. 42, 46, 48).

Menge (1866) first used the term "embolus." Simon (1892) later used the term "style," but the former term is now used universally.



FIGS. 33-39

33, Subtegulum, right, subfrontal aspect, *Agelenopsis pennsylvanica* (C. Koch).  
 34, Subtegulum, right, subfrontal aspect, *A. pennsylvanica*. 35, Subtegulum,  
 right, mesal aspect, *A. pennsylvanica*. 36, Genital bulb, right, expanded, mesal  
 aspect, *Agelenopsis aperta* (Gertsch). 37, Subtegulum, left, frontal aspect, *A.*  
*aperta*. 38, Genital bulb, right, expanded, mesal aspect, *Agelenopsis naevia*  
 (Walckenaer). 39, Cymbium, right, frontal aspect, *A. pennsylvanica*.

Numerous authors have given special consideration to the embolus as a taxonomic feature. Chamberlin and Ivie (1941) and Seyler (1941) placed particular emphasis on the embolus of the agelenopsids in this respect. Comstock (1910, p. 183) was responsible for the embolic nomenclature now in use. Barrows (1925) and later Harm (1931, 1934) advanced evidence that the embolus is homologous to the tarsal claw of the immature male palpus and of the female palpus. Gerhardt (Gerhardt and Kaestner, 1937-1938, pp. 534-535) was of the opinion that these structures needed a more exhaustive investigation in order to determine whether they are actually homologous. The agelenopsid embolus is a heavily sclerotized, coiled structure (figs. 4, 6, *em*). It varies markedly in males of the genus *Agelenopsis*. In specimens of *A. pennsylvanica*, the embolus forms a spiral of approximately  $470^\circ$  (figs. 16, 29, 30); in *A. oklahoma* it approaches  $720^\circ$  (fig. 14); while in most agelenopsids the spiral is approximately  $540^\circ$  (figs. 18, 20).

The proximal portion is heavy in construction and more or less hemispherical in configuration (figs. 29, 30). The truncus of the embolus is the body of this structure, extending distad from the base. It also is U-shaped in cross section, with the closed portion being peripheral. The truncus shows distinct, longitudinal fluting on its flattened, peripheral margin (figs. 31, 32). The pars pendula is the membranous portion of the embolus which is attached to the concave side of the truncus. In expanded genital bulbs this membrane becomes prominent. The ejaculatory duct can be traced through cleared emboli, particularly toward the less heavily pigmented distal end.

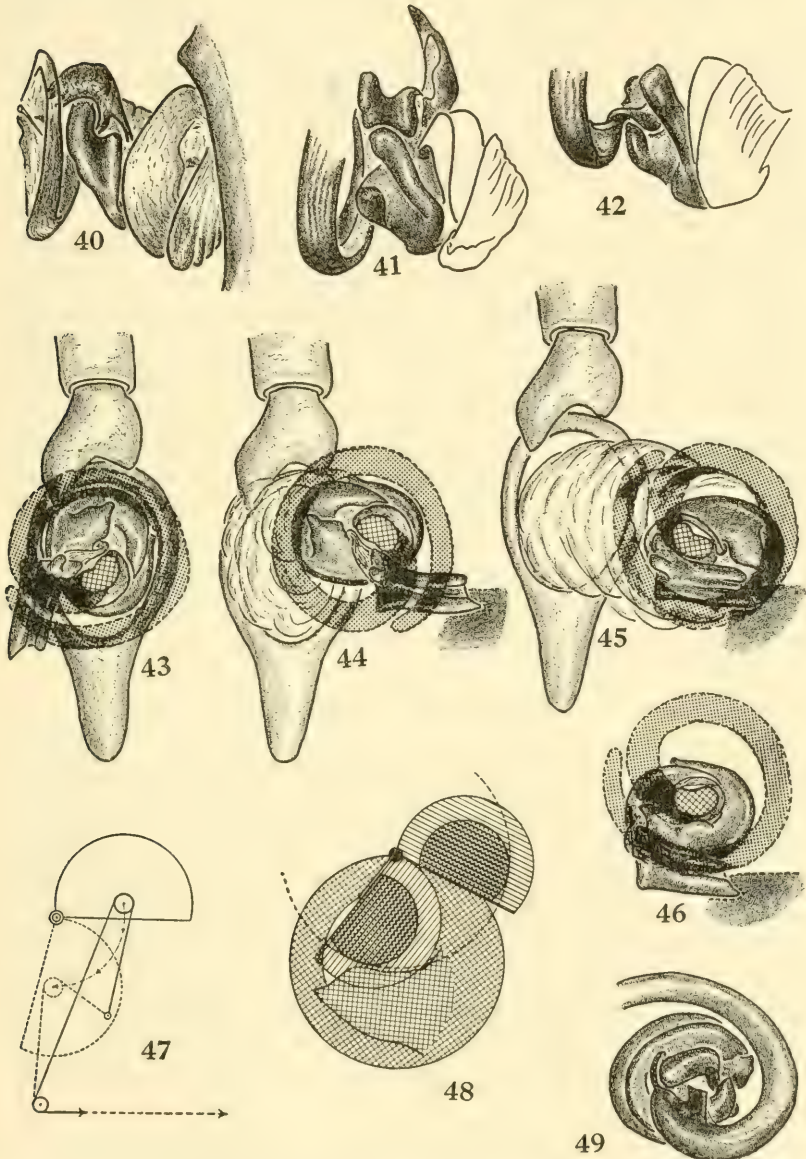
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FIGS. 40-49

40, Genital bulb, right, partially expanded, subdorsal aspect, *Agelenopsis pennsylvanica* (C. Koch). 41, Genital bulb, right, expanded, mesal aspect, *Agelenopsis spatula* Chamberlin and Ivie, showing normal position. 42, Genital bulb, right, expanded, mesal aspect, *Agelenopsis spatula* Chamberlin and Ivie, showing embolus in extreme rotated position. 43, Genital bulb, right, frontal aspect, semidiagrammatic, genus *Agelenopsis*, showing normal position of bulb before inflation. Embolus stippled, hemispherical groove of embolic base cross-hatched. 44, Genital bulb, right, frontal aspect, semidiagrammatic, genus *Agelenopsis*, after three-quarters turn, showing conductor engaged. [Note: Displacement is here shown to be mesad to simplify illustration; actual displacement of genital bulb is ectad. Cf. fig. 7.] 45, Genital bulb, right, frontal aspect, semidiagrammatic, genus *Agelenopsis*, after one and one-quarter turns, showing rotation of tegulum onto anchored conductor. 46, Genital bulb, right, frontal aspect, semidiagrammatic, genus *Agelenopsis*, after one and three-quarters turns of tegulum, showing genital bulb relationships during locked condition. [Note: Additional one-half turn of embolus only resulting from articulation of embolus.] 47, Mechanics of articulation of embolus due to strain produced on embolic base by tethering membrane, schematic, genus *Agelenopsis*. 48, Mechanics of articulation of groove on embolic base with median apophysis, schematic, genus *Agelenopsis*. 49, Genital bulb, right, subfrontal aspect, *A. spatula*, showing embolic base in fully articulated position during locked condition.



Distally, the truncus of the embolus loses its U-configuration, becoming flattened and tapering into a relatively thin structure. The extreme tip of the terminus is unpigmented in most agelenopsids. A subtriangular segment is found on the dorsoconvex side of the embolic



Figs. 40-49.—See opposite page for legend.

terminus. This is most evident in the embolic terminus of *A. pennsylvanica* (figs. 17, 30). The sclerotized portion of this triangular structure is called the apical sclerite of the embolus. The opening of the ejaculatory duct is contiguous to this sclerite (figs. 29, 30).

The primary function of the embolus is to carry the ejaculatory duct deep into the genital tract of the female for deposition of the seminal fluid. The complex functions of the heavy embolic base are discussed later. Structurally the truncus is light. While it is rigid enough to be forced into the bursa copulatrix, it also is sufficiently flexible to negotiate the necessary turns in order to reach the distal end of the bursa without breaking. Breakage of the distal portion of the embolus, however, is not unknown. Dahl (1902) reported finding embolic fragments in the bursa. Gerhardt (Gerhardt and Kaestner, 1937-1938, p. 537) credited Bertkau, Jaervi, Wiehle, and himself with having described such fragments in the atria of representatives of the genera *Delena*, *Clastes*, and *Nephila*. Dr. R. V. Chamberlin has told the writer of finding such fragments in many families of spiders. The writer has found several such instances in females belonging to *A. oklahoma*, and one in a female of *A. kastoni*. The apical sclerite precludes, in a large measure, the possibility of collapse of the ejaculatory duct aperture during maximum total insertion and ejaculation. Petrunkevitch (1925, p. 570) stated that the embolus "is very flexible, and when the haematodocha is turgescient the spiral is wider than in the quiescent state." The writer has not been able to verify this statement conclusively, but it appears to be correct.

#### ACTIVATION OF PEDIPALPUS

Petrunkevitch (1909) and Brown (1939) studied the musculature of the legs of spiders. Brown worked specifically with representatives of *A. naevia*. Petrunkevitch showed that the extensor muscles are entirely wanting in the femoropatellar and the tibiometatarsal joints. Ellis (1944) subsequently demonstrated the hydraulic extensor mechanism for these extensorless joints. Osterloh presented evidence of a hydraulic mechanism for the copulatory structures as early as 1922, while Homann (1935) ably demonstrated the role of hydraulic activation of the genital bulb. That haemolymphatic pressure is involved in the activation of the palpus is further substantiated by the simultaneous erection of the setae with each paroxysmatic inflation of the haematodochae.

Dissections of the legs of agelenopsids by the writer revealed no essential deviation from the findings of Ellis. Dissections of the

agelenopsid pedipalpi agreed with Barrows's (1925) findings. The chitinous plate at the distal end of the femur, which Ellis indirectly showed to be responsible for extension of the leg proximal to the patella, is readily demonstrable in the femur of the agelenopsid pedipalpus. The chitinous plate of the interarticular membrane of the tibia-metatarsus is found in the ambulatory legs of the agelenopsids also, but apparently is wanting between the pedipalpal tibia and the cymbium. Homann (1935) showed that approximately 1.5 atmospheres of pressure are necessary to inflate the genital bulb, making a special mechanism to confine normally increased haemolymphatic pressures proximad of the cymbium unnecessary. The writer's observations of living male agelenopsids revealed that the portion of the pedipalpus distal to the femur is extended rarely except during copulation. The vast preponderance of pedipalpal activity is restricted to the trochanter and the femur.

Flexure of the pedipalpus, on the contrary, apparently is entirely under muscular control. With these two different mechanisms available, it appears that a combination of both is involved in directing the specific movements of the pedipalpus, particularly in the case of the monocondylar articulations. Differential or selective contraction of muscles which are normally involved in flexure, but having points of insertion at opposite sides of the distal segment, thus would combine with the extensor movements in producing directed movements, both of an extensor and flexure nature. Hence, with all the muscles in a given segment in a state of normal or uniform tonus, the extensor movements would be in a vertical plane. Increasing the degree of contraction in any one group of muscles would produce a variation in the plane of articulation.

The same haemolymphatic pressure which extends the proximal segments of the pedipalpus is responsible for inflation of the haematodochae and thus, for the activation of the genital bulb. Reduction in the haemolymphatic pressure within the haematodochae results in their collapse. The natural elasticity of the membranous portions is apparently the most important single factor in recovery. The petiole probably plays a considerable role in the retraction of the collapsing genital bulb. The less heavily sclerotized segments, e.g., the subtegulum and its anelli, appear to assist in this reduction and retraction of the genital bulb, but the exact degree of their importance is still unknown.

#### PEDIPALPAL VARIATION

The most marked variations found in the pedipalpi of the agelenopsids are those pertaining specifically to the genital bulb. Variations

found in the segments proximal to the tibia are confined almost exclusively to proportional differences. The facies of these segments, when compared with those of other agelenid genera, are remarkably constant. Furthermore, the intersegmental angles were found to be essentially the same in all species here considered.

The tibial process shows some variation in superficial configuration. The position of this process, its length, and the manner in which it fits into the depression in the ectoproximal margin of the cymbium, indicate that it is a constant feature within the genus. The cymbium and the alveolus are subject to proportional differences, but along with such morphological features as the incomplete alveolar wall and the depression for the tibial process, are relatively constant.

The haematodochae display no apparent variation. The subtegulum varies in degree of sclerotization, but not in fundamental configuration. The anelli vary markedly among some species of agelenopsids, particularly with regard to the general facies and the degree of sclerotization. No instances were found, however, in which the anelli could not be demonstrated. The general facies of the lunate plate deviates considerably among the various species of agelenopsids, but the strongly sclerotized condyle of this structure is found in every specimen. In some species, but not all, the distal end of the fundus appears to terminate within the lunate plate. The receptaculum is relatively constant throughout the genus *Agelenopsis*.

The tegulum proper is constant in facies throughout the agelenopsids with only superficial differences being demonstrable. The median apophysis also is constant in fundamental configuration, although its facies is highly variable. The median apophysis of males belonging to *A. pennsylvanica* is the nearest approach to deviation from the basic mechanical design (fig. 25), but it still conforms closely enough to be capable of fulfilling its role in the locking of the genital bulb. The size of the mammae-like tubercle on the median apophysis is highly variable (figs. 22-25), and subject to considerable individual variation within any given species. In some agelenopsid species (e.g., *A. utahana*) this tubercle is reduced to a membranous area having a heavily sclerotized margin (fig. 24). The ectoproximal margin of the conductor in these instances is sufficiently small in size, and occupies a position such that it may easily be introduced into this membranous area. While the function performed by the tubercle, when it is present, apparently is essential, the tubercle itself is not. For example, the peg-and-socket relationship between the conductor and the median apophysis of specimens of *A. utahana* fulfills the essential function

of the tubercle without the tubercle, as such, being present. Hence, the tubercle is not universally found in all species of agelenopsids, but when lacking an analogous mechanism is always demonstrable.

The facies of the conductor varies markedly in the different species. The ectodistal process is always present, and is closely correlated with the configuration of the coupling cavity of the female in all agelenopsids. The mesal curvature of the conductor, its mesal processes and their articulation with the embolic base, and the tethering membrane also are constant throughout the males of this genus.

The radix displays proportional and configurational deviations which are only of a superficial nature. The diagonal articulation between the radix and the embolic base is found in all male agelenopsids.

The embolic base is relatively divergent in superficial configuration; however, the fundamental mechanical design is invariable. The truncus varies in length, in the circumference of its spiral, and in its diameter in the various species. There is little individual variation in these respects within any given species. The embolic terminus varies drastically in the different species (figs. 15, 17, 19, 21), with the apical sclerite apparently being entirely wanting in males of such species as *A. oklahoma*. The marked variability of the embolus in the different species is paralleled by a correlated variability of the bursa copulatrix of the corresponding females. The variability of the embolus, particularly in the light of the close correlation between the bursa and the embolus, is limited to configurational superficialities and not to mechanical fundamentals.

Excluding the subgenus *Barronopsis*, the agelenopsid pedipalpi are remarkably homogeneous in fundamental mechanical design and basic configuration.

Considerable diversity is found in the palpal configurations of representatives of the various genera of Agelenidae. In the following summary the genus *Agelenopsis* is used as the basis for comparison. Unless otherwise stated, the genera are essentially in agreement with the agelenopsids. Males are as yet unknown in the genera *Chorizomoides* and *Ritalena*.

The tibial apophyses are reduced in males of *Blabomma*, *Chorizomma*, *Ethobuella*, *Melpomene*, and *Wadotes*. In contrast, the apophyses are strongly developed in *Hololena*, *Novalena*, and *Rualena*. In representatives of some species of the genus *Cicurina*, the tibial apophysis is nearly as long as the cymbium. The ectoproximal portion of the tibia bears accessory processes in many genera of agelenids, but these processes are most elaborate in *Coras*. *Cybaeota* and *Cybae-*

*ina* are unique in that the tibial processes of the males are found behind the cymbium rather than in front of it. Thus, in these two genera, the extension, rather than the flexure, of the cymbium is limited. A similar condition exists in males of *Zelotes duplex* Chamberlin (Gnaphosidae). The tibial apophysis in *Tegenaria domestica* (Clerck) [= *T. derhami* (Scopoli)], is in such a position that the cymbium cannot impinge against it.

The cymbial apex tends to be somewhat shortened in some genera, e.g., *Calilena* and *Cicurina*, while it is markedly elongated in *Calymmaria* and *Tortolena*. *Coras* and *Wadotes* have a flat, platelike elaboration of the ectoproximal margin of the cymbium. In *Hololena* the ectoproximal margin of the cymbium presents a square configuration when viewed from the frontal aspect. The proximomesal margin of the cymbium in *Wadotes* is greatly enlarged, and bears a deep excavation. The size and position of this excavation, along with the marked reduction of the tibial apophysis, suggests that it might serve in the locking mechanism of the palpus during copulation. If such a function actually does exist, however, the copulatory position and the copulatory sequence would, in all probability, be markedly different from those of the agelenopsids because of the radically different mechanical configurations involved.

In males of *Agelena labyrinthica* a sclerotic, triangular partition is found originating on the mesal side of the cymbial margin. The apex of this partition is directed toward the middle of the alveolus. Nothing comparable to this was demonstrable in any of the other genera of Agelenidae. The petiole is well developed in all genera except *Calymmaria*, *Cybaeina*, and *Cybaeus*. In *Cicurina brevis* Emerton, the petiole is reduced to a tiny, buttonlike sclerite approximately one-half the way distad along the ectal margin of the alveolus. In males of *Chorizomma*, the petiole is filamentous but darkly pigmented. In *Cryphoeca peckhami* Simon, this same filamentous configuration of the petiole is found except that it terminates distally in a definitive, sclerotic bulb. The petiole is well developed in such divergent spiders as are represented by males of *Spirembolus vallicolens* Chamberlin (Micyrphantidae), *Pardosa xerampelina* (Keyserling) (Lycosidae), and *Clubiona abboti* L. Koch (Clubionidae).

The haematodochae of the agelenids vary only slightly in relative size, and little, if any, in configuration. The subtegulum is found in all agelenids. The anelli and the lunate plate are definitive structures showing varying degrees of sclerotization and pigmentation. In the genus *Wadotes*, however, the subtegulum is virtually wanting as a

sclerotized structure. It consists of a delicate sclerotic ring, and a vestigial lunate plate. The anelli are entirely obliterated. In most agelenid genera, the fundus of the receptaculum seminis is clearly discernible within the subtegular lumen after the palpi have been cleared. The subtegula found in males of *Spirembolus* and *Clubiona* are very similar to those of the agelenopsids. Specimens of *Pardosa*, while having a strongly developed lunate plate, have neither a definitive subtegulum nor the slightest traces of anelli. The tegulum of *Clubiona abboti* suggests that of the agelenopsids in its morphological configuration.

The basic mechanical configuration of the tegulum is relatively constant in the agelenids. The tegula found in representatives of *Wadotes* are superficially aberrant, but appear to retain the fundamental configuration of the other agelenids. *Hololena* agrees closely with the agelenopsids in tegular configuration. The tegulum is only weakly developed in *Calymmaria* and *Cybaeus*. In *Chorizomma* and *Cryphoeca* the tegulum has extensive membranous areas.

The heavy agelenopsid-type embolus is found in *Tegenaria*, but it is short. In *Agelena* the embolus is slightly arched and is much shorter than even that of *Tegenaria*. The embolic configuration of the agelenopsids is retained in *Calilena*, *Calymmaria*, *Ethobuella*, and *Novalena*. In these four genera, however, the emboli are short, describing less than a sixth of a turn. The emboli of *Tortolena* are bizarrely twisted into an S-configuration. Males of *Melpomene singula* (Gertsch and Ivie) have the heavy, agelenopsid-type embolus coiled around so as to produce a conelike configuration, which is strikingly suggestive of the emboli found in males of the subgenus *Barronopsis*. The emboli of *Melpomene bicavata* (P. Cambridge), on the contrary, are unquestionably of the filamentous type. Other agelenid genera having the filamentous type of embolus include *Blabomma*, *Chorizomma*, *Cicurina*, *Coras*, *Cybaeina*, and *Cybaeus*. The transitional forms of emboli found in the Agelenidae typically have a heavy proximal portion, but taper down to a long filamentous terminus. Genera displaying this transitional form of embolus include *Cybaeota*, *Cybaeozyga*, *Hololena*, *Rualena*, and *Wadotes*.

Because of the addition or loss of certain tegular apophyses, and the elaborate modifications of the distal portions of the genital bulb in the various genera of agelenids, there is no general agreement as to the nomenclature of these structures. The addition of a terminal apophysis, in such genera as *Wadotes*, further complicates the process of ascertaining homologies.

Structures similar to the agelenopsid conductor (including the membranous attachment to the tegulum) are present in representatives of the following genera: *Calilena*, *Calymmaria*, *Coras*, *Cryphocca*, *Cybacina*, *Cybacus*, *Novalena*, *Rualena*, *Tegenaria*, and *Wadotes*. The conductorlike structures of *Agelena*, *Blabomma*, and *Cybaeota* appear to be fused to the tegulum.

Deviations from the basic configurations of the component parts of the agelenid genital bulb appear to be limited almost exclusively to those distal portions which come into actual physical contact with the copulatory structures of the female. Apparently these distal modifications are correlated with parallel modifications found in the copulatory structures of the females. Furthermore, there appears to be a close similarity between the proximal portions of the genital bulb of the agelenids and other families of spiders, such as the Clubionidae, Lycosidae, and Micryphantidae.

#### REPRODUCTIVE ORGANS OF THE FEMALE

The reproductive organs of the female spider are organized into two separate systems, connected only by a pair of delicate fertilization tubes (fig. 51). The ovaries and their associated structures constitute one system; the other consists of the copulatory system proper. The copulatory system is here considered to include all structures, both external and internal, which are involved in copulation and insemination. This system is the equivalent of Jaervi's "Vaginalorgane" (1905) and his "Vaginalsystem" (1908, 1912, 1914). The ovaries and their associated structures are not involved in the actual process of copulation in the agelenopsids.

#### OVARIES AND ASSOCIATED STRUCTURES

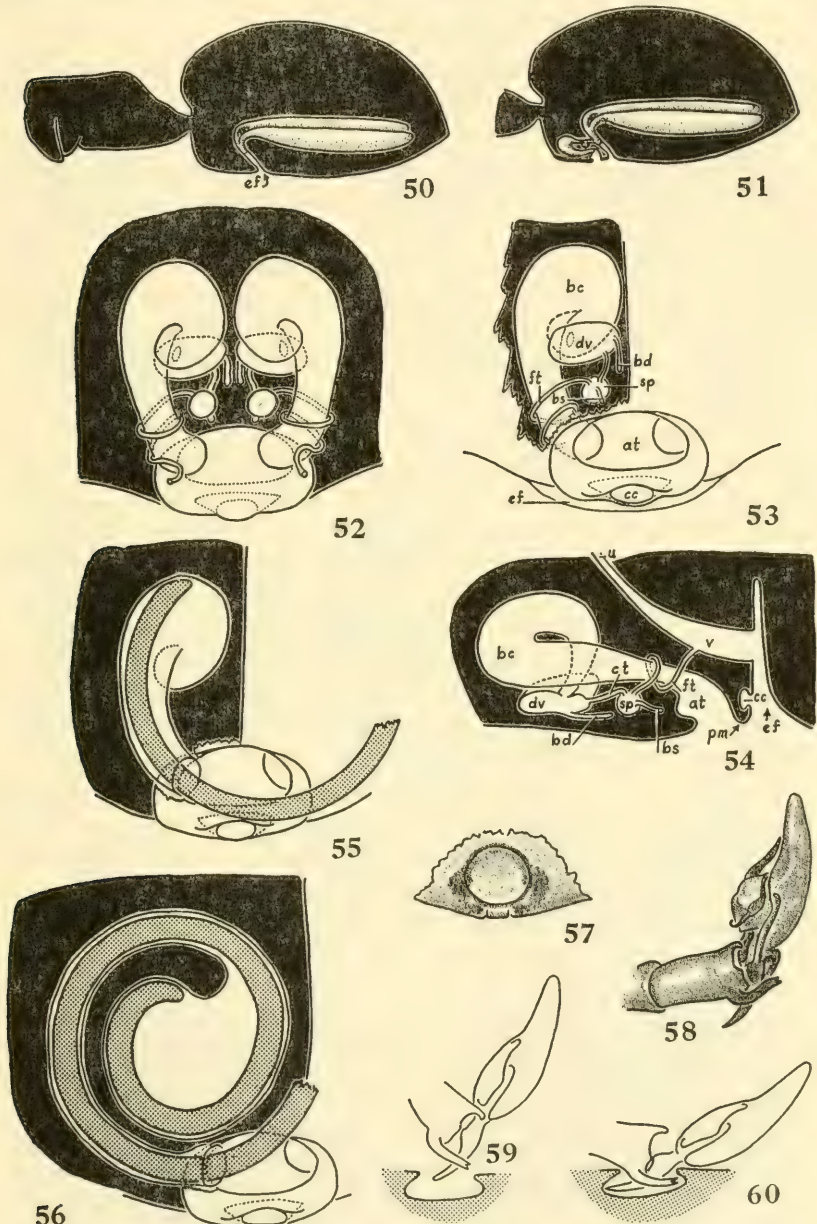
The ovaries and their respective oviducts are simple, paired structures situated in the ventral portion of the abdomen (fig. 51). They

#### FIGS. 50-60

50, Longitudinal section of male, diagrammatic, genus *Agelenopsis*, showing internal genital structures. 51, Longitudinal section of abdomen of female, diagrammatic, genus *Agelenopsis*, showing internal genital structures, including copulatory structures. 52, Copulatory structures of female, dorsal aspect, diagrammatic, genus *Agelenopsis*. 53, Epigynum and copulatory structures of female, ventral aspect, diagrammatic, genus *Agelenopsis*. 54, Epigynum and copulatory structures of female, ectal aspect, diagrammatic, genus *Agelenopsis*. 55, Maximum initial insertion of embolus into bursa, ventral aspect, diagrammatic. Embolus stippled. 56, Maximum total insertion of embolus into bursa, ventral aspect, diagrammatic, genus *Agelenopsis*. Embolus stippled. 57, Epigynum, ventral aspect, *Chiracanthium inclusum* Hentz (Clubionidae). 58, Palpus, left, ectal aspect, *C. inclusum*. 59, Coupling initiated, diagrammatic, *C. inclusum*. Female structure stippled. 60, Coupling completed, diagrammatic, *C. inclusum*. Female structure stippled. (For explanation of lettering see p. 10.)



extend caudad from the general region of the epigynum. Cephalad, the oviducts unite to form a common uterus (*u*), which opens into the vagina (fig. 54, *v*). The vagina opens mesally through the vulva which is located near the cephaloventral margin of the epigastric furrow (*ef*).



FIGS. 50-60.—See opposite page for legend.

Fertilization tubes (*ft*) transport the seminal fluid from the spermatheca to the vagina where fertilization occurs. This basic organizational pattern is common to all female spiders.

#### COPULATORY SYSTEM

An urgent need exists for a comprehensive study of the copulatory system of female spiders, with at least an effort at standardization of terminology. Comstock's work (1910) on the palpi of male spiders did much to unify and clarify nomenclature pertaining to those structures. As Blauvelt (1936, p. 92) stated "the early authors mention the organ but do not describe it with sufficient accuracy to clarify their terminology." Menge especially was given to the use of several names for each part, and was rather indiscriminate in his application of them. Blauvelt (*loc. cit.*) justifiably attributed much of the confusion in nomenclature to the unquestioning adoption of the terminology of Menge by subsequent workers.

Walckenaer (1837) introduced the term "epigyne" for the external portion of the copulatory apparatus. This term, however, has since become rather generally accepted as embracing both the internal and external portions of the copulatory apparatus of the female. Petrunkevitch (1925, p. 564) objected to this usage, being of the opinion that the term should be restricted (in *A. naevia*) to a specific portion (*viz.* structure *g*, fig. 71) of the external surface of the copulatory structure. On the basis of priority and general convenience of usage it appears preferable to retain Walckenaer's interpretation and to apply the term to the entire external portion of the female copulatory structure only. The term is thus used in this paper.

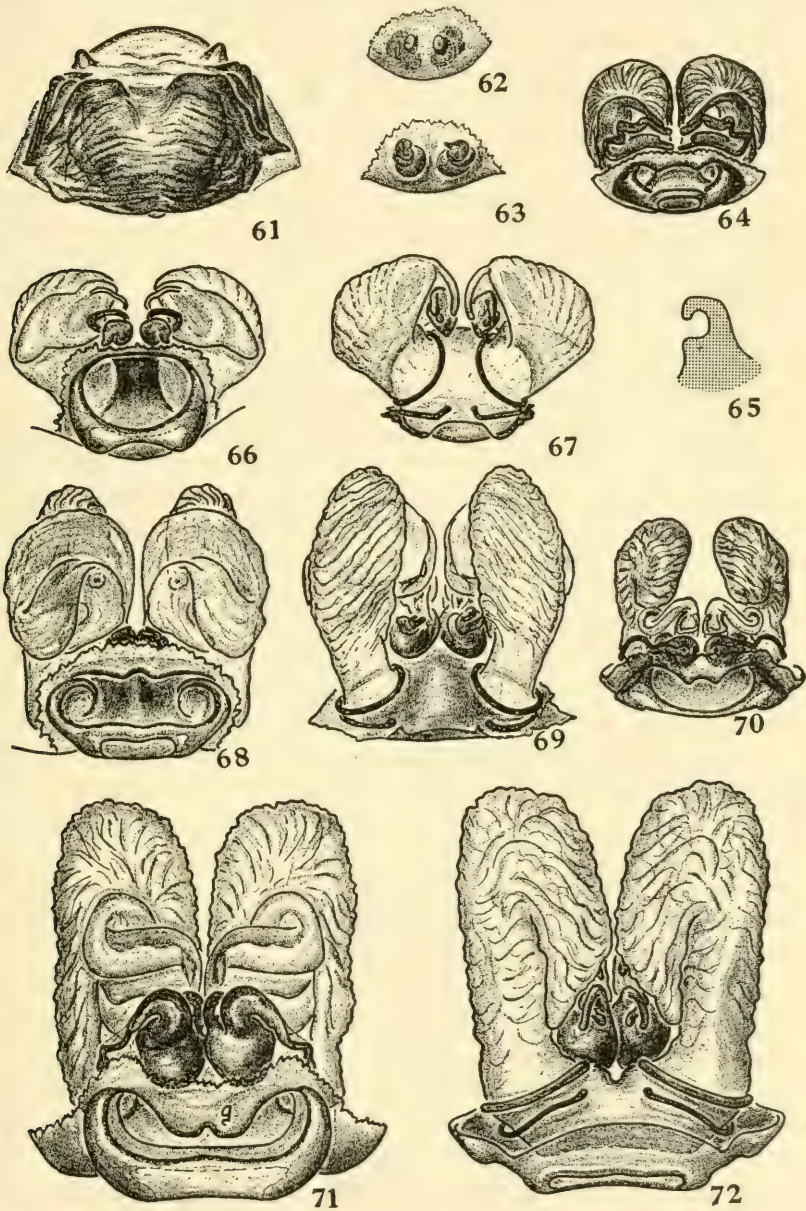
*Epigynum*.—The epigyna of spiders have been described and figured by so many araneologists that a detailed review of this literature would be prohibitive here. As previously indicated, Walckenaer introduced the term. Menge variously referred to this structure as the "sarum," "claustrum," and the "schloss," while Dahl used the term "vulvafeld."

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#### FIGS. 61-72

61, Epigynum, ventral aspect, *Coras medicinalis* (Hentz) (Agelenidae). 62, Epigynum, ventral aspect, *Cryphoeca peckhami* Simon (Agelenidae). 63, Copulatory structures, dorsal aspect, *Cryphoeca peckhami* Simon. 64, Epigynum and copulatory structure, ventral aspect, *Agelenopsis utahana* (Chamberlin and Ivie). 65, Coupling cavity, cross section, schematic, *A. utahana*. 66, Epigynum and copulatory structure, ventral aspect, *Agelenopsis pennsylvanica* (C. Koch). 67, Copulatory structure, dorsal aspect, *A. pennsylvanica*. 68, Epigynum and copulatory structure, ventral aspect, *Agelenopsis oklahoma* (Gertsch). 69, Copulatory structure, dorsal aspect, *A. oklahoma*. 70, Epigynum and copulatory structure, ventral aspect, *Agelenopsis longistylus* (Banks). 71, Epigynum and copulatory structure, ventral aspect, *Agelenopsis naevia* (Walckenaer). 72, Copulatory structure, dorsal aspect, *A. naevia*.

Petrunkevitch (1925) and Seyler (1941) followed Dahl by using the term "vulva" for this external plate. McCook (1894, p. 126) introduced the term "atriolum" for this structure. Several authors, including Comstock (1948, p. 132) and Blauvelt (1936, p. 92) adopted this



FIGS. 61-72.—See opposite page for legend.

term. Jaervi (1905, 1908) used the terms "epigynum" and "receptacula" respectively to distinguish between the single external and the paired internal portions of the copulatory apparatus.

Gerhardt (1937-1938, p. 535) stated "Die Simonsche Unterscheidung zwischen haplogynen und entelegynen Spinnen is berechtigt, und sogar in weiterem Umfange, als ihr ihr Urheber zugestanden hat." In the Haplogynae, the females lack a definitive epigynum, while the male palpi consist of a simple bulb with a terminal embolus and lack a distensible bulb. The males of this group typically employ simultaneous insertion of both emboli during copulation. Included in the Haplogynae are such families as the Dysderidae, Oonopidae, Segestriidae, Leptonetidae, and Scytodidae. In the Entelegynae, the females possess a definitive epigynum, while the males have a distinctly formed conductor and a distensible haematodocha intercalated between the tarsus and the embolus. The males typically copulate by applying the palpi singly. The Entelegynae include such families as the Agelenidae, Gnaphosidae, Linyphiidae, and Lycosidae.

The agelenopsid epigynum is a strongly sclerotized plate found immediately cephalad of the epigastric furrow on the venter of the female (fig. 53). The atrium is a large, single cavity in the epigynum (figs. 53, 54, *at*). The atrium is typically ellipsoid in the agelenopsids. Atrial proportions range from 1.7 times as broad as long in *A. longistylus* (fig. 70) to 4.7 times as broad as long in *A. oklahoma* (fig. 68), with the most frequent proportion being 2.4 times as broad as long as found in *A. kastoni*, *A. spatula*, and *A. utahana* (fig. 64). The proportions are based on typical specimens. The writer found, however, that in a series of more than two hundred females of *A. pennsylvanica* taken within a period of less than one month from a single locality, the atrial proportions ranged from 1.8 times as broad as long to 3.9 times as broad as long, with the most frequent proportion being 2.0 times as broad as long.

The atrial wall is heavily sclerotized. A pair of large, round apertures are located ectally in the cephalic portion of the atrium. These apertures are the entries into the internal bursae copulatricae.

In some females (e.g., those of *A. naevia*) the cephalad margin of the atrial rim is projected, ledgelike, back over a portion of the atrial cavity (fig. 71, *g*). It was to this structure that Petrunkevitch limited the term "epigynum" in *A. naevia*. It appears, however, that this structure corresponds to the guide (Chamberlin, 1904, p. 174) of the lycosid epigynum and is so considered in this paper.

The posterior median sclerite (Chamberlin and Ivie, 1941, p. 587)

constitutes the caudal margin of the epigynum (fig. 54, *pm*). The vulva opens into the epigastric furrow immediately dorsal to the posterior median sclerite. The coupling cavity, located on the caudal margin of this sclerite, is discussed later.

The epigynum serves a triple function: (1) It serves to protect the delicate, internal portions of the copulatory system; (2) it bears the coupling cavity; (3) the atrium constitutes a cavity in which the embolic terminus is initially engaged prior to final orientation of the palpus for copulation.

*Coupling cavity.*—The writer proposes the term “coupling cavity” for the transverse cavity found in the caudal margin of the posterior median sclerite (figs. 53, 54, *cc*). Ectally this cavity terminates in a pair of conical depressions lying deep within the sclerite (fig. 53). The coupling cavities range from 0.3 to 0.4 times as long as the atrial breadth in *A. utahana* and *A. oregonensis*, respectively, to 1.6 times as long as the atrial breadth in *A. longistylus*, with the most frequent proportion being 0.8 times as long as the atrial breadth being found in such forms as *A. kastoni*, *A. actuosa*, *A. emertoni*, *A. spatula*, and *A. oklahoma*. In the literature this cavity is shown in all drawings of the epigyna of agelenopsids. Petrunkevitch (1925, p. 563) stated that the function of this structure “remains unknown” and suggested that it might “have something to do with the process of egg laying.” Petrunkevitch (op. cit., p. 564) credited Jaervi with having described “similar pouches in *Torania occidentalis*—a spider belonging to the family Sparassidae, under the name of ‘Lobaltaschen.’” No function was indicated for the “Lobaltaschen” by Jaervi. Savory (1928, p. 226) figured similar excavations in the posterior median sclerite in *Sparassus* (= *Micrommata*) *virescens* (Clerck), and discussed Bristowe’s description of the correlations between these concavities and the tibial apophysis of the male. Bristowe found that copulation could not transpire until the tibial apophysis was properly engaged in these cavities, coupling the palpus and the epigynum together. The same vital correlation, existing between the conductor and these concavities in the agelenopsids, justifies using the term “coupling cavities” for these morphological structures.

Seyler (1941, p. 56) stated that in the epigynum of *A. utahana* the “concavities at the lateral extremities are not prominent and are sometimes lacking.” Seyler’s material consisted of 25 females taken in Ohio. The writer examined 112 females of this species, including the allotype and 5 female paratypes, as well as 42 males including the holotype and 5 male paratypes taken from 10 States and three prov-

inces of Canada. Two of the female paratypes showed reduced ectal concavities of the coupling cavity. Six other females showed extreme reduction of these lateral depressions amounting to virtual obliteration (fig. 64). The configuration of the coupling cavity (figs. 64, 65), and particularly the correlated configuration of the ectal process of the male conductor (figs. 24, 26) are such, however, that the coupling function is mechanically feasible even though the ectal depressions are reduced or even wanting. This same type of reduction of the ectal depressions of the coupling cavity is found in *A. oregonensis*. The ectal process of the conductor of the male in this species is very similar in configuration to that of *A. utahana*.

The agelenopsid coupling cavity serves as a repository for the ectal process of the male conductor during copulation (figs. 44-46). Hence, the cavity provides a means of anchoring the conductor and thus is involved in activating the locking mechanism which is essential for copulation.

*Bursa copulatrix*.—Siebold (1848) stated "Die Scheide oeffnet sich mit einer Querspalte nach aussen, nachdem sie Einfuehrungsgaenge von zwei nebeneinander liegenden Receptacula seminis aufgenommen hat" (quoted from Engelhardt, 1910, p. 34). Wagner (1887), however, used the term "receptaculum seminis" in reference to the internal portion of the male genital bulb. This latter usage has become so generally accepted that it appears advisable to retain Wagner's term and interpretation for the male structure. Engelhardt (1910, p. 51) used the expression "beckenfoermige Vertiefung" for the bursae of *Agelena labyrinthica*. Petrunkevitch (1925, p. 565) stated that as he had always found the sperm in the spermathecum and not in the bursa, he believed that the bursa "is a true bursa copulatrix and not a receptacle." Petrunkevitch, therefore, used the term "copulatory pouch," as did Seyler (1941). Blauvelt (1936) used the term "bursa copulatrix" as did Chamberlin and Ivie (1940, 1941). The bursae copulatrixes are paired membranous structures extending cephalad from their atrial origin (figs. 52-54, *bc*). The walls are nearly transparent, and are typically traversed by distinctive plications (figs. 64, 67, 69, 70, 72). Distally, the bursae communicate with the diverticles. There is considerable variation in the general configuration of the internal portion of the copulatory apparatus (figs. 66-72). The bursae are relatively constant within each species.

The plications of the bursae are somewhat variable in their degree of development. Their orientation, however, remains relatively constant in each agelenopsid species. While the bursal plications are

obscure in many specimens of *A. pennsylvanica*, the writer found vague traces of these plications in the majority of specimens of this species examined (figs. 66, 67). The plications of the bursae of *A. naevia* (figs. 71, 72) are strongly developed as indicated by Petrunkevitch (1925) and Seyler (1941) except for a small percentage of specimens. In this group the plications are only weakly developed. The typical orientation of the plications was found to be the same in any given species irrespective of the degree of development.

Petrunkevitch (1942, p. 177) stated:

The embolus and the conductor, if the latter is present, do not in any way correspond with the structure of the seminal receptacles and their ducts. Where a resemblance is present it is only superficial. For example, in *Agalena* [= *Agelenopsis*] *naevia* the embolus and the fertilization duct are both spirally wound, but the embolus is too thick to be introduced into the duct and is held during copulation in the atrium.

The bursae of the agelenopsids were subjected to detailed study by the writer through use of both in vivo and in vitro methods. Their function is that of receiving and accommodating virtually the entire length of the embolus during copulation. The fundamental spiral configuration of the ectal margin of the bursae conforms closely to that of the emboli (fig. 55).

The plications apparently endow the bursae with the ability to stretch, permitting the bursae to accommodate the emboli. Petrunkevitch (1925, p. 567) also stated, "Nor can the pouch be stretched by an increase of internal pressure, since the wall is quite rigid." The writer, using freshly excised copulatory structures from newly killed specimens of *A. aperta*, *A. oklahoma*, and *A. pennsylvanica*, found that the bursae stretched readily upon manual introduction of the emboli. The stretching of the bursae caused virtual obliteration of the plications. Removal of the emboli permitted the bursae and their plications to resume their original configuration. Further investigations of a similar nature with preserved copulatory structures of the remaining species of agelenopsids gave identical results, although the elasticity of the preserved bursae was considerably reduced.

*Diverticle*.—The diverticle (Petrunkevitch, 1925, p. 567) is a pouchlike structure composed of the same light-colored, membranous material as are the bursae (figs. 52-54, *dv*). The diverticle, however, has heavier walls and a smoother surface than does the bursa (figs. 66, 68, 71). The proximal opening into the diverticle is located at the distal end of the reverted portion of the bursa. Distally, the diverticle terminates in a small blind tube on the dorsal surface of the

internal copulatory structures between the bursae (figs. 52-54, *bd*). Each diverticle is connected to its own spermathecum by means of a single connecting tube. The connecting tube's point of origin on the diverticle is variable, both in individuals and in the various species. Examples of the variability found in the agelenopsid diverticle are shown in figures 64, 66, 68, 70, and 71.

The function of the diverticle is probably twofold: (1) Reception of the seminal fluid from the embolic terminus, and (2) possibly that of an accessory reservoir for temporary storage of seminal fluid in cases of rapidly repeated copulations. The blind terminus of the diverticle is universally present in the agelenopsids, but it is highly variable. Its function is unknown.

*Connecting tube.*—The spermathecum communicates with the diverticle by means of the connecting tube (figs. 52-54, *ct*). This tube is so variable both interspecifically and intraspecifically that its configuration is difficult to generalize. Seyler (1941, p. 57) indicated that in some of his specimens this tube "is so short that the receptacle appears to be connected directly with the copulatory sac." Typically, however, the tube is long and narrow. It is composed of the same heavily sclerotized and pigmented material found in the spermathecum. In some species the proximal end of the connecting tube arises "from the medial edge of the copulatory sacs along with, and as a part of the diverticle" (Seyler, 1941, pp. 57-58). At the other extreme the tube is found arising from the ectal margin of the diverticle and connecting with the spermathecum after passing under the ventral surface of the bursa.

The sole function of the connecting tube is that of carrying seminal fluid from the diverticle to the spermathecum.

*Spermathecum.*—Englehardt (1910) used the terms "receptaculum seminis I" and "primaerer Samenbehälter" interchangeably for the structure which Petrunkevitch (1925, pp. 565-566) called the "seminal receptacle." The latter term is used rather extensively, although the term "spermathecum" is not infrequently found in literature. The use of the term seminal receptacle for a female structure is somewhat objectionable in view of the general acceptance of the term receptaculum seminis for the internal structure of the male palpus. The writer, therefore, has adopted the term spermathecum (Chamberlin and Ivie, 1940, 1941) for this structure. The paired spermatheca of the agelenopsids are located just cephalad of the atrium, and ventral to the bursae (figs. 52-54, *sp*). These structures are heavily sclerotized and pigmented. Because of their proximity to the ventral surface of



the body and their dark color, the spermatheca are prominent landmarks in cleared specimens. They often are discernible even through uncleared epigyna. While the two spermatheca frequently are fused, their lumina are always discrete. The spermatheca are connected to the diverticle by means of the connecting tubes, and they are also the point of origin for the fertilization duct.

Extending from each spermathecum is a short "blind tube" (figs. 52-54, *bs*). This tube apparently is homologous to Engelhardt's (1910) "receptaculum seminis II" and "sekundaerer Samenbehälter." Engelhardt's (op. cit.) "receptaculum seminis III" or "tertiärer Samenbehälter" in *Agelena labyrinthica* is wanting in the agelenopsids.

The semen is stored in the spermathecum. Engelhardt (1910) indicated that both the receptacula seminis II and III have a glandular function, or serve as ducts for glands. Petrunkevitch (1925, pp. 567-568) found that the blind tube of the spermathecum in *A. naevia* was capped by a gland, each cell of which opened separately into the blind duct through a series of pores.

*Fertilization tube.*—The term "fertilization tube" is used almost universally in the literature. This tube originates on the ectal margin of the spermathecum (figs. 52-54, *ft*). Passing under the ventral surface of the bursa, the fertilization tube describes one and one-half turns around the neck of the bursa before it terminates in the vagina on the dorsal surface of the atrium (figs. 67, 69, 72). The tube is darkly pigmented and heavily sclerotized. Its lumen is small but distinct and extends throughout the entire length of the tube. The size and configuration of the tube is relatively constant in the agelenopsids.

The function of the fertilization tube is limited to conveying the seminal fluid from the spermathecum to the vagina. The eggs apparently are fertilized as they pass through the vagina during oviposition.

#### COPULATORY SYSTEM VARIATION

The copulatory system of the agelenopsid female is given to considerable variation, both interspecifically and intraspecifically. Typical configurations and some extremes of configurational deviation within the genus *Agelenopsis* are shown in figures 61-72.

The epigyna are relatively constant in basic configuration. Atrial variations have already been considered. The guide is present in females of *A. longistylus*, *A. naevia*, *A. oregonensis*, and *A. utahana*. The coupling cavity is strongly developed in all agelenopsids, although the ectal concavities may be considerably reduced in specimens of

*A. oregonensis* and *A. utahana*. In species showing a reduction of these ectal concavities, the conductors of the males show a correlated modification.

The bursae copulatrices are relatively long in the agelenopsids (e.g., *A. naevia*, figs. 71, 72), except in *A. pennsylvanica* (figs. 66, 67). In the latter species, the bursae tend to be markedly shorter than in the other agelenopsids. The bursae of *A. utahana* (fig. 64) are intermediate in length between those of *A. pennsylvanica* and those of the remaining species which resemble *A. naevia*. All bursae are distinctly plicated, except in *A. pennsylvanica*. In this latter species the plications are demonstrable, but are weakly developed. The bursae are widely separated in *A. kastoni*, *A. longistylus* (fig. 70), and *A. spatula*, while in the remainder of the genus the bursae are contiguous mesally, or nearly so.

The diverticles are so variable interspecifically that generalizations are virtually impossible. All diverticles agree, however, in having the coils oriented in a direction opposite to that of the bursa to which they are attached. *A. utahana* (fig. 64) is distinctive in having diverticles which are rather heavily sclerotized and pigmented.

The connecting tubes are too variable intraspecifically to permit generalizations. The connecting tubes in *A. kastoni*, however, are rather distinctive. They are unusually thick, and are both heavily sclerotized and pigmented.

The spermatheca are heavily sclerotized and pigmented in all agelenopsids. *A. utahana* (fig. 64) is distinctive in having the spermatheca widely separated. They lie near the ectal margins of the bursae instead of between them, as is typical of the agelenopsids. The spermatheca of *A. actuosa*, *A. oklahoma* (figs. 68, 69), and *A. pennsylvanica* are sufficiently dorsal that they are effectively hidden by the bursae and the diverticles. On the contrary, the receptacles of *A. emertoni*, *A. kastoni*, *A. longistylus* (fig. 70), *A. naevia* (figs. 71, 72), and *A. potteri* lie so near the ventral surface of the body that they may be seen through the body wall. In the remaining species, the spermatheca are somewhat more dorsal than in this latter group, but less so than in the former. In this intermediate group the spermatheca are seen through the body wall only rarely.

The fertilization tubes describe  $1\frac{1}{2}$  turns around the bases of the bursae before terminating on the dorsal surface of the atrium in all agelenopsids. In *A. kastoni*, these tubes are thick, heavily sclerotized, and deeply pigmented. The fertilization tubes of *A. longistylus* are relatively large as compared with those of the other agelenopsids. The

tubes of *A. spatula* are typical in size, but are considerably more heavily pigmented than are the tubes of other agelenopsid species.

The fundamentally basic features of the agelenopsid copulatory system are the presence of the coupling cavity; the mesally curved, plicated bursa; the oppositional curvature of the diverticle; the connecting tube leading to the spermathecum; the spermathecum itself; and the coiling of the fertilization tube around the base of the bursa. While all these vary superficially, both interspecifically and intraspecifically, the fundamental configuration of each appears to vary only within certain mechanical limits.

Before summarizing the copulatory structures of the agelenid females, it should be noted that the writer has not had an opportunity to study the internal structures of representatives of the genera *Chorizommoides*, *Cybaeozyga*, *Ethobuella*, *Melpomene*, and *Tortolena*. The fundamental morphological configurations of the copulatory structures of the females are radically divergent in the various agelenid genera (cf. figs. 61, 66). Most of the genera have a common atrium opening into the paired, internal copulatory structures. In the genera *Blabomma*, *Chorizomma*, *Cryphocca* (fig. 62), *Tegenaria*, and *Tortolena*, however, two discrete openings replace the typical atrium. In *Chorizommoides*, *Cybacina*, and *Cybaeus*, specimens of some species have a typical epigynal atrium, while other species of the same genus have two separate copulatory apertures.

A specialized bursa copulatrix, such as is found in the agelenopsids, is uncommon in the Agelenidae. Definitive, well-developed bursae are found in females belonging to *Agelena*, *Ritalena*, and *Wadotes*. These are directed caudally, in contrast to the cephalic orientation of the agelenopsid bursae, and are less elaborate in structure. The bursae found in *Cicurina* are directed cephalically, but apparently serve to guide the emboli of the males toward the spermatheca rather than to accommodate the emboli in the same sense as the bursae of the agelenopsids do. The bursae found in *Coras* are somewhat reminiscent of the agelenopsid bursae, but they are highly complex. The simple copulatory system of *Cryphocca* is shown in figure 63. Only the agelenopsids possess plicated membranous bursae and membranous diverticles.

The coupling cavity, which is so distinctive in the agelenopsids, is duplicated in miniature in the posterior median sclerite of the genus *Blabomma*. In *Calilena*, a pair of small cavities can be demonstrated in the posterior median sclerite. It is possible that the caudal ridge, which is a part of the posterior median sclerite in the genus *Rualena*,

also could serve a coupling function. Various lesser ridges, concavities, and definitive processes on the posterior median sclerites of representatives of *Novalena*, *Tegenaria*, and *Wadotes* might also have a coupling function. These are so weakly developed in most instances, however, that such a function appears problematic. In *Blabomma*, *Calilena*, and *Rualena* the mechanical configurations are such that relatively secure coupling probably could be achieved.

Well-developed atrial guides are distinctive features in *Calilena*, *Ethobuella*, and *Wadotes*. The role of the guide, and other accessory processes found on the epigyna of many of the agelenid genera, in securing the palpus to the epigynum during copulation can only be hypothesized until such time as detailed studies, both in vivo and in vitro, can be made. In view of the importance of coupling in the agelenopsids and in the genus *Agelena*, as reported by Osterloh (1922), it appears possible that a comparable mechanism might well exist in other genera in this family.

All genera of the family Agelenidae examined agreed in having the spermatheca well developed, heavily sclerotized, and darkly pigmented. Fertilization tubes were demonstrable in all mature females, and all communicated with the vagina. The fertilization tubes were heavily sclerotized and pigmented in all specimens examined.

### INTRASPECIFIC COPULATION

Much has been written in regard to the courtship and mating of spiders. Unfortunately, much of this information is based on superficial observations. Most of it is limited to only certain phases of these two processes. Gerhardt (Gerhardt and Kaestner, 1937-1938, pp. 537-557) contributed materially to this field of investigation by bringing together the widely scattered literature, and then summarizing and systematizing the data. Several noteworthy sections on courtship and mating are found in Gertsch's recent book (1949).

The investigation relative to intraspecific copulation herein presented was based on detailed observations of 85 matings (see Appendix, A) involving specimens of *Agelenopsis aperta*, *A. oklahoma*, and *A. pennsylvanica*. Typically there is considerable difference in the mating behavior patterns in different species within a genus. This has been demonstrated by the Peckhams (1889, 1890) in the Salticidae; by Montgomery (1903) in some Agelenidae; by Bristowe (1926) in the Thomisidae and Sparassidae; by Kaston (1936) in the Lycosidae, Pisauridae, Salticidae, and Thomisidae; and most recently by Crane (1948-1950) in the Salticidae. Therefore, a special effort was made

to find such differences in the agelenopsids. The fundamental sexual behavior patterns were found to be so similar that a single discussion of the mechanics of copulation will suffice for all three species here considered.

As this paper is devoted specifically to an analysis of the mechanical dynamics of copulation a detailed consideration of the preceding courtship is not included. It is anticipated, however, that an analysis of the considerable data pertaining to courtship which accrued from this investigation will be published as a separate paper at a later date.

The sexual biology of spiders may be divided into five distinct, behavioristic stages, viz, precourtship, courtship, precopulation, copulation, and postcopulation.

#### PRECOURTSHIP

The precourtship stage consists of sperm induction by the male, and has no counterpart in the female. Sperm induction is the process whereby the male spider transfers the seminal fluid from his genital aperture to the receptaculum seminis in his palpus. The genital bulb apparently cannot be activated prior to sperm induction. Petrunkevitch (1911, p. 372) stated "my observations leave no more room for doubt that a male with empty palpi does not court and avoids contact with the female."

The charging of the palpus was first reported by Menge (1843) in *Agelena labyrinthica*. Gerhardt (Gerhardt and Kaestner, 1937-1938, p. 537) stated that sperm induction subsequently was reported in over 80 species of spiders, principally by Bertkau, Montgomery, Bristowe, and himself. Gerhardt (op. cit., p. 539) classified sperm induction as being either direct or indirect, i.e., the embolic terminus is introduced directly into the seminal drop, or else it is introduced into the seminal drop indirectly after first being forced up through the meshes of the semen web. The agelenids utilize the indirect method.

As each male spider attains sexual maturity, he spins a special semen web of simple construction. Standing over it, he rubs his abdominal venter against the web. This behaviorism appears to be correlated with the concentration of heavy setae near the genital orifice. The male's action presumably produces a tactile stimulation which causes extrusion of the seminal fluid droplets. These droplets coalesce to form a single drop of seminal fluid which remains on the web.

The agelenopsid male reaches back under and up through the web with his palpi, touching the embolic terminus to the drop of seminal fluid. The small size of the receptaculum seminis lumen produces a

strong capillary action which draws the fluid into the ejaculatory duct. The palpus is raised from time to time, permitting the fluid to flow down through the reservoir into the fundus. Kaston (1948, p. 32) stated that "it is possible that sperm induction is effected by a lowering of the pressure around the sperm duct, causing the semen to be sucked in."

The writer witnessed only three such induction operations by the agelenopsids, and only one of these in its entirety. The limited data thus obtained were in agreement with Gerhardt's (Gerhardt and Kaestner, 1937-1938, pp. 539-540) account of this process. Two points could be added, however: (1) There was no indication of haematodochal swelling during induction, and (2) the male agelenopsids appeared to be hypersensitive to disturbances of any kind during induction. This is particularly unusual in view of the males' relative insensitivity to handling and observation during copulation. Petrunkevitch (1911, p. 371), on the contrary, found that the male of *Dugesia hentzi* was not easily disturbed during sperm induction. Once the receptaculum seminis is charged, and the subsequent period of quiescence is passed, the male becomes sexually active. In nature he leaves his web and wanders about until he finds a sexually mature and receptive female.

Except for the rudimentary semen webs, male agelenopsids do not spin webs after undergoing terminal ecdysis. Only rarely do male spiders retain the ability to spin extensive webs during their terminal stadium. Like most male spiders, however, the male agelenopsids continue to produce drag lines. Isolated virginal females show no apparent change in behavior patterns as a result of reaching sexual maturity, except for the oviposition of unfertilized eggs. Both virginal and mated females make cocoons, deposit their eggs, and guard their egg masses in the same manner.

The writer found one male agelenopsid engaged in sperm induction even though this spider had been completely isolated from all other spiders for the entire duration of his penultimate and terminal stadia. Hence it appears likely that this process is stimulated from within the spider himself. Kaston (1948, p. 32) suggested that "the stimulus for sperm induction is presumably the sensation of fullness in the testes and of emptiness in the palpal organs." Whatever the stimulus is, it manifests itself whenever the receptaculum seminis is empty. Furthermore, this initial stimulus seems to be instrumental in initiating the chain-reflex sequence that apparently constitutes the sexual biology of spiders.

## COURTSHIP

The courtship stage is that phase of the spider's mating behavior sequence during which the sexual instincts of the female are sufficiently aroused to permit the male to approach the female safely, and to establish physical contact. The colorful antics of the Salticidae during their courtship dances were described in great detail by the Peckhams (1889, 1890). Kaston (1936) vividly described the courtship of many of the Lycosidae, Pisauridae, Salticidae, and Thomisidae. In the agelenopsids, however, the courtship stage is prosaic, and in most instances brief. Petrunkevitch (1911) and Kaston (1936) presented considerable evidence indicating that the courtship of each species of spider is of such a nature as to exploit the sense or senses most highly developed in that species. This is also borne out by Crane's analysis of display (1949) in the salticids. On the basis of this evidence the agelenopsid courtship should be, and apparently is, restricted primarily to tactile stimulation.

Savory (1928, p. 208) reported placing a male "house spider" (probably *Tegenaria domestica*) on the web of a mature female. The male, using both palpi, initiated a unique strumming on the web. The female remained passive amid the resultant vibrations as the male approached. Gertsch (1949, p. 89) reported that the male of *A. pennsylvanica* "moves on the web of the female and signals to her by tapping the silk with his legs and palpi. His advance is usually slow and measured until he is able to touch her with his legs, whereupon he actively seizes her." This agrees with the writer's field observations of *A. aperta*, *A. oklahoma*, and *A. pennsylvanica*.

Later, the behavior of the male was observed in a mating case with a binocular microscope, using strong, condensed light. It was not possible to demonstrate conclusively that the palpi are tapped against the substratum. The palpi moved rhythmically, but they appeared never to quite touch the substratum. It is probable that vibrations from any movements of the body were transmitted to the female through the cardboard substratum at the bottom of the mating case.

Upon being placed in the mating case, both the male and female normally are inactive for a few minutes. Then follows a period of variable duration during which they move about the case slowly. It is during this period that either one or both of the spiders shows the first evidence of being aware of the presence of a second animal by instantly elevating the palpi. Typically this response is elicited when the activated spider sees its partner or, more rarely, when physical contact is accidentally established prior to seeing its partner.

When sexually mature agelenopsids are placed together the male ultimately recognizes the female. Only sexually mature females belonging to the same species as the male elicit this response in the agelenopsids here considered. Both animals remain quiet for a variable period of time. A slight palpitation of the abdomens and legs of both animals, and a rhythmic movement of the male palpi are the only discernible movements.

In a few instances the female suddenly moved toward the male and struck at him with legs I. This occurred when the female recognized the male, but before the male showed any evidence of being aware of the female. In each instance, the male initially attempted to escape, but later assumed the typical male role, while the female became passive. Never was any attempt made to injure the male.

Slowly, and with progressively stronger palpitations, the male moves straight toward the female. At times he raises his entire body briefly, and then lowers it to the normal position. Occasionally the female moves. The male then immediately reorients himself so as to compensate for this movement. The tarsi of legs I are frequently elevated very slightly and directed toward the female momentarily before they are lowered to the substratum. During the period of elevation, the tarsi palpitate strongly and synchronically with the less apparent palpitation of the body.

The male's approach to the female spider appears to be a positive tropotaxis. Finally, the male attains a position sufficiently close to the female to be able to grasp her with a single rapid lunge. Establishment of continuous physical contact terminates the courtship stage in the agelenopsids, and initiates the precopulation stage.

The physiological processes involved in both the precourtship and the courtship stages of the agelenopsids are obscure. Kaston (1936, p. 152) concluded that the sense of sight, or the sense of touch, or a combination of both are involved in the courtship of the vagabond spiders which he investigated. While no special study of this phase of mating was included in the investigation herein reported it appears that both sight and touch are involved in the courtship of the agelenopsids. The sense of touch, however, appears to be the more important of the two.

#### PRECOPULATION

The precopulation stage is initiated with the establishment of continuous contact between the male and the female, and includes all subsequent activities preceding engagement of the embolic terminus



in the atrium. This stage is made up of a series of distinct behavior sequences on the part of the male. These behaviorisms are referred to here as the contact, reversal, positioning, and the cleaning phases. During the precopulation stage, and the two subsequent stages, the female is passive. This passive condition is the manifestation of the catalepsis phenomenon, which is discussed later.

*Contact phase.*—Contact is usually established quickly and vigorously. The male suddenly darts or lunges at the female, grasping her with legs I and embracing both her legs and carapace. The female immediately lapses into catalepsis. Generally the male approaches the female from the side and somewhat from the rear. Approaches from all quarters were observed, however, including a few instances in which the male approached the female directly from the front. Occasionally the female makes an effort to escape. She almost invariably succeeds initially, but runs only a few steps before stopping. In this event, the male shifts his position and pauses for a period of time ranging from a few seconds to several minutes. Then he resumes his efforts to establish contact with the female. The male usually needs to make only a single lunge to reach the female again. If the female, however, has moved a considerable distance, the male resumes his characteristic courtship approach until he is sufficiently close to make his contacting move. In several instances this procedure was repeated as many as eight times before continuous contact was finally established. In no instances did the male fail to establish contact after he had once initiated these efforts.

Having succeeded in grasping the female with legs I, the male starts to mount the female. In so doing he is able to further embrace her with his legs II, and to a limited extent with legs III. In no instance are legs IV used in this initial embrace. The male normally mounts the female from the rear; although when the male approaches the female from the front, he usually mounts her from that direction.

As the male embraces the female, he extends his chelicerae almost horizontally in front of himself, and opens them widely. He then quickly grasps the proximal ends of the female's patellae of legs II (rarely, legs III), holding them firmly between the fangs and the distal end of the falces, or the body of the chelicera. The male then completes the mounting of the female. This is accomplished by minor shifts of the male's legs, but with no relaxation of his hold on the female's patellae. A quiescent period, lasting for several minutes, follows. During this period the carapace and abdomen of the male are directly above those of the female. Cardiac and respiratory pulsations

can be seen in both animals. The male shifts his body and legs slightly from time to time.

*Catalepsis of female.*—Reference to feigning death, sham death, immobilization reflexes, and to the cataleptic trance are found relatively frequently in literature pertaining to the biology of spiders. This unique reaction to sudden disturbance is found almost universally throughout the Araneida. Robertson (1904) studied this mechanism by making neural transections and applying various types of stimuli in representatives of *Epeira producta* (L. Koch), *Amaurobius candidus* (?) (L. Koch), and *Celaenia excavata* (L. Koch). He found that in active species of spiders, as represented by *E. producta* and *A. candidus*, either the two anterior or the two posterior thoracic ganglia, even when severed from the remainder of the central nervous system, were capable of activating the cataleptic response. In "sluggish species," as represented by *C. excavata*, this mechanism appeared to stem from the thoracic ganglia, but could not be induced without the assistance of the "head ganglia."

Catalepsis is a state of muscular tetany involving the entire body of the spider, but particularly the appendages. Catalepsis serves a particularly significant function during copulation. At the instant the male agelenopsid establishes continuous contact with the female, she manifests the cataleptic condition. The body drops to the substratum as if the haemolymphatic pressure in the legs had suddenly decreased. The legs are drawn up high above the carapace until the patellae of legs II, III, and IV are subcontiguous. Legs I are drawn close together throughout their entire length, and are extended forward and down so that the tarsi are curled up under the mouth parts. The metatarsi and the tarsi of legs II and III are extended and initially remain affixed to the substratum. The legs lie close to the sides of the body, but the distal portions are extended sufficiently far ectad to maintain the position of the body. Legs IV are directed caudad, and slightly ectad, giving the body additional stability.

The female is capable of making sudden, independent efforts to escape, especially during the early phases of the precopulation stage. In no instance, however, did the female make an attempt to escape after the positioning phase, except when the spiders were disturbed rather violently. In most instances, the female's efforts to escape are successfully resisted by the male. In two instances in which the female succeeded in escaping, she made a rapid circuit of the mating case, and then, without hesitation, crawled back into her original position beneath the male. The male remained entirely passive during her

brief escape. In both instances, the copulatory sequence was resumed as though there had been no interruption.

In view of the complexity of both the genitalia and the mechanics of copulation, the cataleptic state of the female agelenopsid assumes major importance. Even relatively slight movements of the female during certain phases of copulation could effectively preclude the possibility of mating.

*Reversal phase.*—The reversal phase follows the period of inactivity which terminates the establishment of contact between the male and female agelenopsid. During this phase, which is usually of brief duration, the male moves his body around so as to face in the opposite direction. He momentarily loosens but does not release the grasp of his chelicerae on the female's patellae in order to accomplish this. The reversal phase terminates when the male has successfully accomplished this change of position, and has once again lapsed into inactivity. Upon completion of reversal, the male's carapace is directly above that of the female with the long axes of their bodies parallel, but facing in opposite directions. After reversing his position, the male once again firmly embraces the female. He continues to maintain his hold on the patellae of the female. From the reversed position, the male is better able to position the female and then to move himself into the copulatory stance.

*Positioning phase.*—Occasionally the male first attempts to roll the female on her side before reversing his position. Almost invariably he meets with considerable resistance on the part of the female. Usually, however, the male makes no effort to move the female into the copulatory position until after he has reversed his position. The positioning phase includes the successful rolling of the female into a position suitable for copulation, with the subsequent assumption of the copulatory stance by the male. This suitable position of the female is one in which the vertical axis of her body is inclined approximately  $70^\circ$  either dextrally or sinistrally.

Making use of his hold on the patellae of the female almost exclusively, the male lifts the female slightly as he tries to turn her over on her side. From one to nine attempts are needed to position the female. Once the female is positioned, the male releases the hold of his chelicerae on the patellae of the female. Bristowe (1929, p. 350) reported on the use of the chelicerae in positioning the female in the genus *Agelena*. The slight movements of the female during these attempts are difficult to evaluate or interpret. They may be movements of actual resistance, or they may be manifestations of the male's

activity. If this resistance is active on the part of the female it would appear to consist of such subtle actions as moving her legs slightly farther ectad to increase her stability, or grasping the substratum more tenaciously.

The first evidence of movements of the spines on the male's appendages appears after the male has succeeded in positioning the female. The distinct though not pronounced movements of the spines correspond with the cardiac pulsations. There is no evidence of any swelling of the haematodochae at any time prior to the actual copulatory stage.

After positioning the female, and prior to moving into the copulatory stance himself, the male initiates the cleaning of the palpi. This behaviorism is considered later. As the tempo of the cleaning process reaches its climax, the male moves his body in the direction of the female's dorsum until he has placed himself at approximately a  $45^\circ$  angle to the long axis of the female's body. Thus he faces ventrocaudad relative to the female (fig. 8). This is the copulatory stance of the male. The male immediately resumes the cleaning of his palpi. There is no quiescent period following the positioning phase. This phase terminates with both spiders in the copulatory position.

Gerhardt (Gerhardt and Kaestner, 1937-1938, pp. 546-549) recognized five basic copulatory stances in the Araneida, but he also noted (op. cit., p. 545) "dass sich immer mehr gezeigt hat, dass man nicht zu streng schematisieren darf, und dass es Uebergaenge gibt, die von der einen Begattungsstellung auf zweifellos verschiedenen Wegen erreicht werden konnte." Gerhardt's (op. cit., p. 547) agelenid- or lycosid-type copulatory stance is typical of most agelenids, including the genus *Agelenopsis*. Other families utilizing this copulatory position include the Lycosidae, Salticidae, Pisauridae, and the Clubionidae. It should be noted that the agelenid-type copulatory position necessitates rolling the female over on her opposite side each time before the alternating palpus can be applied. Emerton (1878, p. 36) gave a brief description of the copulatory stance of *A. naevia* which agrees essentially with the writer's observations of other agelenopsids.

*Cleaning the palpi.*—The process of cleaning the palpi during mating is so distinctive that special consideration is warranted. Savory (1928, p. 226) credited Blackwall (1873) for first reporting pauses in the mating process during which the palpi were drawn between the chelicerae. Savory (loc. cit.) further stated that Locket later investigated this phenomenon more closely and found that it was actually the embolus that was involved.

In the agelenopsids, the process of cleaning the palpi is initiated previous to the assumption of the copulatory stance by the male. The palpi are placed well back and between the chelicerae, and then are rapidly withdrawn. A fluid from the oral region is spread over the palpi during this process. The palpi are drawn between the chelicerae in a random fashion prior to the male's assumption of the copulatory position. Gradually the male limits the cleaning process to the genital bulbs, and finally to the embolic termini only. Once having assumed his copulatory stance, however, he becomes rigidly selective as to which palpus is cleaned. If the female rests on her right side, the left atrial opening is uppermost, and the male commences to clean the left palpus. While the right palpus is also cleaned sporadically, the cleaning process is concentrated on the left. The male then uses the left palpus for copulation. Reversal of the female's position results in the right palpus being cleaned instead. No deviation from this behavior pattern was observed in the agelenopsids.

As the cleaning process continues, the pulsations of the spines become stronger. At this time the first evidence of their actual erection is evidenced. The spinnerets also appear to pulsate more strongly. The female remains in her cataleptic state. Her only movements consist of vague, rapid pulsations of the tips of her tarsi and spinnerets.

Suddenly the male ceases his cleaning activities and immediately attempts to engage the embolus in the atrium of the female's epigynum. This action terminates the precopulation stage and initiates the copulation stage. The position of the female determines which palpus is used for copulation, and it is this circumstantially selected palpus which is initially cleaned after the male assumes his copulatory stance. This same palpus is cleaned almost to the exclusion of the nonutilized palpus, and it is the last palpus cleaned prior to actual copulation.

The number of times that each palpus is drawn between the chelicerae after the male assumes his copulatory position ranges from two to more than fifty. The variability in any given male is great.

The writer's studies support Savory's suggestion (1928, p. 226) that the cleaning process serves to lubricate the genital bulb and its component parts. Genital bulbs which have not been subjected to the cleaning process are dry; those that have are well moistened. This is true particularly of the membranous portions of the bulbs. The cleaning process precedes every instance of haematodochal inflation in the agelenopsids.

## COPULATION

The copulation stage includes all phases of sexual activity involved during the period of actual physical contact between the palpal structures of the male and the copulatory structures of the female. The mechanical aspects of this stage have been largely neglected except by a few men such as Osterloh (1922). The copulation stage consists of a series of distinct processes: engaging the embolus, inflation of the haematodochae, coupling of the conductor, locking of the palpus, maximum distention, ejaculation, reduction of the haematodochae, breaking of the locking mechanism, uncoupling of the conductor, retraction of the embolus, and the embolic terminus release. Each mating consists of a series of separate insertions or copulations. The number of insertions per mating is highly variable (Appendix, B).

*Engaging embolus.*—In the agelenopsids, the process of engaging the embolus is initiated without pause after completion of the embolic cleaning of the preceding stage. It should be noted again that the position of the female determines which palpus is used for copulation.

The process of engaging the embolus was found to be one of the most critical points in the mechanics of copulation in the agelenopsids. The male initiates a series of slapping movements which move the genital bulb in an arc across the face of the epigynum. The entire palpus is involved in this process. The swings are started a short distance caudad of the epigastric furrow, and move back and forth over the atrium. The number of attempts needed to engage the embolus, the frequency rates, and the duration of this process are given in Appendix, B. Ultimately, by means of slight changes in the position of the palpus, in the degree of distention of the haematodochae, and even of the position of his body, the male succeeds in engaging the tip of the embolus in the female's atrium. The necessity for the catalepsis of the female is most obvious during this process. Once the tip of the embolus is engaged, the random nature of the copulatory act ceases; the remainder of the copulation follows an almost invariable sequence with machinelike precision.

*Inflation of haematodochae.*—As the male draws his palpus from between the chelicerae and lowers it into position to initiate the swinging movements just described, the basal haematodocha is activated suddenly and begins to swell rapidly. This inflation lacks the spasmodic pulsations that are so distinctive of the activated haematodochae during later phases of copulation. There is no evidence of even the slightest haematodochal swelling prior to this time. While the middle

haematodocha inflates slightly, pronounced distention does not occur until later.

The initial inflation of the basal haematodocha forces the genital bulb out of the alveolus and ectad, probably with the assistance of the petiole (fig. 7). This ectal displacement is accompanied by sufficient rotation to place the embolic terminus in a position suitable for engagement in the atrium, during the swinging movements. Once the embolic terminus is engaged in the atrium, continued swelling of the basal haematodocha provides the rotation necessary for consummation of copulation. As previously stated, the haematodochae are inflated by increased haemolymphatic pressures.

*Insertion of embolus.*—The continuing inflation of the basal haematodocha causes the tegulum to rotate. As the tegulum rotates, the embolic terminus, which is already within the atrium is forced ectad and cephalad (fig. 55). The configurations of both the atrium and the embolus are obviously responsible for directing the embolic terminus through the aperture into the bursa. Further entry beyond the point of maximum initial insertion (fig. 55) is accomplished only by short, abrupt advances of the embolus resulting from strong, spasmodic pulsations of the basal and middle haematodochae. The middle haematodocha starts to inflate strongly during the insertion process.

The following interpretation of this insertion process is based on observations and detailed studies of both specimens and models: The embolic terminus is rotated into the bursa smoothly and rapidly until it reaches the cephalic end of the bursa. This constitutes the point of maximum initial insertion. Any subsequent advance of the embolus can be accomplished only by exerting sufficient force to cause the plicated walls of the bursa to stretch, and to cause the embolus itself to bend sufficiently to conform to the configuration of the stretching bursa (fig. 56). In this way, maximum total insertion can be achieved with the embolic terminus coming to rest at the distal end of the recurved bursa. The opening of the ejaculatory duct thus is in close proximity to the opening between the bursa and the diverticle (figs. 52, 53, 55, 56).

*Coupling of conductor.*—The conductor rotates as an integral part of the tegulum during the initial portion of insertion (figs. 43, 44). However, as the conductor strikes the posterior median sclerite during this process, the genital bulb stops rotating briefly. The conductor is, thereby, properly oriented to be engaged in the coupling cavity. The ectodistal process of the conductor is introduced into the coupling cavity by a slight depression of the palpus. By means of a second

slight palpal movement this process is then forced into the ectal depression of the coupling cavity (fig. 44). The conductor is always engaged in the ectal depression opposite to the bursa being utilized, e.g., if the right embolus of the male is introduced into the right bursa of the female, the ectal process of the conductor is engaged in the left depression of the coupling cavity.

The conductor is always engaged prior to completion of maximum initial insertion of the embolus. The coupling of the conductor is the second critical point in the mechanics of copulation in the agelenopsids. Unless coupling is satisfactorily accomplished, the embolus is partially retracted (by a slight deflation of the basal haematodocha) with complete disengagement of the conductor. Subsequent attempts at coupling follow immediately and continue until this is achieved (Appendix, B). In no instance was the embolus found to attain maximum initial insertion unless the conductor was first securely coupled. The existence of a comparable coupling mechanism was reported for *Dictyna benigna* by Karpinski (1882, pp. 714-715) and for *Agelena similis* Keyserling and *Lycosa amentata* Clerck by Osterloh (1922, pp. 412, 414). Both of these authors maintained that maximum distention of the haematodocha was dependent on successful coupling. The obvious function of the conductor is that of securing the genital bulb to the epigynum, and thereby forming a solid base to facilitate driving the embolus farther into the bursa in spite of the considerable resistance met with there.

*Locking of palpus.*—Once the conductor is securely coupled, maximum initial insertion is quickly accomplished. As maximum total insertion is being attained, however, several other actions are manifest. The conductor remains fixed in the coupling cavity, and the entire genital bulb is drawn down into intimate contact with it as the tegulum continues its pulsating rotation. The entire palpus shows marked evidences of becoming progressively more tense. The middle haematodocha can be seen quite clearly through the greatly swollen, transparent basal haematodocha, particularly at the zeniths of the paroxysms. The middle haematodocha is strongly inflated, forcing the tegulum to rotate out of and away from the subtegulum except for their common articulation. The spines on all the appendages of the male are erected to a nearly vertical position with each pulsation of the haematodochae, and then drop back slowly to a nearly horizontal position. The spinnerets and the abdomen show marked pulsations corresponding with those of the haematodochae.

Suddenly, the segments of the entire palpus appear to lock into a



rigid position with the cymbium drawn tightly against the tibial apophysis. Simultaneously, the entire genital bulb jerks sharply, as though some solid restraint had been removed suddenly, and then remains immobile. The embolus, however, moves forward sharply, although for only a short distance. Maximum total insertion has been attained. The female remains completely passive throughout the entire process.

The transparent nature of the haematodochae during maximum distention permits observations of the relative positions and the functions of many of the components of the genital bulb. Unfortunately, however, the heavily pigmented tegulum conceals much of the radix and the embolic base, while the median apophysis and the tethering membrane are hidden entirely. For this reason, only indirect evidence is available to substantiate some of the following hypotheses pertaining to the mechanical aspects of the locking mechanism.

The following interpretation of the locking process is based on hypotheses formulated from observations of agelenopsids during copulation, and with the aid of models and manual manipulation of the genital bulbs from both preserved and newly killed males: Maximum total insertion is accomplished by means of higher haemolymphatic pressure than is needed to attain maximum initial insertion. This is substantiated by the more nearly vertical erection of the appendicular spines during the paroxysms than is evidenced prior to this point in copulation. Observations reveal that as the genital bulb continues its spasmodic rotation and the conductor remains fixed in the coupling cavity, the tethering membrane is brought under tension and presumably begins to stretch (fig. 45). This can be demonstrated by manipulation of genital bulbs taken from newly killed males. The elasticity of the tethering membrane from preserved genital bulbs is considerably reduced by the preservative. As the tethering membrane becomes taut, the tegulum literally rolls down along the membrane toward the anchored conductor. The paired proximomesal processes of the conductor articulate with the hemispherical groove and ridges on the embolic base (figs. 36, 38, 40, 41). The genital bulb thus is drawn into the large, mesal curvature of the conductor. This also can be observed.

The tegular ridge slides down along the caudal surface of the conductor, while the embolic base and radix similarly are drawn down into the atrium in front of the cephalic surface of the conductor. As the genital bulb continues to rotate, the tethering membrane continues to stretch and appears to be drawn through the groove at the embolic

base. The decreasing rate of insertion, as the locking process continues, is very apparent during this phase of copulation in the agelenopids. Three factors appear to be responsible for this decreasing rate: (1) Increased resistance within the bursa, (2) additional resistance resulting from the intimate physical contact between the tegulum and the conductor, and (3) increasing resistance from the tethering membrane as it is progressively stretched.

When rotation has virtually ceased, a particularly strong haematodochal paroxysm is observed. The tegulum rotates sharply, driving the embolus forward, and simultaneously completing the locking process. During the ejaculation period which follows the entire genital bulb is completely immobile. If the tethering membrane has reached its limit of elasticity immediately prior to the aforementioned paroxysm, the resulting action may be hypothesized as follows: The tethering membrane, no longer capable of further stretching, is very tightly drawn into the groove at the base of the embolus. The rotation of the tegulum, resulting from the particularly strong haematodochal inflation, thus produces sufficient tension on the embolic base to cause the already-strained embolic-radix articulation to buckle (fig. 47). Manipulation of the embolus reveals that this flexure can be induced only by the application of considerable force. This articulation permits the base of the embolus to fold up under the radix (figs. 42, 46, 48, 49). As the embolic base folds under the radix, the median apophysis fits into the groove of the embolic base (figs. 46, 48). The purpose of this mechanical configuration obviously is that of increasing the strength and rigidity of the union between the embolus and the remainder of the genital bulb during this critical period. The morphological configurations of the structures involved in this mechanism make such a hypothesis mechanically feasible, while the actions which are manifest during the attainment of maximum total insertion further substantiate it.

*Maximum distention of haematodochae.*—Maximum distention of the haematodochae is achieved only after the locking of the palpus is completed. During this period, the haematodochae pulsate quite constantly during any single insertion. The pulsation rates and the duration of maximum distention vary markedly even in the several insertions making up a single mating (see Appendix, B).

Maximum distention is actually a dynamic state in which complete inflation of the haematodochae is maintained only momentarily, followed by a slow, slight deflation. The pulsating erections of the spines of the male are synchronous with the haematodochal palpitations, and

are markedly manifest during this period. As the haematodochae reach the zenith of each spasmodic swelling, they become transparent, losing the textured appearance which makes them semitranslucent at all other times. The transparency of the haematodochae is somewhat counteracted by the slight turbidity of the haemolymph, which can be seen swirling inside of them.

*Ejaculation.*—In all probability, ejaculation occurs during the maximum distention of the haematodochae. Apparently the seminal fluid is forced from the receptaculum seminis, upon collapse of the fundus, by the greatly increased haemolymphatic pressure which produces the maximum distention. As suggested previously by the writer, the articulation of the tegulum on the subtegulum may play a minor role in collapsing the fundus. In the agelenopsids, the seminal fluid is presumably ejaculated within the distal end of the bursa in the immediate vicinity of the aperture between the bursa and the diverticle. The duration of ejaculation is probably as variable as is that of maximum distention. Considerable work yet remains to be done relative to the receptaculum seminis, and particularly to the detailed mechanics of ejaculation.

*Reduction of haematodochae.*—Following ejaculation, the haematodochae begin to deflate. This process introduces a reversal of all the mechanical functions which led to maximum distention and maximum total insertion. Deflation is slow until after the locking mechanism is released, while subsequent deflation is accomplished rapidly. The reduction of the haematodochae is a progressively accelerated process. There is no appreciable retraction of the embolus until after the palpus has been unlocked. During the latter part of deflation there is little or no indication of the paroxysms which are so characteristic of the maximum distention phase.

*Breaking of locking mechanism.*—Once maximum distention is reduced, the effects of the locking mechanism of the palpus are terminated. This can be predicted accurately by observing the entire palpus. The spasmodic contractions of the haematodochae are paralleled by slight, synchronous movements of the entire palpus. As the haematodochae begin to deflate, the throbbing of the palpus becomes progressively stronger. As the palpitations gain in intensity, the palpal segments flex rather slowly at first, and then more rapidly. Suddenly, the palpus flexes sharply indicating clearly that the locking mechanism has been broken. This is accompanied by a simultaneous breaking of the conductor coupling (Appendix, B). Once the effect of the locking mechanism is eliminated, the speed with which the haematodo-

chae are reduced is greatly accelerated. The palpitations of the entire palpus, which are so evident in the haematodochae during the period of maximum distention, are reduced in intensity in direct proportion to the degree of deflation.

*Uncoupling of conductor.*—As the haematodochae begin to deflate, the embolus retracts slightly. This initial retraction is apparently due to a slight counterrotation of the tegulum, which somewhat relieves the strain on the tethering membrane. This in turn permits the restoration of the normal radix-embolic configuration. The elasticity of the tethering membrane could conceivably be a major factor in producing the initial counterrotation of the tegulum.

Continued counterrotation of the tegulum further retracts the embolus, and further reduces the tension on the tethering membrane. As this tension on the tethering membrane is completely eliminated, the tegulum rotates away from the conductor, while the conductor itself is disengaged from the coupling cavity. Finally, only the embolic terminus remains in contact with the copulatory structure of the female.

*Retraction of embolus.*—The retraction of the embolus occurs simultaneously with the uncoupling of the conductor (see preceding section). The final phase of retraction is accomplished rapidly when compared with the relatively slow initial stages of withdrawal. If, however, the agelenopsids are disturbed during copulation, retraction of the embolus is virtually instantaneous. It appears likely that the embolic termini are subjected to greater danger of breakage during such hasty retractions than in normal withdrawals. The embolic fragments occasionally found in the bursae of females probably indicate an interrupted copulation. Data pertaining to the retraction of the embolus are given in Appendix, B.

*Embolus terminus release.*—Almost invariably, the embolus is smoothly retracted until only the terminus remains within the atrium. The entire palpus is then subjected to a series of jerking movements reminiscent of the swinging movements used to engage the embolic terminus in the atrium at the onset of copulation. The number of disengaging movements necessary to free the embolic terminus is highly variable (Appendix, B). This characteristic behaviorism is manifest except in instances of disturbed copulation. When the animals separate suddenly, the additional force thus obtaining forcibly pulls the terminus from the atrium. As the genital bulb swings free from the epigynum, the first of the series of insertions which make up a single mating is completed.

## POSTCOPULATION

The postcopulation stage includes all those activities which take place following the release of the embolic terminus. Ultimately the male has two alternatives during the postcopulation stage: he may either repeat insertion (Appendix, B), or he may terminate the mating process and leave the female. During the postcopulation stage, the female generally remains in a state of catalepsis until the male leaves her. In some instances, however, the female may make feeble attempts to right herself. Usually the male has little or no difficulty in suppressing these efforts.

Immediately upon release of the embolic terminus the male resumes the process of cleaning his palpi. This is a continuation of the cleaning process which immediately precedes insertion. Even when disturbed, the male runs only a few steps before he stops to clean his emboli.

In instances where reentry is made almost immediately following release of the embolic terminus, the process of cleaning the terminus is reduced to little more than a formality, i.e., the termini are drawn between the chelicerae only once or twice. Not a single instance of release of the terminus was observed, however, which was not immediately followed by the cleaning process.

The mechanics of each subsequent insertion were found to be the same as that described for the initial insertion. The period of time that elapses between insertions is highly variable (see Appendix, B). Typically, however, subsequent insertions are initiated within a few seconds. Following the terminal insertion, the male cleans his palpi and then walks away from the cataleptic female unhurriedly. Almost immediately thereafter, the female rights herself. She then frequently commences to groom herself by drawing her legs between her chelicerae and then brushing her body with them.

Savory (1928, p. 225) stated that the "total number of insertions during one mating varies from one to over a hundred." Osterloh (1922, pp. 401-402) reported six consecutive matings between a pair of spiders belonging to *Agelena similis*, in which the right palpus was used twice, and the left, four times. In other spiders he found the number of insertions per mating to range from 45 to 272, with an average of 131.5 insertions per mating. In the agelenopsids herein considered the number of insertions per mating ranged from 3 to 18 (Appendix, B). These figures do not present a completely accurate account, however, because the mating spiders were usually separated after approximately six insertions had been observed and recorded.

One and two unsuccessful attempts were observed respectively in *A. oklahoma* and *A. aperta*, in which males endeavored to turn the females on their opposite side to permit copulation with the other palpus. Of the five similar attempts witnessed in *A. pennsylvanica*, three were successful.

Several facts were revealed during laboratory observations of 7 matings involving spiders of *Chiracanthium inclusum* (Clubionidae) and 11 involving *Misumena calycina* (Thomisidae). In both of these species the cleaning behaviorism is as manifest as it is in the agelenopsids. Courtship, likewise, is virtually nonexistent in both species. Moreover, in both, the inflation of the haematodochae and the rotation of the tegulum agree closely with that of the agelenopsids.

The males of *C. inclusum* apply the right palpus to the right portion of the copulatory apparatus, as do the agelenopsids. The coupling of the genital bulb to the epigynum is accomplished by means of a pair of processes located on the base of the cymbium and at the distal end of the tibia respectively (fig. 58). The mechanism of this locking process is shown in figures 59 and 60.

Upon being placed in the mating case, the tiny male of *Misumena calycina* immediately runs over the body of the female and assumes his copulatory position on the venter of her abdomen. He applies his chelicerae to the epigynum, and while he manipulates his fangs in the atrium, an oral fluid is extruded and drawn back into his mouth. The function of this behaviorism is unknown. Following this, the mating is consummated. Gerhardt (Gerhardt and Kaestner, 1937-1938, p. 546) stated "Im Falle von *Segestria* beisst sich das Maennchen mit seinen Cheliceren an der Bauchhaut des Weibchens fest," and further indicated a similar behaviorism had been reported in the Dysderidae, Sicariidae, and Pholcidae by Bertkau and himself.

The mechanical configuration of the male's palpus (*M. calycina*) necessitates a shift in his position each time he alternates his palpi. The right palpus is applied to the right portion of the copulatory apparatus and vice versa. No evidence of a special locking mechanism is apparent in *M. calycina*.

### INTERSPECIFIC COPULATION

The purpose of this portion of the investigation was to determine, if possible, the validity of the lock-and-key concept in the agelenopsids. The 23 attempts (Appendix, A) to effect copulation between spiders belonging to discrete morphological groups which are generally accepted as being valid species were entirely negative. Instances of

cross copulation between members of different species of spiders are reported, however, in the literature. Gerhardt (Gerhardt and Kaestner, 1937-1938) reported the occurrence of copulation between spiders belonging to two different species of the genus *Eresus*. Bonnet (1933b) reported two cases between males of *Dolomedes fimbriatus* and females of *D. plantarius*. Bonnet found it necessary to anesthetize the females before these matings could be consummated. Locket (1939) briefly reported still another instance of interspecific copulation in spiders. None of the females produced viable eggs following these copulations.

Initially it appeared possible that *A. pennsylvanica* and *A. oklahoma* would provide ideal material for studies relative to interspecific copulation because: (1) These two species attain sexual maturity during the same period; (2) although *A. oklahoma* typically is slightly smaller than *A. pennsylvanica*, sufficiently large numbers of spiders were available to permit selection of individuals of comparable size; (3) the general coloration and morphological configurations of these two species is remarkably similar; (4) preceding studies of intraspecific matings showed the copulatory behavior patterns to be virtually identical in each of the species considered; and (5) using both preserved and freshly killed material no major mechanical incompatibilities were apparent which should have prevented such cross matings. In spite of these encouraging indications, interspecific copulation between members of *A. oklahoma* and *A. pennsylvanica* did not occur. Attempted cross matings involving spiders of *A. aperta* with those of the aforementioned species were also unsuccessful (Appendix, A).

Mature males were placed in the same mating case with immature males of the same and different species; and with both immature and mature females of the same and different species. The reactions of the males to the presence of mature females of their own species have already been described. In any other combination the spiders displayed the following reaction sequence: The male became aware of the presence of another spider, but there was little, if any, evidence of the initiation of courtship. Both spiders typically displayed a mutual indifference toward each other. In a few instances one attacked the other. Unless the writer intervened, these attacks always culminated in the death and consumption of one of the spiders. Kaston found (1936) that certain males of the families Salticidae, Lycosidae, Pisauridae, and Thomisidae could be stimulated to initiate courtship by the presence of females of other species, and even by other males. The writer has been unable to demonstrate satisfactorily a comparable response

in male agelenopsids. Additional investigation of this specific problem is indicated, however, by the data already obtained.

All spiders used in the attempted cross matings were permitted to copulate with spiders of their own species both before and after the attempts at interspecific mating. This was done to insure selection of individuals that were capable of sexual stimulation. In many instances one or both of the spiders failed to copulate with members of their own species after attempts at cross mating. These instances have not been included in Appendix A, as their significance is questionable.

## DISCUSSION AND CONCLUSIONS

While few araneologists have attempted to unravel the complexities presented by the mechanical aspects of copulation in the spiders, the literature is quite voluminous relative to the superficial aspects of mating. Nevertheless, virtually nothing has been reported with reference to correlating the behavioristic manifestations with the morphological and physiological characteristics of the copulatory structures. In the investigation herein reported the characteristics of the copulatory structures were found to be responsible for many of the behavioristic manifestations of the agelenopsids. On the basis of the correlations found to exist, this investigation was expanded as much as time and material permitted in order to determine the morphological possibility of the existence of similar correlations in other genera of Agelenidae and in other families of Entelegynae.

## STRUCTURE AND FUNCTION OF GENITILIA

In spite of the fact that the structure of the palpus of the agelenopsids appears to be very complex and to vary markedly in representatives of the various species of this genus, the fundamental structural design is relatively simple and remarkably constant throughout the genus.

The fundamental configuration of the proximal segments of the palpus is constant in all agelenopsids. Similarly, the functions, including such things as the angles of articulation and the extensor mechanism, appear to be similar. The same basic similarities are found in the other genera of Agelenidae.

The tibial apophysis serves in the locking mechanism of the agelenopsid palpus. The position of this apophysis varies sufficiently in members of *Cybacota* and *Cybaeina* as to possibly necessitate slight modifications of the behavior pattern of locking. The lack of the tibial apophysis in *Wadotes* appears to be compensated for by the strongly



produced depression in the proximomesal margin of the cymbium. A special problem is posed by the fact that the cymbium cannot impinge upon the tibial apophysis in the specimens of *Tegenaria domestica* available for this study. Studies in vivo of representatives of the four genera just mentioned would be necessary to determine the extent of the behavioristic changes which probably would be necessitated by the morphological variations. In such genera as *Erigone* (Micryphantidae), *Epeira* (Epeiridae), *Dolomedes* (Pisauridae), *Gnaphosa* (Gnaphosidae), *Clubiona* (Clubionidae), *Oxyptila* (Thomisidae), and *Habronattus* (Salticidae) the frequent occurrence of a tibial apophysis, which is similar to that of the agelenopsids, indicates that this apophysis is commonly present, and probably serves a similar function in all these genera.

Morphologically, the proximal portion of the genital bulb is relatively invariable not only in the Agelenidae, but also in a considerable number of other families of the Entelegynae. Structurally, the basal haematodochae of representatives of *Chiracanthium* and *Clubiona* (Clubionidae), *Gnaphosa* (Gnaphosidae), *Pardosa* (Lycosidae), *Spirembolus* (Micryphantidae), and *Misumena* (Thomisidae) are similar. Moreover, the agelenopsid rotating type of haematodochal expansion is demonstrable, by means of artificial inflation, in each of the aforementioned genera. In some instances, however, the magnitude of this rotation appears to be somewhat less than that of the agelenopsids. Thus, the morphology of the basal haematodocha is strikingly uniform in all representatives of the Entelegynae examined during this investigation. A comparable similarity can be observed in the function of the basal haematodocha during copulation in the Agelenidae, Clubionidae, and Thomisidae. These observations indicate that the fundamental mechanical aspects of the activities of the genital bulb are similar, if not identical, in these three families. Furthermore, it appears probable that the fundamental mechanics of the genital bulb, as previously described in the agelenopsids, may apply to most of the Entelegynae as well.

The petiole varies considerably in its degree of development in the various genera of Agelenidae. It is strongly developed in the Clubionidae, Lycosidae, and Micryphantidae. Owing to the extreme reduction of this structure in some genera of Agelenidae, it appears that the function of the petiole may be advantageous but not necessarily vital to the activity of the genital bulb. When the petiole is present, however, its apparent function in facilitating the ectal displacement of the inflating genital bulb is clearly indicated.

Only superficial variations are found in the subtegulum of the agelenopsids. The lunate plate is well developed in every specimen of *Entelegynae* examined. The fundus also is demonstrable in virtually every expanded subtegulum. The anelli, although variable in their degree of development and in morphological configuration, are found in all *Agelenidae* except in the genus *Wadotes*. The anelli are also found in the *Clubionidae* and the *Micryphantidae*, but are wanting in the genus *Pardosa* (*Lycosidae*). Thus the subtegulum should probably be considered as a vital structure in the genital bulb of the *Agelenidae*, and possibly in most, if not in all, of the *Entelegynae*. The lunate plate, likewise, appears to be a vital structure. Strongly developed anelli, on the contrary, are not universally found in either the *Agelenidae* or in the *Entelegynae*. Probably the most important function of the anelli is that of strengthening the subtegulum. What effects the absence of the anelli would have on the action of the genital bulb are not known.

The middle haematodocha is found in all *Entelegynae* examined, although its degree of development varies somewhat in the different families. The facies of the tegulum are extremely variable. Fundamentally, however, the tegulum is essentially the same throughout the *Agelenidae*, and in the other *Entelegynae* considered. The frontal plate of the tegulum is rather variable even within the homogeneous agelenopsids. That the tegulum constitutes a solid base for the embolus and accessory structures is amply attested by this investigation.

The conductor performs an essential function in the locking mechanism in the agelenopsids. Conductorlike structures of comparable basic configuration are found in functionally suitable positions on the tegula of representatives of other genera of *Agelenidae*. However, only studies *in vivo* can conclusively determine whether or not they also have a coupling function. In view of the dual locking and coupling function performed by the tibial apophysis of males of the species *Sparassus virescens* observed by Bristowe, and the same function performed by the tibial and cymbial apophyses of males of *Chiracanthium inclusum* as herein reported, it appears that the locking mechanism may also occur in other *Entelegynae*. Gertsch (1949, p. 97) was of the opinion that some of the apophyses of the genital structures were used to "fix the palpus in just the right position to make pairing possible," but he further considered that many of these structures have undergone excessively elaborate modifications beyond those needed to fulfill their original function. The tibial apophyses found in *Hololena* and *Novalena* appear to be such excessively elaborate developments, although they probably are still functional.

In the agelenopsids, the locking mechanism serves not only in orienting the embolus, but in providing a sufficiently solid base to permit forcing the embolus into the bursa. In view of the considerable resistance incidental to maximum total insertion, this anchoring effect of the locking mechanism assumes major importance. The locking mechanism is so vital in the copulation of the agelenopsids, and apparently in the clubionid genus *Chiracanthium*, that further investigations relative to the locking mechanism in other Entelegynae are indicated.

The morphological configuration of the long, heavy embolus of the agelenopsids is closely correlated with the large, cavernous bursa of the female. In the *Cicurina*, the long, filamentous embolus appears to be closely correlated with the slender, convoluted tubes extending from the atrium to the spermatheca. The emboli of the agelenids are highly variable in length and in diameter. Fundamentally, the agelenid embolus has a circular configuration when viewed from the frontal aspect. This circular configuration is not limited to the Agelenidae, however. It occurs in such widely divergent genera as *Clubiona* (Clubionidae), *Dictyna* (Dictynidae), *Argiope* (Epeiridae), *Gnaphosa* (Gnaphosidae), *Linyphia* (Linyphiidae), *Walckenaera* (Micryphantidae), *Habronattus* (Salticidae), *Asagena* and *Theridion* (Theridiidae), and *Oxyptila*, *Tmarus*, and *Xysticus* (Thomisidae). The aforementioned examples display a strikingly diagrammatic conformity to the basic circular configuration of the embolus. The preponderance of other genera of the Entelegynae similarly have emboli which generally agree with this configuration. The circular embolus virtually necessitates a rotating movement of the genital bulb in order to accomplish insertion. This in turn indicates that the fundamental mechanical functions of the genital bulb are essentially the same in at least most members of the Entelegynae.

In the agelenopsids such features as the radix, the tethering membrane, and the median apophysis are important in the mechanics of copulation. The radix loses its identity in other genera of agelenids by being incorporated into the tegulum or the tegular plate. The functions of the tethering membrane and the median apophysis in the other genera of agelenids have not yet been determined. In fact, the existence of a tethering membrane has not been demonstrated in many of the agelenid genera.

The copulatory apparatus of the agelenid females can be classified conveniently as belonging to two fundamental morphological types: (1) Those having saccular bursae, and (2) those having filamentous

bursae. The bursae of some *Cicurina* are more or less transitional between the two basic configurations. As previously indicated, a very close correlation exists between the size of the embolus of the male, particularly in reference to its diameter, and the degree of bursal development in the female. Thus, while it would be mechanically possible to introduce a filamentous embolus of the *Cicurina* into the saccular bursa of an agelenopsid, a reciprocal mating would be impossible. This incompatibility stems from the small diameter and the convoluted configuration of the bursa of the *Cicurina*. Cephalically directed, saccular bursae with definitive plications appear to exist exclusively in the agelenopsids.

The fundamental configurations of the epigyna are relatively constant in any given genus in the Agelenidae. The specific functions of the various accessory processes on the epigyna in this family can be determined only through studies *in vivo*. It appears likely, however, that at least some of these processes serve a function similar to that of the coupling cavity in the agelenopsids. The coupling cavity is an essential morphological feature in agelenopsid copulation. Morphological configurations of the posterior median sclerite, which would be mechanically suitable for coupling, are found in the agelenid genera *Blabomma*, *Calilena*, and *Rualena*. If the coupling mechanism does exist in other agelenids, the morphological structures involved in the process are still obscure. The occurrence of definitive coupling cavities in the females of *Sparassus virscens*, however, suggests that the coupling mechanism may occur more generally in the Entelegynae than has been suspected heretofore.

Because of the great variability of the female copulatory structures in the agelenids and other Entelegynae, generalizations are difficult to formulate. In the Entelegynae all females have atrial apertures leading through a bursa into a heavily sclerotized and darkly pigmented spermathecum.

In all probability, the various configurations of the agelenid bursae have necessitated marked modifications in the morphological configurations of the various parts of the genital bulb and their relative positions on the bulb of the male. These modifications in turn probably have necessitated additional modifications in the details of the coupling and the locking mechanisms, as well as in the process of insertion.

#### COPULATION AND MECHANICAL STRUCTURES

A close correlation exists between the process of copulation and the mechanical configuration of the copulatory structures in the agelenop-

sids. The proximal segments of the palpus permit the positioning of the genital bulb for copulation. The limits of articulation of these proximal segments play a major role in the locking mechanism. The tibial apophysis is an integral factor in the locking mechanism. The mechanical configurations of the proximal segments of the palpi of other agelenids indicate the probability of a similar mechanism in them also.

The mechanical configurations of the genital bulb of the agelenopsids are admirably adapted for their functions with relatively little indication of orthogenetic tendencies. The size, position, and the twisted configuration of the basal haematodocha permit ectal displacement of the genital bulb to a position directly over the epigynal atrium, while subsequent inflation provides sufficient rotation to drive the embolus to maximum total insertion within the bursa. Virtually the same morphological configuration of the basal haematodocha is found in every specimen of *Entelegynae* herein considered. While the petiole appears to assist in the ectal displacement of the genital bulb in the agelenopsids studied *in vivo*, its marked reduction in other agelenids raises some question as to its actual value in this process. The petiole is found, however, in a considerable number of other *Entelegynae*.

The lunate plate of the subtegulum is found in all male *Entelegynae* previously considered. Its articulation with the tegulum appears to be an integral part of the fundamental mechanical operation of the agelenid bulb, and probably is equally as important in the majority of other *Entelegynae*. The absence of anelli from the subtegula in *Wadotes* could be interpreted as being indicative of the relative unimportance of these structures in the mechanics of copulation. If the anelli are not vital, the strong development of these structures in the agelenids and certain other families of *Entelegynae* could conceivably be the result of orthogenesis.

The universal occurrence of the tegulum, with virtually no change in its fundamental morphological configuration throughout the *Entelegynae*, indicates that this structure probably is of major importance in the process of copulation in these spiders. It further suggests that the fundamental mechanics of copulation may be the same throughout the *Entelegynae*.

The intimate correlation existing between the conductor and the coupling cavity in the agelenopsids was discussed earlier. The importance of this physical correlation in the agelenopsids leads one to suspect that comparable mechanisms probably exist in other agelenids, and possibly in many other families of *Entelegynae*.

As previously indicated, a close physical correlation exists between the embolus and the bursa throughout the agelenids. The large, flattened embolus of the agelenopsids, with its ability to bend sufficiently to negotiate the turns necessary to attain maximum total insertion, conforms closely to the physical configuration of the agelenopsid bursa. Presumably similar correlations exist in other Entelegynae.

The function of the median apophysis of the agelenopsids has been discussed. The roles of the elaborate median apophyses found in other agelenids and in other Entelegynae are unknown. They may serve in the coupling and locking mechanisms; or they may be structures, with or without function, which have undergone marked orthogenesis.

#### STRUCTURAL MECHANICS AND COPULATORY BEHAVIOR

Most of the copulatory behavior patterns are essentially only manifestations of the mechanical aspects of copulation. Thus, the correlations existing between the copulatory structures and the mechanical details of the process of copulation are reflected in the more easily observed sexual behavior patterns.

The morphological configurations of the bursa and the embolus necessitate the assumption of the typical agelenid copulatory stance if copulation is to be accomplished by the agelenopsids. It can be demonstrated, by means of models, that coupling can be accomplished from other positions by the agelenopsids. However, the structural and functional limitations of the genital bulb preclude the possibility of bringing the locking mechanism into effective use except when the male is in the typical copulatory position. Hence it is impossible, except when the spiders are in the "normal" copulatory position, to force the embolus beyond the point of initial insertion. It is doubtful whether ejaculation could occur under these conditions. Even if ejaculation could occur, the seminal fluid would be deposited in the proximal portion of the bursa, and would tend to flow back down toward the atrium because of the inclined orientation of the bursa. Under these conditions, the entry of sufficient seminal fluid into the spermathecum to insure subsequent fertilization of any sizable number of eggs would be highly improbable.

The grasping of the patellae of the female by the male upon establishment of initial contact, the reversal of the male, the positioning of the female by the male, and finally the assumption of his own copulatory stance are all behavior patterns forced upon the male agelenopsid by the mechanical configurations of the copulatory structures. The

possibility of successful copulation is largely precluded if the male deviates radically in his performance of any of these activities. The results of this investigation suggest that a similarly close correlation probably is demonstrable between the mechanics of copulation and many of the copulatory behavior patterns in other *Entelegynae*.

The habit of cleaning the palpi has been described in several different families of spiders. This study indicates a lubricative function for this process. The resistances encountered during the insertion of the embolus and in the process of locking warrants such a function in the agelenopsids. However, further study is indicated as necessary relative to the cleaning process, its function, and its significance.

It is becoming increasingly more evident that many of the behaviorisms seen during the copulation of spiders stem from limitations imposed on the spider by morphological configurations and the dynamics of copulatory mechanics rather than from "instinct patterns" originating within the animal's nervous system.

#### VALIDITY OF LOCK-AND-KEY CONCEPT

Extreme size difference will preclude both intra- and interspecific matings. It appears, however, that in agelenopsids of approximately comparable size all emboli can be introduced to the maximum total insertion position in any bursa, with one possible exception. The emboli of males of *A. pennsylvanica* are so short that maximum total insertion can be accomplished in representatives of other species only when the females are unusually small. Conversely, the bursa of females of *A. pennsylvanica* can accommodate the long emboli of males of *A. oklahoma*. Practically, however, it is questionable if a living female would submit to the treatment that such accommodation would necessitate. In the agelenopsids, neither the morphological configuration of the embolus nor that of the bursa appear to present incompatibilities which would conclusively preclude interspecific mating.

The coupling cavities found in females of *A. oregonensis* and *A. utahana* are unique in this genus because of the frequent reduction of the ectal depressions. The ectodistal process of the conductors of the males in these two species, however, are modified into a hook which fits in behind the strongly recurved margin of the coupling cavity. Thus coupling can be achieved in these two species. All other agelenopsids force the straight, fingerlike ectodistal process of the conductor into the coupling cavity depressions in order to accomplish coupling. Mechanically, it is possible for the straight conductor to be coupled to the epigynum of females of *A. oregonensis* and *A. utahana*

whose ectal depressions are not too strongly reduced. Whether the males of these two species could secure a sufficiently firm attachment in the coupling cavities of other agelenopsid females in order to copulate can be determined only by further studies *in vivo*. The remaining features of the agelenopsid genital structures are sufficiently alike in morphological configuration that they may be eliminated as possible mechanical incompatibilities.

Thus it is possible that mechanical incompatibilities might prevent a male of *A. pennsylvanica* from successfully mating with a female of some other agelenopsid species. Mechanical incompatibilities might make interspecific mating difficult, though not necessarily impossible, between specimens of either *A. oregonensis* or *A. utahana* and the other agelenopsids. Except for extreme size differences and the aforementioned instances, there appear to be no mechanical incompatibilities which would prevent interspecific copulation within the agelenopsids. The lock-and-key concept is not applicable in the majority of agelenopsids. Additional studies, particularly studies *in vivo*, would be necessary in order to definitely establish whether or not the morphological features in the specimens of the species just mentioned actually do constitute mechanical incompatibilities.

While a close morphological correlation exists between the emboli of the males and the copulatory structures of the females in the other agelenids as well, the degree of this correlation does not appear to be sufficient to constitute a morphological incompatibility which could generally prevent cross mating. It appears likely that mechanical incompatibility, if it exists at all, will be found to be the exception rather than the rule within other genera of Agelenidae as it apparently is within the genus *Agelenopsis*. Gertsch (1949, p. 98) suggested that the possibility of copulation between specimens of different but closely allied groups of spiders would probably be impossible in most instances. Certainly copulation between males of the subgenus *Barronopsis* and females of any of the other species of *Agelenopsis* gives every indication of being mechanically impossible. The radically different configurations of the genital structures would preclude this possibility. Such matings, *i.e.*, between representatives of different genera or subgenera, however, are of little importance from the evolutionary point of view. On the contrary, a functional isolating mechanism resulting from mechanical incompatibilities between specimens of two closely related species could be of major importance in the process of speciation. The preponderance of evidence indicates that the isolating mechanism in the agelenopsids is not mechanical incompatibility of the



copulatory structures, but is rather of a psychological or physiological nature.

#### INTERSPECIFIC COPULATION

No instances of interspecific matings were obtained during the investigation herein reported, although the specimens used were known to be sexually excitable. In each instance the male became aware of the female, but apparently failed to recognize her as a potential mate. The response of the male toward a mature female of a different species was found to be essentially the same as that toward other males and immature females of his own and other species.

Kaston (1936, pp.143-144) stated:

In those species in which the male does not court upon merely seeing the female, it may mean that either he has too low an acuity of vision and hence cannot recognize her, or that this recognition is insufficient stimulus to incite courtship. There may be a threshold value which constitutes a link in the chain of instinctive reactions. If this threshold is not attained courtship does not ensue. But if the visual stimulus is combined with another, such as touch, there will be a summation, the effect of which will bring about the response in question.

Kaston's explanation of the failure of the male vagabond spider to initiate courtship appears to explain the actions of the male agelenopsids equally as well. The fact that the males display their typical initial reactions upon seeing a female, or any other spider for that matter, indicates that they have been stimulated optically. Apparently some additional form of stimulation is needed to activate the courtship instinct in these males. As this additional stimulation is not forthcoming from the female of any species except his own, the male remains sexually passive. Thus the primary active isolating mechanism which prevents interspecific copulation in the agelenopsids appears to be either physiological or psychological in nature.

#### SUMMARY

1. The palpi of males in the genus *Agelenopsis* conform closely to a single, basic, mechanical configuration, with the exception of the subgenus *Barronopsis*. Furthermore, a fundamental pattern of the genital bulb exists throughout the other genera of the Agelenidae, and in representatives of 11 other families of Entelegynae.

2. The copulatory structures of females in the genus *Agelenopsis* conform closely to a single, basic, mechanical configuration. The copulatory structures in representatives of this genus are distinct from those of all other genera of Agelenidae in having plicated, saccular bursae which are directed anteriorly. The copulatory structures vary

radically in morphological configuration throughout the Agelenidae and other Entelegynae.

3. The previously unreported specific functions of the following copulatory structures are presented: the lunate plate, the middle haematodocha, the conductor, the tethering membrane, the median apophysis, the tibial apophysis, the coupling cavity, and the bursal plications.

4. The previously unreported probable functions of the following copulatory structures are discussed: the petiole, the anelli, and the diverticle.

5. During copulation the embolus of the male agelenopsid is introduced into the female's bursa copulatrix. The plications of the bursa permit it to stretch sufficiently to accommodate the embolus.

6. A close mechanical correlation exists between the genital bulb of the male and the copulatory apparatus of the female in many genera of Agelenidae. The detailed mechanical aspects of copulation are intimately correlated with the morphological configurations of the copulatory structures in the genus *Agelenopsis*, and apparently throughout the other genera of Agelenidae. The general conformity of the genital bulb to a fundamental mechanical configuration which is found in a considerable number of Entelegynae suggests that the detailed mechanics of copulation may be more or less uniform throughout the Entelegynae.

7. The mechanical configurations of the copulatory structures of the males and females in the genus *Agelenopsis* necessitate certain mating behavior patterns, or at least limit the range of variability found in these patterns. The mating process is virtually identical in all agelenopsid species observed.

8. The existence of a specific coupling and locking mechanism in the genus *Agelenopsis* is described. Coupling and locking are essential in the process of copulation in this genus. The significance of the mechanisms is discussed, as is the probability of their occurrence and their possible necessity in other Agelenidae and other Entelegynae.

9. The cataleptic state of the female is an essential feature in copulation in the genus *Agelenopsis*.

10. No examples of interspecific copulation were obtained during this investigation. The lock-and-key concept is poorly supported, if at all, by the morphological study of the genus *Agelenopsis*. There appears to be little if any mechanical preclusion of cross mating within this genus. The primary isolating mechanism preventing interspecific copulation appears to be either physiological, psychological, or a combination of both.

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## APPENDIX

## A. ATTEMPTED MATINGS

Family AGELENIDAE, genus *Agelenopsis*

Females	Males		
	<i>A. aperta</i>	<i>A. oklahoma</i>	<i>A. pennsylvanica</i>
<i>A. aperta</i> .....	21 (21) <sup>1</sup>	1 (0)	1 (0)
<i>A. oklahoma</i> .....	1 (0)	27 (27)	8 (0)
<i>A. pennsylvanica</i> .....	1 (0)	11 (0)	37 (37)

Family CLUBIONIDAE, genus *Chiracanthium*

Females	Males
<i>C. inclusum</i> .....	<i>C. inclusum</i> 7 (7)

Family THOMISIDAE, genus *Misumena*

Females	Males
<i>M. calycina</i> .....	<i>M. calycina</i> 11 (11)

<sup>1</sup> Figures represent matings attempted (matings achieved).

## B. COPULATION DATA

## Family AGELENIDAE

	<i>A. aperta</i>	<i>A. oklahoma</i>	<i>A. pennsylvanica</i>
Copulations observed .....	21	27	37
Insertions observed .....	112	179	256
Insertions: Number per copulation. <sup>1</sup> .....	4- 16 (5) <sup>2</sup>	5- 18 (7)	3- 18 (7)
Engaging embolus: Duration (seconds) .....	1- 13 (4)	1- 11 (5)	1- 8 (3)
Engaging embolus: Attempts, including terminal.....	2- 16 (7)	1- 19 (9)	1- 11 (5)
Engagement of embolus to engagement of conductor (seconds) .....	4- 61 (13)	2- 41 (12)	2- 49 (8)
Engagement of embolus to maximum distention (seconds) .....	7- 73 (21)	5- 87 (16)	4- 68 (11)
Maximum distention: Duration (seconds) .....	3-193 (21)	2-142 (18)	3-171 (31)
Maximum distention: Zenith paroxysms (frequency/minute) .....	3- 43 (17)	6- 47 (13)	11- 62 (24)
Withdrawal: <sup>3</sup> Duration (seconds) .....	4- 39 (18)	2- 26 (16)	3- 34 (8)
Withdrawal: Paroxysms (frequency/minute) .....	7-120 (24)	16- 98 (22)	16-144 (32)
Initiation of withdrawal to conductor release (seconds)....	2- 34 (11)	1- 23 (8)	2- 32 (7)
Terminus release: Attempts, including terminal .....	1- 31 (9)	1- 28+(9)	1- 18 (4)
Terminus release: Duration (seconds) .....	1- 36 (8)	1- 23+(9)	1- 18 (4)
Terminus release: Attempts (frequency/minute) .....	20-160+(54)	34-140 (60)	22- 96 (60)
Duration of period between insertions (seconds) .....	4-192+(15)	3-215+(11)	3-138+(9)

<sup>1</sup> See comment, last three lines, page 63.<sup>2</sup> Figures represent minimum-maximum (mean).<sup>3</sup> When disturbed, withdrawal of embolus is virtually instantaneous.





SMITHSONIAN MISCELLANEOUS COLLECTIONS  
VOLUME 121, NUMBER 5

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Roebling Fund

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SOLAR VARIATION AND PRECIPITATION  
AT ALBANY, N. Y.

BY

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(PUBLICATION 4103)

CITY OF WASHINGTON  
PUBLISHED BY THE SMITHSONIAN INSTITUTION  
JANUARY 27, 1953

The Lord Baltimore Press  
BALTIMORE, MD., U. S. A.

## Goebbling Fund

# SOLAR VARIATION AND PRECIPITATION AT ALBANY, N. Y.

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In three recent papers<sup>1</sup> I have demonstrated that the solar radiation varies simultaneously in 23 regular periods, all nearly aliquot parts of 272 months; that normals of weather records should discriminate between intervals of numerous and few sunspots; and that the precipitation at Peoria, Ill., when considered with due regard to the season of the year and the prevailing sunspot activity, responds to the regular periodic solar variations. It was shown that when the forms and amplitudes of precipitation responses to solar variations were determined from the records of the Peoria precipitation, from 1856 to 1939, a very fair prediction of the march of precipitation from 1940 to 1950 was made by synthesis.

In short, it may be claimed that, at least for Peoria, the fluctuations of precipitation are governed chiefly by the regular periodic variations of the sun. Apart from occasional displacements of phase, as yet unpredictable, the march of precipitation has been predicted 10 years in advance to a degree of accuracy worth while for seasonal prevision, from knowledge of solar variation, combined with precipitation records for many past years. Such a prediction involves no scientific knowledge of meteorology.

*Precipitation at Albany, N. Y.*—Wishing to learn if similar results would obtain at other stations, I have carried through tabulations of the precipitation at Albany, N. Y.<sup>2</sup>

It is certainly a bold assumption that the combined influences of about 20 independent periodicities, used because they make up the variation of solar radiation, will also comprise completely the variation of terrestrial precipitation. It is an extrapolation, far beyond our present knowledge, though derived from 30 years of solar-constant observation, to suppose that these solar periodic variations

<sup>1</sup> Smithsonian Misc. Coll., vol. 117, Nos. 10, 11, and 16, 1952.

<sup>2</sup> The attention of critical readers is especially invited to figures 1, 4, and 5, and to the discussions which accompany them.

continue indefinitely with unchanging amplitudes and unchanging phases. The secular fluctuation of the sunspot period indeed argues to the contrary. Yet the results of the Peoria investigation seem to warrant further inquiry at other stations. Further remarks along this line will appear below.

As in the study of Peoria, Weather Bureau records of precipitation at Albany, in this case from 1850 to 1951, were reduced to percentages of normal, with due regard to sunspot frequency. The normal values used were as follows, decimal points omitted:

Sunspots	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Wolf numbers												
>20.....	256	252	264	245	303	351	402	364	318	269	276	209
<20.....	232	209	296	291	313	381	343	389	338	319	275	232

For a few months of excessive precipitation, the percentage values were cut down to 200, for reasons explained in the Peoria paper. With this slight modification, the percentage values of monthly precipitation were smoothed by 5-month running means.

The smoothed monthly means of percentages of normal precipitation at Albany were tabulated in the manner fully explained in the Peoria paper, above cited. Readers are referred to that paper. With advantage from my long experience in such tabulations, it is believed that the tabular departures from mean values for the numerous Albany tables are more trustworthy than those obtained for Peoria.

*Interference by alien periodicities.*—Attention was drawn in the Peoria paper to the complexity introduced by interference. Not only do all the periods confuse the record for determining each, but means of long-period precipitation tables encounter the superposition of one or several shorter periods, which are aliquot parts of the longer periods under consideration. A particularly instructive case of this kind is presented by the tabulation of the  $45\frac{1}{2}$ -month period for Albany. It will be best understood by referring to table 1 and to figure 1, curves *a, b, c, d, e, f, g*.

Table 1 contains 12 columns, relating to the  $45\frac{1}{2}$ -month period. Columns 1 and 2 are the mean values representing, respectively, the Albany precipitation of 1850 to 1899 and 1900 to 1939 as tabulated according to the  $45\frac{1}{2}$ -month period. In these two columns are given the smoothed percentages of normal precipitation. In all the subsequent columns the units used are tenths of 1 percent.

The averages of the 45 values in each of the columns 1 and 2 were computed, and the departures from these averages were obtained. These departures are not given in table 1, but they are plotted in curves *a* and *c* of figure 1.



As it is plain that the curves *a* and *c* are highly similar, and in identical phases, the mean values of the departures which compose them were obtained, as given in column 3, and plotted in the heavy curve *b*.

TABLE I.—*Treatment of the periodicity of 45½ months. Unit values tabulated are percentages of normal precipitation or tenths thereof*

(See text for explanation.)

I	2	3	4	5	6	7	8	9	10	11	12
100.8	96.6	- 30	-16	- 14	+30	- 44	-44	0	-27	+27	+25
98.3	89.3	- 79	-20	- 59	- 2	- 57	-38	-19	-29	+10	+17
106.3	93.9	- 15	0	- 15	-10	- 5	- 9	+ 4	-10	+14	+10
109.5	97.2	+ 17	+ 9	+ 8	-21	+ 29	+16	+13	- 8	+ 5	+ 6
104.1	95.6	- 18	+ 3	- 21	-41	+ 20	+25	- 5	- 6	+ 1	+ 2
107.1	100.3	+ 20	+29	- 9	-41	+ 32	+31	+ 1	+ 4	- 3	- 5
109.2	104.5	+ 52	+23	+ 29	-27	+ 56	+32	+24	+23	- 4	- 8
108.1	102.6	+ 37	+34	+ 3	- 1	+ 4	+12	- 8	+10	-18	-12
107.7	103.4	+ 39	+20	+ 19	+26	- 7	-21	+14	+41	-27	-14
112.4	103.1	+ 61	+28	+ 33	+54	- 21	-44	+23	+39	-16	-16
113.3	101.1	+ 55	+20	+ 35	+30	+ 5	-38	+43	+37	+ 6	-18
108.3	96.5	+ 4	-15	+ 19	+30	- 11	- 9	- 2	+34	-36	-19
107.0	97.6	+ 6	-28	+ 34	- 2	+ 36	+16	+20	+34	-14	-20
105.1	93.1	- 25	-35	+ 10	-10	+ 20	+25	- 5	+18	-23	-22
102.7	94.0	- 33	-23	- 10	-21	+ 11	+31	-20	+13	-33	-24
99.6	95.0	- 43	-16	- 27	-41	+ 14	+32	-18	+ 3	-21	-26
97.3	89.5	- 80	-20	- 60	-41	- 19	+12	-31	-15	-16	-28
90.8	87.6	-124	0	-124	-27	- 97	-21	-76	-44	-32	-30
92.8	92.4	- 91	+ 9	-100	- 1	- 99	-44	-55	-17	-38	-31
93.7	92.2	- 88	+ 3	- 91	+26	-117	-38	-79	-40	-39	-32
95.8	92.3	+ 13	+29	- 16	+54	- 70	- 9	- 61	- 35	-26	-32
105.6	99.3	+ 8	+23	- 15	+30	- 45	+16	- 61	- 9	-52	-30
109.4	102.6	+ 43	+34	+ 9	+30	- 21	+25	-46	-23	-23	-27
106.0	102.5	+ 26	+20	+ 6	+30	- 24	+31	-55	-27	-28	-23
105.9	101.5	+ 20	+28	- 8	- 2	- 6	+32	-38	-29	- 9	-18
102.5	100.5	- 1	+20	- 21	-10	- 11	+12	-23	-10	-13	-13
93.3	92.7	- 86	-15	- 71	-21	- 50	-21	-29	- 8	-21	- 7
90.4	89.2	-120	-28	- 92	-41	- 51	-44	- 7	- 6	- 1	- 1
90.8	91.0	-107	-35	- 72	-41	- 31	-38	+ 7	+ 4	+ 3	+ 5
101.5	97.7	- 20	-23	+ 3	-21	+ 24	- 9	+33	+28	+ 5	+10
107.6	101.0	+ 26	-16	+ 42	- 1	+ 43	+16	+27	+10	+17	+14
115.6	107.5	+ 99	-20	+119	+26	+ 93	+25	+68	+41	+27	+18
119.5	111.5	+139	0	+139	+54	+ 85	+31	+54	+39	+15	+20
115.2	108.6	+102	+ 9	+ 93	+30	+ 63	+32	+31	+37	- 6	+22
116.0	110.1	+114	+ 3	+111	+30	+ 81	+12	+69	+34	+35	+23
109.3	105.0	+ 55	+29	+ 26	- 2	+ 28	-21	+49	+34	+15	+25
105.8	99.3	+ 9	+23	- 14	-10	- 4	-44	+40	+18	+22	+27
107.7	99.8	+ 21	+34	- 13	-21	+ 8	-38	+46	+13	+33	+29
106.3	95.7	- 6	+20	- 26	-41	+ 15	- 9	+24	+ 3	+21	+31
107.2	97.0	+ 4	+28	- 24	-41	+ 17	+16	+ 1	-15	+16	+32
105.7	98.7	+ 5	+20	- 15	-27	+ 12	+25	-13	-44	+31	+34
107.6	103.1	+ 37	-15	+ 52	- 1	+ 53	+31	+22	-17	+39	+35
106.0	103.1	+ 29	-38	+ 57	+26	+ 31	+32	- 1	-40	+39	+37
104.2	102.4	+ 26	-35	+ 61	+54	+ 7	+12	- 5	-35	+30	+39
101.9	98.4	- 15	-23	+ 8	+30	+ 22	-21	+43	- 9	+52	+39

Scanning the curve *b*, one suspects a subperiod of  $\frac{1}{3}$  of 45½ months. The values in column 3 were arranged in three columns of 15½ months; their mean, computed and repeated three times, is given in

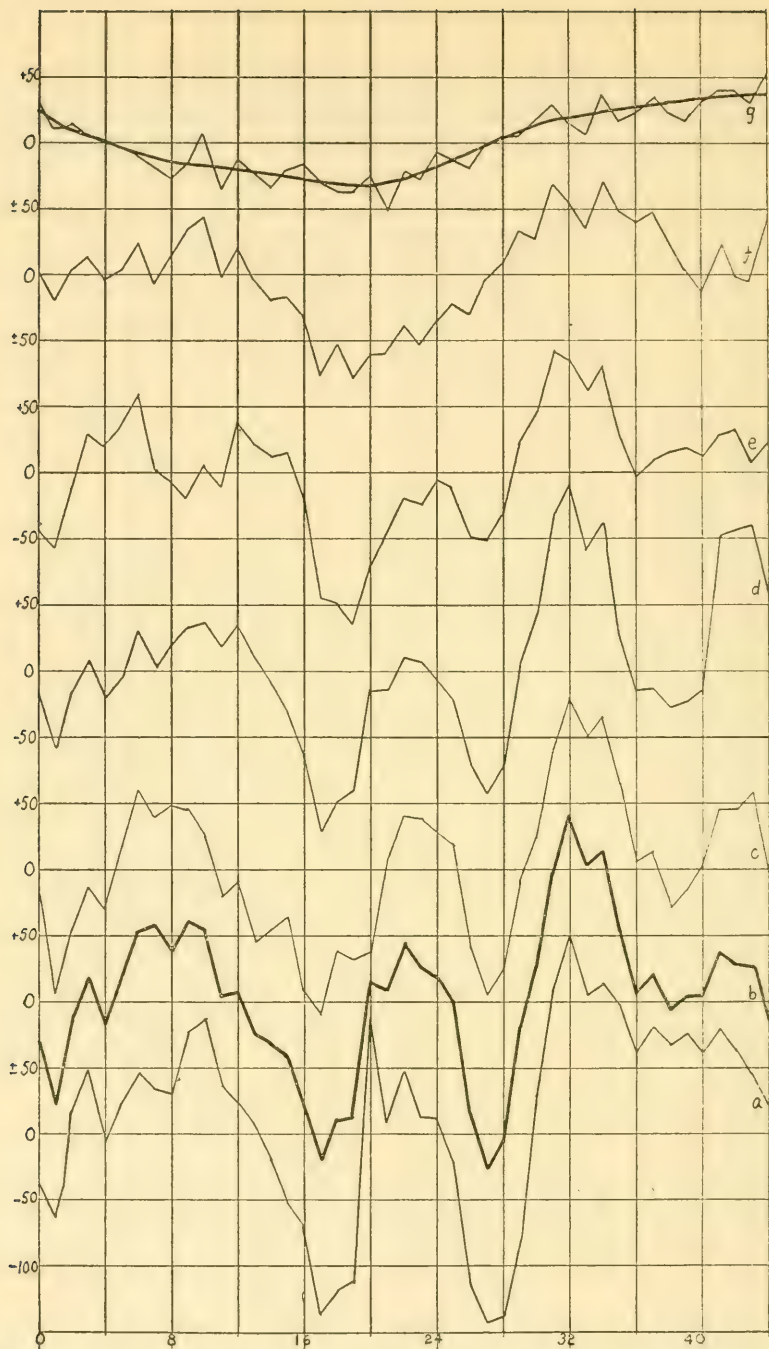


FIG. 1.—The 45½-month periodicity in Albany precipitation, cleared of overriding periodicities, integral submultiples thereof.

column 4, table 1. Subtracting column 4 from column 3 yields column 5, as plotted in curve *d* of figure 1.

There now appears a suggestion of four subperiods. The  $11\frac{1}{5}$ -month period was therefore determined similarly, yielding columns 6 and 7 of table 1, and curve *e* of figure 1. Curve *e* suggests five subperiods of  $9\frac{1}{6}$  months. Proceeding similarly, we obtain columns 8 and 9 of table 1, and curve *f* of figure 1.

It is now apparent that there remains, as curve *f*, a curve of a double maximum, with similar halves. Computing for the period of  $22\frac{4}{5}$  months, we obtain columns 10 and 11 of table 1, and curve *g*. Curve *g*, being smoothed by the heavy line, yields column 12 of table 1.

Here, then, is the  $45\frac{1}{2}$ -month period in Albany precipitation cleared of periods of  $\frac{1}{2}$ ,  $\frac{1}{3}$ ,  $\frac{1}{4}$ , and  $\frac{1}{5}$  of itself. These periods, together with that of  $45\frac{1}{2}$  months are  $\frac{1}{6}$ ,  $1/12$ ,  $1/18$ ,  $1/24$ , and  $1/30$  of approximately  $22\frac{3}{4}$  years. This is confirmatory of the conclusion that the sun's regular periodic variations are all aliquot parts of  $22\frac{3}{4}$  years.

*Improvements over Peoria tabulations.*—In the Peoria paper very little attention was given to thus clearing the longer periods from overriding shorter periods. Consequently such shorter periods entered more than once into the predictions synthesized in the Peoria paper. They came in directly by including them intentionally, but they came in again one or more times in the longer periods, of which these shorter periods are aliquot parts.

In the present Albany paper all the longer periods,  $22\frac{4}{5}$  months and over, were analyzed as has just been shown regarding the period of  $45\frac{1}{2}$  months. All these longer periods were cleared of the incumbrance of the shorter ones, whose lengths were aliquot parts of theirs, whenever such incumbrances were of significance.

*Counteracting the weakness due to great subdivision of data.*—Another important improvement was made for the periods ranging from  $9\frac{3}{4}$  to  $15\frac{1}{6}$  months, inclusive. Owing to the necessary subdivision of the data, because of phase changes proper to the season of the year and to sunspot activity, as explained in the Peoria paper, these seven periodicities were all determined by too few columns of repetition to yield weighty mean values. To overcome this defect, in the present paper all the individual mean values relating to a single periodicity, within a single status of sunspot activity, were shifted to a common phase and the mean of all of them taken. These general means, one relating to low, the other to high sunspot numbers, and depending on all the monthly records from 1850 to 1939, were employed to represent the period in question. Appropriate shiftings of its phase were made to suit the time of the year, when these mean

values were used in the syntheses to be disclosed below. This treatment will be better understood by the following tabular and graphical illustrations, relating to the period of  $11\frac{1}{2}$  months. Of course, it involves the doubtful assumption that the effect of a solar change is of equal amplitude at all seasons of the year. But even if not, a strong mean value is better than three poor ones.

Directing our attention to years of sunspot numbers  $>20$ , table 2 gives the six mean marches of the  $11\frac{1}{2}$ -month period corresponding to the seasons January-April, May-August, September-December, in two groups of the years 1850 to 1899 and 1900 to 1939. These mean values are plotted in figure 2, and are there distinguished by subscripts,  $A_1 A_2, B_1 B_2, C_1 C_2$ . The curves marked with subscripts 1 relate to the years 1850-1899, and those with subscripts 2 to the years 1900-1939. Along with each of the six curves is given an arrow and a figure. These symbols denote that the numerical values representing the curve in table 2 were shifted up, for arrows pointing to the left, by as many months as given by the figures, and down, correspondingly, for arrows pointing to the right. The curves as thus shifted are given in dotted lines in figure 2. Brought thus to a common phase, the general mean was taken, as given by the next to last column of table 2. These general mean values are plotted as  $D$  at the top of figure 2. In figure 3 and table 3 a similar treatment is indicated for years of sunspot numbers  $<20$ . It will readily be seen that the two curves representing the general means for sunspots  $\geq 20$  are of similar form, though in different phases.

*Relation of phases in periodicities.*—Comparing individually the phases of the curves in figures 2 and 3, which, as has been said, are representative of periods of high and low sunspot numbers, we notice that the two curves  $C_2$  are similar and in the same phase. That is to say, for the periodicity of  $11\frac{1}{2}$  months, in the months September to December, the precipitation march is similar in form and in phase, for sunspot numbers  $\geq 20$ , in the years 1900 to 1939. The curves  $B_2$  are too indefinite to be compared advantageously. The curves  $A_2$ , while somewhat similar in form, are separated by about two months in phase. The phases of the pairs of curves  $C_1, B_1$ , and  $A_1$  representing the years 1850 to 1900, differ greatly, and indeed are nearly opposite in the case of curves  $C_1$ . These comparisons bring out clearly why it was necessary to separate years of high and of low sunspot numbers in this analysis, as well as the necessity of separating the seasons.

In tabulating the periodicities between  $9\frac{3}{4}$  and  $15\frac{1}{6}$  months in length, for the syntheses to be described below, departures from the average in such general mean values as  $D$ , just explained, are entered in the

TABLE 2.—Treatment of 11½-month periodicity in Albany precipitation  
Sunspot numbers >20

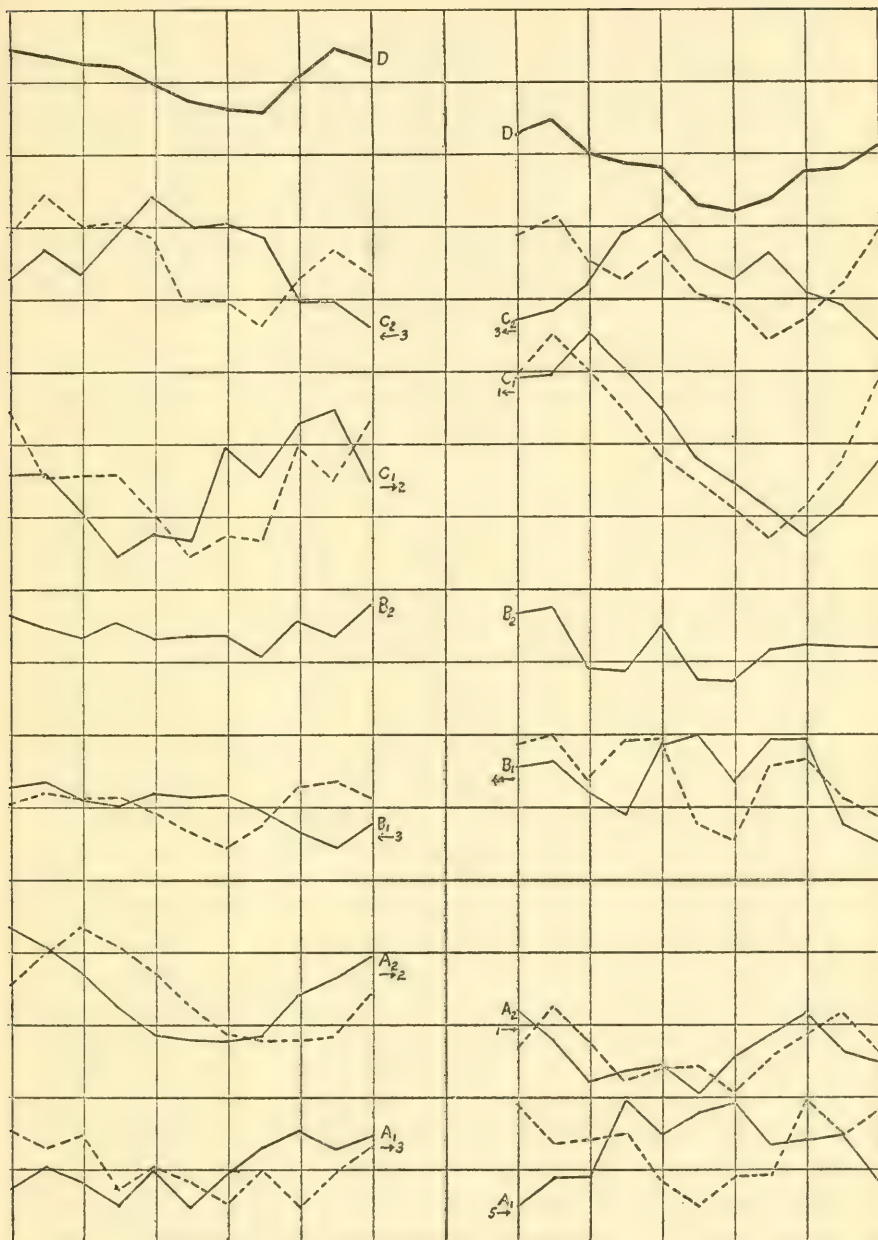
Mean values tabulated are percentages of normal precipitation. Units tenths percent  
(See text for explanation.)

Jan.-Apr.		May-Aug.		Sept.-Dec.		$A_1\sqrt{3}$	$A_2\sqrt{2}$	$B_1\sqrt{3}$	$B_{2-0.K.}$	$C_1\sqrt{2}$	$C_2\sqrt{3}$	Mean	Departures
1850 to 1900	1000 to 1939	1850 to 1899	1900 to 1939	1850 to 1899	1900 to 1939	1152	1018	1001	964	1148	998	1045	+35
1899	1939	1899	1939	1899	1939	1130	1037	1018	946	1052	1042	1037	+27
$A_1$	$B_1$	$C_1$	$C_2$	$A_1$	$B_1$	1147	1017	1011	932	1058	1002	1028	+18
1071	1035	1027	964	1058	928	1071	1032	1015	952	1059	1004	1022	+11
1101	1008	1036	946	1059	968	1081	964	992	931	1007	986	997	-13
1081	972	1010	932	1007	936	1071	1032	1015	952	1059	1004	1022	-13
1051	924	1001	952	944	988	1071	1032	1015	952	1059	1004	997	-13
1096	886	1018	931	973	1042	1081	964	992	931	1007	986	997	-13
1048	878	1011	857	967	1002	1081	995	963	857	944	890	973	-37
1094	877	1015	937	1006	1004	1051	973	944	937	973	898	963	-47
1131	882	1053	908	1053	896	1096	946	975	908	967	861	959	-51
1152	940	1127	899	1127	899	1048	986	1027	956	1096	928	1007	-3
1130	903	1148	808	1148	808	1094	943	1036	934	1053	968	1047	+37
1147	996	1052	861	1052	861	1131	987	1010	976	1127	936	1028	+18

Mean 1010

TABLE 3—Treatment of 11½-month periodicity (continued)  
Sunspot numbers <20

$A_1$	$A_2$	$B_1$	$B_2$	$C_1$	$C_2$	$A_1 \downarrow_c$	$A_2 \downarrow_1$	$B_1 \downarrow_1$	$B_2 \text{ o. r. c.}$	$C_1 \downarrow_1$	$C_2 \downarrow_a$	Mean	Departures
940	923	1154	966	1090	972	1090	847	1184	966	1096	989	1029	+47
987	878	1161	973	1096	883	1033	923	1198	973	1153	1015	1049	+67
980	821	1121	891	1153	919	1040	878	1136	891	1104	952	1000	+18
1094	835	1089	888	1104	989	1049	821	1187	888	1050	927	987	+5
1049	843	1184	945	1050	1015	983	835	1100	945	982	962	982	0
1077	805	1198	876	982	952	949	843	1074	876	949	907	933	-49
1090	855	1136	874	949	927	987	805	1054	874	911	891	920	-62
1033	886	1187	916	911	962	989	855	1154	916	870	844	938	-44
1040	915	1190	922	870	907	1094	886	1161	922	913	872	975	-7
1049	863	1074	920	913	891	1049	915	1121	920	973	883	977	-5
983	847	1054	919	973	844	1077	963	1089	919	1090	919	1009	+27
												Mean	982



FIGS. 2 (left) and 3 (right).—Fig. 2, combination of six separate determinations of the 11½-month periodicity into one general mean, for times when Wolf sunspot numbers exceed 20. Fig. 3, same as figure 2 for Wolf sunspot numbers less than 20.

tabulation with contrary shiftings to those indicated by figures attached to the curves  $A_2$ ,  $B_2$ , and  $C_2$ , in figures 2 and 3. That is, for example, for  $\leftarrow 2$  use  $\rightarrow 2$  in tabulating for syntheses. It will be clear to the reader that the use of departures from the average comprising general means, such as  $D$ , will tend to reduce the large accidental errors in the syntheses, such as were caused in the Peoria paper by the paucity of data then used in forming mean values. This improvement in accuracy, together with the elimination of an obvious source of error by cutting off overriding periodic values of shorter lengths from the longer periods, already explained above, make the Albany results much better than those published for Peoria.

In other respects it would be superfluous to repeat the discussions given in the Peoria paper on the methods used and the reasons for them. Interested readers may consult that paper and may be assured that the same steps were pursued for Albany as for Peoria and for the reasons elaborated in the cited paper.

*Solar periods as major aids in forecasting.*—In the Peoria paper I laid stress upon the synthesis of periodic values covering the years 1940 to 1950. I advanced the opinion that, despite unpredictable changes of phase at several points, this synthesis showed that tabulation of a long series of monthly precipitation values, in terms of 20 known regular periods of solar variation, gives a valuable basis for a prediction of seasons far in advance. But I am prepared to go farther, for on further reflection I now suggest that every monthly value resulting from such a synthesis, between the years 1900 and 1940, such as will appear in figure 4, is just as truly a prediction as if it related to the years 1940 to 1950, or even 1950 to 1960.

For consider: According to the procedure described above, each of the monthly mean periodic precipitation values obtained by synthesis for Albany rests, as a basis, on 90 years of monthly records, or 1,080 months in all. The tables are all adjusted to the average phase relations that obtained between 1900 and 1940. Considering any single month of this just-named interval, its published record of precipitation contributes only  $1/1080$  of the weight of the mean tabular representation. This consideration holds for any and for all of the 22 periods used here in synthesis. Hence the other 1,079 months govern almost exclusively the result to be obtained by synthesis for any particular month under consideration.

*Significant differences from Fourier's series in my method.*—Some critics will suggest, and of course it is true, that almost any curve can be represented by a series of a sufficient number of sine and cosine terms. Hence, they may say, a fair correspondence between my syn-



thesis of periodic terms and the observed march of precipitation has no weight as a predictive test of the method. My late friend, Dr. Dayton C. Miller, with his harmonic analyzer, even represented a girl's facial profile by a Fourier series of sine and cosine terms.

But there is a significant difference between a Fourier analysis and my treatment of the precipitation at Albany. In the first place, the march of precipitation over a long term of years is a far more complicated curve than a girl's facial profile. In the second place, I am limited to 22 periodic terms to represent it, and these periodicities are dictated by the variations demonstrated in the sun's radiation. In the third place, instead of being a mathematical derivative of a sine or cosine form, each of the 22 periodicities found in the precipitation at Albany, has an individual form, independently determined. This form, though subject to moderate changes of phase, it preserves throughout its repetitions, over an interval of 90 years.

There can be no "fudging," or, in other words, correction of the periodicities to better suit the event. Each is determined once for all, the number of them is limited, and the sum total of them all is rigidly added up. It is quite otherwise in a Fourier's series. The number of terms is unlimited. New terms may be added indefinitely to better and better approximate the curve to be represented. And none of these sine and cosine terms represents a reasonable physical fact of observation. It is merely a mathematical abstraction.

*The merit of the method tested.*—As stated earlier, it is undoubtedly a very bold presumption that the synthesis of 22 independently determined periodic effects, chosen because their periods coincide with periods in the variation of solar radiation, should closely represent the total fluctuation of terrestrial precipitation. It involves the belief that no other factors, such as highly complicated atmospheric reactions involving the earth's rotation, and all of the sun's and the moon's obscure influences in combination, compare in effect with the control exercised by the regular periodic variations of the sun's emission of radiation, small in percentage though these are. What next follows, I hope, supports this presumption.

*A very long-range test forecast.*—It will doubtless be admitted by critics that if a synthesis of my periodicities, determined from records far antedating the particular years under consideration, should show a good correspondence with observation, and with the synthesis plotted in figure 4, it would be both an unexceptionable forecast, and a support to my contention that figure 4, itself, deserves to be regarded as a forecast.

I have made such a synthesis, based entirely on precipitation records for the years 1850 to 1899. It purports to indicate what the precipitation should be at Albany from January 1928 to May 1931. Referring to figure 5, the heavy full curve represents the observed smoothed percentage departures of precipitation from normal at Albany, N. Y. The full light curve is identical to that part of the synthetic curve of figure 4 which covers the interval 1928 to 1931. The dotted curve is synthesized from records of precipitation of the years 1850 to 1899 exclusively, using no records from later years.

For the first 16 months, January 1928 to April 1929, there is obvious similarity of forms and phases between the three curves of figure 5. Then occur moderate changes of phase, much less considerable than some that were encountered in the Peoria paper. The thin full curve goes, at first one, and then two months ahead of the heavy full curve. Not until May 1930 does the thin full curve return to the same phase as the full heavy curve. As for the dotted curve, it goes two, then three months ahead of the full heavy curve. But from January 1930 the phase of the dotted curve falls behind the full heavy curve by two, then three months, then two months again; quite up to the end of the interval considered.

Apart from these moderate shifts of phase in the latter half of figure 5, such as were discussed in the Peoria paper, though here smaller than there, there is certainly a marked similarity of march of the two synthesized curves with that of observation, from January 1928 to May 1931. One of the two curves of synthesis, it will be remembered, is determined by the records of precipitation from 1850 to 1939, centering about 1900, 30 years previous to the interval of comparison. The other curve of synthesis is determined by the records of precipitation from 1850 to 1899, centering about 1875, 55 years before the interval of comparison.

If one fair forecast of precipitation may be made successfully from records centering 55 years before the event, why not others? Does not the claim that regular periodic solar variations largely control precipitation deserve serious consideration?

*Albany precipitation 1916 to 1939.*—I now refer more particularly to figure 4, which gives interesting results for Albany precipitation. In figure 4 the heavy curve shows the smoothed percentages of normal precipitation, 1916 to 1939. The lighter curve gives the synthesis of the effects of 22 regular periodic variations of solar radiation, which influence the precipitation at Albany. All these periods are approxi-

16  
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2  
1

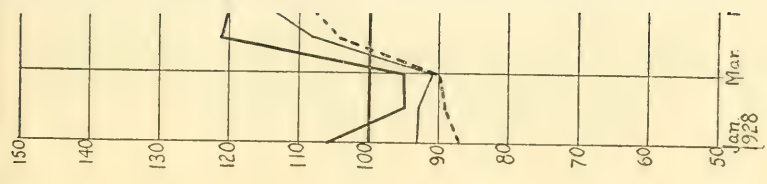
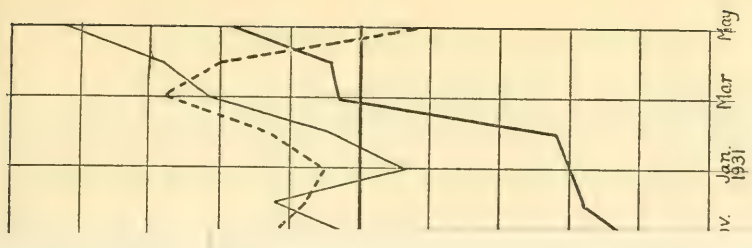


FIG. 5.—Pre years, 1850 to 18 years.



iv. Jan. 1939, and on 40 e == synthesis from 40



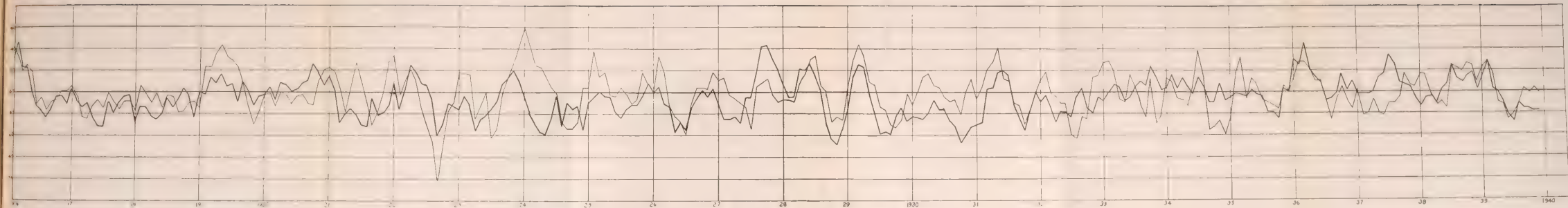


FIG. 4.—Comparison of synthesis of 22 periodic terms, based on records of precipitation at Albany for 90 years, with observed precipitation for the years 1916 to 1939

I have made such a synthesis, based entirely on precipitation records for the years 1850 to 1899. It purports to indicate what the precipitation should be at Albany from January 1928 to May 1931. Referring to figure 5 the heavy full curve represents the observed

to figure 4, which gives interesting results for Albany precipitation. In figure 4 the heavy curve shows the smoothed percentages of normal precipitation, 1916 to 1939. The lighter curve gives the synthesis of the effects of 22 regular periodic variations of solar radiation, which influence the precipitation at Albany. All these periods are approxi-

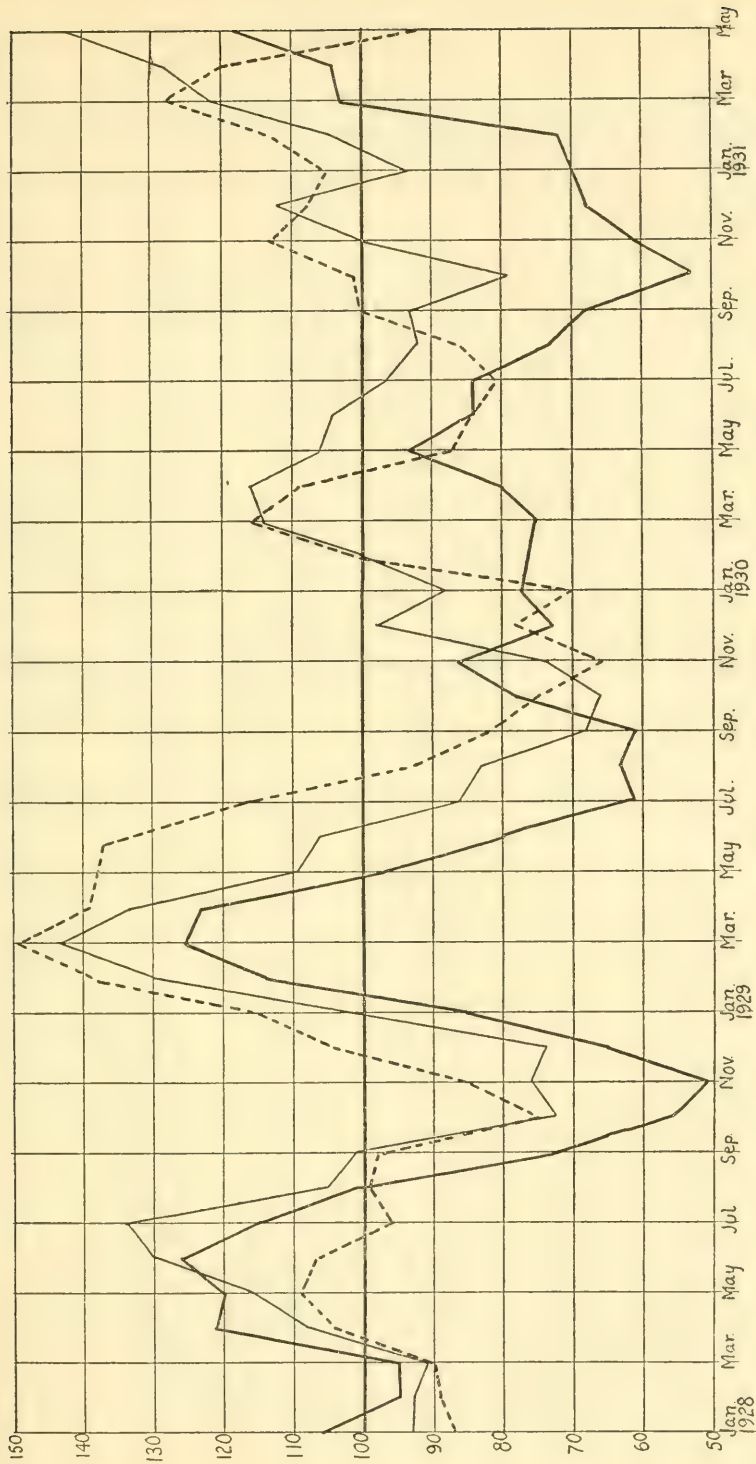


FIG. 5.—Precipitation observed at Albany, 1928 to 1931, compared to syntheses of periodicities based on 90 years, 1850 to 1939, and on 40 years, 1850 to 1899, respectively. Heavy full curve = observed; light full curve = synthesis based on 90 years; heavy dotted curve = synthesis based on 40 years.

mately aliquot parts of  $22\frac{3}{4}$  years. The actual lengths of periods used in the synthesis are as follows, as expressed in months:

$4\frac{1}{3}$ ,  $5\frac{1}{8}$ ,  $6-1/15$ , 7,  $8\frac{1}{8}$ ,  $9\frac{1}{6}$ ,  $9\frac{3}{4}$ ,  $10\frac{3}{8}$ ,  $11\frac{1}{3}$ ,  $13-1/10$ ,  $13\frac{3}{8}$ ,  $15\frac{1}{6}$ ,  $22\frac{4}{5}$ ,  $24\frac{4}{5}$ ,  $30\frac{3}{4}$ ,  $34\frac{3}{4}$ ,  $38\frac{3}{8}$ ,  $45\frac{1}{2}$ ,  $54\frac{1}{2}$ ,  $68\frac{1}{2}$ .

Later added,  $10-1/10$  and  $18\frac{1}{2}$ .

It is obvious that the synthetic curve of figure 4 follows the observed curve in its general form, and with few departures of phase. Slight phase differences occur for certain features of the years 1920, 1923-24, 1927, 1929, and 1937. The amplitudes of vertical wanderings of the synthetic and observed curves are practically identical.

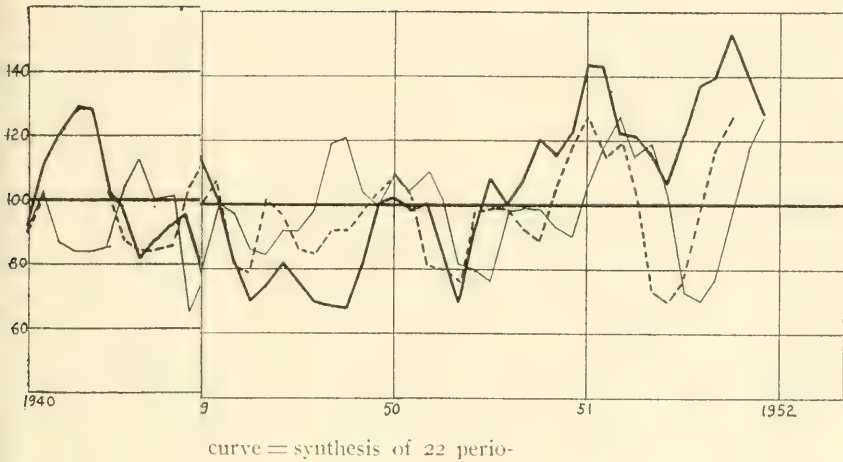
Omitting the intervals July 1923 to November 1924, January to July, 1927, April 1937 to March 1938, when obvious changes of phase occurred, the average discrepancy between synthesis and event for 259 months is 14.9 percent. However, in the first  $5\frac{1}{6}$  years, from January 1916 to February 1921, the average discrepancy is but 12.0 percent for 62 months. Several other stretches, of 18 months or more, each have equally small average discrepancies.

*Remarks on the accuracy of long-range forecasts.*—For the purpose of forecasting, these average discrepancies between synthesis and event do not do full justice to the method. It will be observed, in figure 4, that for long stretches the synthesis is sometimes prevailingly above, or prevailingly below the event. This may possibly have been caused by my neglecting periods of 272, 136, and 91 months. If one were actually forecasting for a year or two years in advance, he would raise or lower his forecast, so that at the start it would be at the average level then prevailing. Thus, for actual forecasting, the mean discrepancy over many years exaggerates the discrepancy which would be encountered in moderately short-term forecasts. For the curve of forecast would be leveled to the height of the prevailing precipitation of a few months prior to the beginning of the forecast, and thus a considerable part of the discrepancy would be eliminated. Also, if one of the puzzling changes of phase were prevailing, naturally the forecast would be advanced or retarded from the direct result of the synthesis, to suit the prevailing phase of a few months next preceding.

*Albany precipitation 1940 to 1951.*—It remains to refer to figure 6 where the synthesis is continued by the thin full line beyond 1940, when the use of records to determine periodicities ceased. The 12 years of synthesis, shown in figure 6, are therefore entirely of the nature of a forecast, and are to be compared with the heavy continuous curve of figure 6, which shows the actual event.



*Unpredictable changes of phase.*—Unfortunately the comparison is less pleasing than the results of synthesis shown in figures 4 and 5 had led me to hope for. It is only when certain changes of phase are



the regular periodic fluctuations of the sun's emission of radiation, demonstrated in a previous paper.<sup>3</sup>

Confirming results relating to precipitation at Peoria,<sup>4</sup> there ap-

<sup>3</sup> Smithsonian Misc. Coll., vol. 117, No. 10, May 28, 1952.

<sup>4</sup> Smithsonian Misc. Coll., vol. 117, No. 16, Sept. 3, 1952.



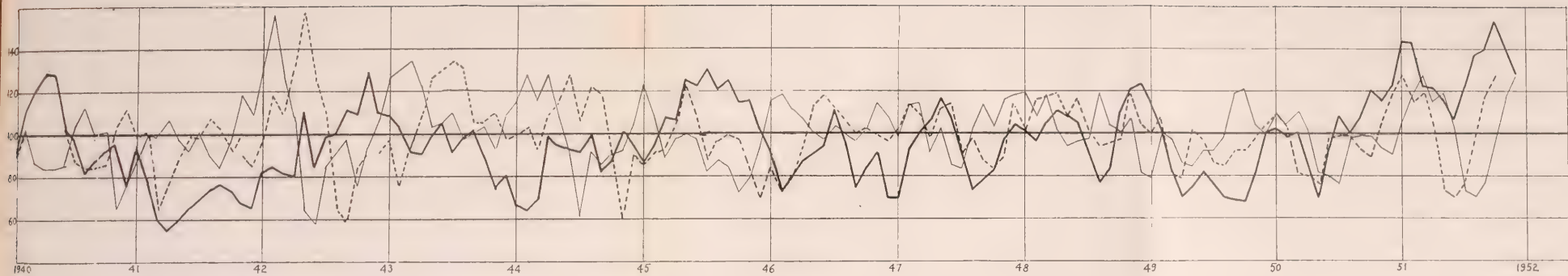


FIG. 6.—Synthetic prediction compared to observed precipitation at Albany, 1940 to 1951. Full heavy curve = smoothed observed; full light curve = synthesis of 22 periodicities; dotted heavy curve = synthesis corrected for unpredictable phase change.

mately aliquot parts of  $22\frac{3}{4}$  years. The actual lengths of periods used in the synthesis are as follows, as expressed in months:

$4\frac{1}{2}$ ,  $5\frac{1}{2}$ ,  $6-1/15$ , 7,  $8\frac{1}{2}$ ,  $9\frac{1}{2}$ ,  $9\frac{3}{4}$ ,  $10\frac{1}{2}$ ,  $11\frac{1}{2}$ ,  $13-1/10$ ,  $13\frac{3}{8}$ ,  $15\frac{1}{2}$ ,  $22\frac{4}{5}$ ,  $24\frac{4}{5}$ ,  $30\frac{1}{2}$ ,  $34\frac{1}{2}$ ,

where the synthesis is continued by the thin line beyond 1940, when the use of records to determine periodicities ceased. The 12 years of synthesis, shown in figure 6, are therefore entirely of the nature of a forecast, and are to be compared with the heavy continuous curve of figure 6, which shows the actual event.

*Unpredictable changes of phase.*—Unfortunately the comparison is less pleasing than the results of synthesis shown in figures 4 and 5 had led me to hope for. It is only when certain changes of phase are admitted, that a moderately satisfactory correspondence between forecast and event is disclosed. These suggested changes of phase are incorporated in the dotted curve of figure 6. The first 2 months of the year 1940 are wholly satisfactory as they stand. Then it is required to shift the synthetic curve ahead 4 months, beginning with March 1940 and ending with November 1941. From there the forward shift is reduced to 3 months, until October 1942. From there the shift returns to 4 months, and so continues till June 1946. From there the shift is again reduced to 3 months, and so continues until August 1949. From there an opposite shift, that is backward instead of forward, of 2 months continues without change until the end of 1951.

Similar, but not such long-continuing shifts, were encountered in the Peoria paper. Similar shifts have already been indicated in figures 4 and 5.

*Accuracy of forecast 1940 to 1951.*—With proposed shifts in figure 6 admitted, there is a marked similarity of form between the curve of forecast for 12 years and the curve of the event. Yet there are alterations of level between the two, which are disconcerting. Thus from November 1940 to October 1944, excepting 6 months in 1942 and 1943, the curve of forecast averages 24 percent above the curve of event. Then from November 1944 until January 1946 the curve of forecast averages 13 percent below the event. From February 1946 to February 1950 the curve of forecast averages the higher by 10 percent. From March 1950 to the end of 1951, the curve of forecast averages the lower by 19 percent.

If these long-continuing systematic differences of level are removed, the remaining average accidental monthly divergence between the dotted curve and the curve of event, for 124 months of the interval between July 1940 and September 1951, is but 10 percent. That neglects the discrepant interval July 1942 to February 1943.

*Summary.*—An investigation has been made of the precipitation at Albany, N. Y., for 102 years, from 1850 to 1951, as it is related to the regular periodic fluctuations of the sun's emission of radiation, demonstrated in a previous paper.<sup>3</sup>

Confirming results relating to precipitation at Peoria,<sup>4</sup> there ap-

<sup>3</sup> Smithsonian Misc. Coll., vol. 117, No. 10, May 28, 1952.

<sup>4</sup> Smithsonian Misc. Coll., vol. 117, No. 16, Sept. 3, 1952.

pears to be no doubt remaining that the regular periodicities in solar variation are major influences controlling precipitation.

Forecasts, for many years in advance, of precipitation at Albany, N. Y., based on solar periods and monthly records of precipitation, 1850 to 1939, show considerable similarity to the event as observed.







SMITHSONIAN MISCELLANEOUS COLLECTIONS  
VOLUME 121, NUMBER 6

# SPONGES OF THE ALASKAN ARCTIC

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(PUBLICATION 4104)

CITY OF WASHINGTON  
PUBLISHED BY THE SMITHSONIAN INSTITUTION

MARCH 19, 1953

The Lord Baltimore Press  
BALTIMORE, MD., U. S. A.

# SPONGES OF THE ALASKAN ARCTIC

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In July and August 1951 it was my privilege to visit the Arctic Research Laboratory at Point Barrow for the purpose of becoming acquainted with the Porifera of the Alaskan Arctic. My study of this interesting fauna was made possible by grants received from the Oregon State College and the Office of Naval Research. I am also indebted to Dr. Ira L. Wiggins, the present director of the Laboratory, for personal and official assistance rendered me.

About 360 species of Porifera have been recorded from Arctic waters east of Greenland. Only about 125 have been recorded west of Greenland, as far as Bering Strait, and nothing is known as to the occurrence of sponges north of Siberia. The greater abundance just east of Greenland is interesting.

In some of my papers, especially the one on the ecology of the sponges of Bermuda (de Laubenfels, 1950, p. 197), there is evidence that sponges grow most abundantly where streams deposit some unknown substance—not silt. This abundant growth is not caused by the fresh water, because it occurs so far out that full oceanic salinity has been restored. Yet its relation to stream delivery is significant. It is here suggested that the Gulf Stream, especially its proliferation, the Norwegian Current, is responsible for the abundant population of Porifera north of Iceland and extending about Spitsbergen and over into Barents Sea.

At least 13 species of sponges occur at depths of less than 100 meters in the sea north of Alaska. This is about the same abundance as at Woods Hole, Mass., but somewhat less than occurs south of Bering Strait and much less than that of England or the West Indies. However, more species are to be found at all these places, including the Arctic, by dredging at greater depths.

In 1891, G. M. Dawson collected sponges that had been cast up on the beach by wave action at various places on the shores of Bering Sea. The following species were reported on by Lambe (1893):

*Halichondria panicea* (Pallas).—Some of the specimens may actually have been of this world-wide sponge, because the United States National Museum has sent me for identification a specimen of

*panicea* collected on the beach at Cape Nome, Seward Peninsula, July 16, 1949, by P. N. Hopkins. On the other hand, because of the very inclusive manner in which Lambe regarded the species, he may well have included specimens of *Halichondria lambei* and even of the genus *Topsentia*. These latter are common north of Bering Strait.

*Reniera rufescens* Lambe.—This is so described that one can be reasonably certain that it was a *Haliclona*, almost certainly the same *Haliclona* that I found north of Alaska. This may indicate relationship between the faunas north and south of Bering Strait. On the other hand, these specimens (both Lambe's and mine) are close to the cosmopolitan *Haliclona permollis*. If they are actually conspecific, no significant faunal relationship is proved.

*Phakellia papyracea* Ridley and Dendy.—Hentschel (1929) recognized that this was not *papyracea* but a new species, and named it *beringensis*. It is certainly the same species I found to be very abundant north of Alaska, but it differs significantly from the genus *Phakellia*; it is, rather, an *Echinoclathria*. In 1942 I called this *E. schmitti*, but Hentschel's specific name has priority. Here, however, we have a definite link between the faunas south and north of Bering Strait.

In 1895 Lambe published on two small lots of the American Arctic Porifera obtained by Healy and by Dall. The first collection, consisting of three species, was made by the U.S. revenue steamer *Corwin*, Capt. M. A. Healy commanding, at Peard Bay, about 80 kilometers southwest of Point Barrow:

*Halichondria panicea*, so identified.—This is *Halichondria lambei* Brøndsted.

*Myxilla barentsi* Vosmaer, so identified.—The descriptions and figures show decisively that this is the *Myxilla* that I found to be common at Point Barrow, and which I regard as being the world-wide species *Myxilla incrustans*. If *barentsi* is really conspecific, it must then fall in synonymy to the earlier *incrustans*, but *barentsi* is so briefly described that one cannot be sure.

*Suberites concinnus* Lambe.—This is perplexing. It cannot be a *Suberites*, because the megascleres of that genus are exclusively tylostyles, whereas *concinnus* has only styles. Lambe's specimens lacked (or he did not find) the peculiar microscleres that distinguish the genus *Neosperiopsis*. Nevertheless the opinion is here hazarded that *concinnus* is a somewhat atypical specimen of some species of *Neosperiopsis*. Burton (1935, p. 77) identified a specimen from north of Japan as being *concinnus*. No opinion is here expressed as to what this might be. *Neosperiopsis quatsinocensis* occurs along the west American coast from the vicinity of Puget Sound northward. I have

thus identified specimens now in the U.S. National Museum, collected at Sanak Island, Alaska, about 1947, by Sadie West. Lambe recorded *quatsinoensis* as far north as Hangemeister Island in Bering Sea.

The second collection was made by W. H. Dall in 1880 at Icy Cape, about 240 kilometers southwest of Point Barrow. It consisted of two species:

*Esperella helios* (Fristedt), so identified.—This is clearly a *Mycale*, but whether conspecific with *Mycale helios* or not cannot now be determined. I did not find any specimens of *Mycale* in Alaska.

*Phakellia ventilabrum* (Linné), so identified.—This, too, is instead *Echinoclathria beringensis*, discussed above.

The present collection comprises 13 species. Of them, four appear to be confined to the American Arctic. Three others occur also in Bering Sea, south of Bering Strait. The remaining six do not occur south of Bering Strait but do occur east of Greenland, in the North Atlantic—European Arctic.

There are no intertidal Arctic sponges because of the very small tidal range and because of the scouring by ice masses that grind along the shore. The collections, which have been deposited in the United States National Museum, were made near Point Barrow by dredging from the diesel-powered boat *Ivik* of the Arctic Research Laboratory. A few specimens in poor condition were found cast up on the beach.

The sponge fauna in this area had previously been extensively collected, in 1948, 1949, and 1950, by Prof. George E. MacGinitie who, while serving as director of the Laboratory during this time, was making an ecologic survey of the offshore and littoral marine life of the region. In his collections all but the first three species here reported upon are represented.

#### SYSTEMATIC DISCUSSION

##### Phylum PORIFERA

##### Class DEMOSPONGEA

##### Order KERATOSIDA

##### Family APLYSILLIDAE

##### Genus APLYSILLA Schulze

##### *APLYSILLA GLACIALIS* (Merejkowsky) Lendenfeld

This species was dredged by Dr. I. L. Wiggins from the icebreaker U.S.S. *Burton Island*, August 14, 1951, from a depth of 67 meters

(37 fathoms), lat.  $71^{\circ}55.5'$  N., long.  $156^{\circ}13'$  W., together with *Pel-  
lina sitiens*.

Among these was a macerated keratose skeleton. The fibers branch in a dendritic manner, without anastomoses. Each fiber tapers as it emits branches, coming almost to a point. Each may be as much as 200 microns thick at the base. These fibers are concentrically laminated, with a suggestion of central or coring pith. This skeleton is characteristic of the family Aplysillidae and is not found in other families. It may be argued that nearly all of the 5 genera and 14 species of the family have such fibers, and that therefore no more-precise identification is possible. On the other hand, one—and only one—species of the family has been recorded from the colder regions of the world—the Arctic, Antarctic, and cold-current localities such as those just west of North America. Therefore the present specimen may with some confidence be regarded as of this hardy species.

This species was first described as *Simplicella glacialis* by Merejkowsky in 1878 (p. 259), from the Arctic north of Russia. It has been found south of Australia, along the north coast of California, and in the North Atlantic. The complete sponge is normally encrusting, conulose, rose pink with more or less gray areas, with soft flesh, and spongy, elastic spongin fibers. The chamber system is eurypylous, the skeleton dendritic.

## Order HAPLOSCLERIDA

### Family HALICLONIDAE

#### Genus HALICLONA Grant

#### **HALICLONA RUFESCENS (Lambe) de Laubenfels**

On July 29, 1951, we dredged two fragments of a small haliclonid sponge 10 kilometers west of Point Barrow from a depth of 46 meters, on gravel bottom. The two irregular masses are each about 20 mm. high and 4 to 6 mm. in diameter. They are drab, softly fragile, comparatively smooth, and lipostomous. As usual in the family, there is no ectosome. The skeleton is a regular isodictyal reticulation with no conspicuous or definite tracts. The spicules are oxeas, about 9 by 176 to 16 by 166 microns.

Lambe (1893, p. 75) described *Reniera rufescens* from Petropaulowski, Kamchatka. In 1895 (p. 115) he recorded it as common in Bering Sea and occurring in the Arctic Ocean. His first specimen, examined dry, exhibited some dull crimson areas; hence his choice of a name. He does not mention this color for other specimens, or note its

absence. My specimens did not show this color upon collection, or in spirits, but may have been in poor physiologic condition. In other ways they agree fairly well with Lambe's descriptions.

Although both Lambe's specimens and those from Point Barrow are very similar to the world-wide species *Haliclona permollis* (Bower-

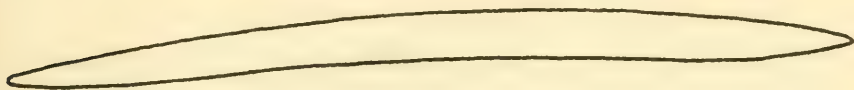


FIG. 1.—Spicule of *Haliclona rufescens*,  $\times 650$ . Camera lucida drawing.

bank), there are some points of difference, and *rufescens* is not here dropped in synonymy. Instead, my *Haliclona permollis* of 1942 (p. 263), from the Foxe Basin (there identified with hesitation) is here regarded as better to be listed also as *Haliclona rufescens* (Lambe). The species possibly is restricted to the American Arctic.

#### Order POECILOSCLERIDA

##### Family ADOCIIDAE

##### Genus PELLINA Schmidt

##### PELLINA SITIENS (Schmidt) de Laubenfels

This was dredged by Dr. I. L. Wiggins from the icebreaker U.S.S. *Burton Island*, August 14, 1951, from a depth of 67 meters (37 fathoms), lat.  $71^{\circ}55.5' N.$ , long.  $150^{\circ}13' W.$ , together with *Aplysilla glacialis*.

These specimens are 2 to 3 mm. thick and up to 30 by 47 mm. in area. They are white, very fragile, smooth, and lipostomous. The

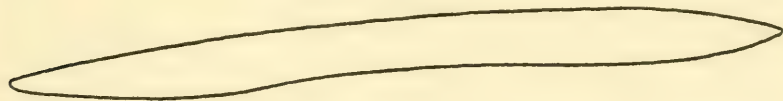


FIG. 2.—Spicule of *Pellina sitiens*,  $\times 570$ . Camera lucida drawing.

surface comprises a tangent isodictyal reticulation, and the interior is a very symmetrical isodictyal reticulation. The spicules are oxeas, all about 12 by 200 microns.

This species was first described as *Eumastia sitiens* by Schmidt (1870, p. 42). It is fairly common from eastern Canada to Greenland and over to the coast of Norway. Needless to say, the identification,

being based only upon fragments, cannot be at all certain. The genus *Pellina*, however, is indicated, and the species *sitiens* is the only one to be expected.

Family MYXILLIDAE

Genus MYXILLA Schmidt

MYXILLA INCRUSTANS (Johnston) Lundbeck

In July and August 1951 this species appeared in our dredges only a few times, from about three localities, all upward of 10 kilometers (6.2 miles) west of Point Barrow, at depths of 50 meters or more, but each time it was abundant, practically filling the dredge. *M. incrustans* has also been dredged in quantity by G. E. MacGinitie on four occasions in September and October 1948 and 1949, at 33 to 100 meters (108-328 feet) from mud and stone, gravel, and rock bottom, 4 to 7.5 miles (6.5-12 km.) off the Point Barrow base. The following description is based on July 29, 1951, material (U.S.N.M. No. 23217).

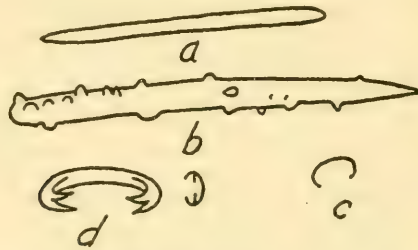


FIG. 3.—Spicules of *Myxilla incrustans*,  $\times 210$ . A, Dermal tornote; B, acanthostyle; C, sigma; D, isochelas. Camera lucida drawing.

The shape is irregularly massive, up to 16 cm. in diameter, color drab, like nearly all Arctic sponges, consistency very slimy, but with little or no odor. The surface is smooth, with indications of abundant but quickly closed pores. The oscules are regularly 2 mm. in diameter, not raised, rather numerous. There is a definite, separable dermis over an endosome characterized by small (1 mm. or less) scattered cavities.

The dermal spicules, chiefly tangentially placed, are smooth, hastate tornotes, ends sometimes microspined, size about 8 by 180 microns. The endosomal spicules are acanthostyles, in "log cabin" reticulation, size about 17 by 260 microns. It is probable that this spicule arrangement represents an exaggerated development of echinating spicules, with a relative suppression of coring spicules. The microscleres are sigmas about 38 microns in chord length, and anchorate (often verging



toward arcuate) isochelas, of two size ranges, about 18 microns long, and about 76 microns long.

This species was first described as *Halichondria incrustans* by Johnston (1842, p. 122) from Great Britain. It is common in the North Atlantic and adjacent Arctic regions. The identification of the Alaskan specimens is not certain. The European specimens have a strong, characteristic odor, also found in some species of *Lissodendoryx*; the absence of this from the American Arctic specimens may be ecologic but may mean that they are a different species. As already noted, Lambe called them *barentsi*, but *barentsi* was described with extreme brevity by its author (Vosmaer, 1885, p. 21); hence Lambe may have been mistaken. The European specimens of *incrustans* are described as having only anchorate chelas, whereas there are also many arcuate chelas in the Alaskan specimens. These latter chelas, however, are not typically arcuate, but of an intermediate type, so nearly like anchorate chelas that they can be distinguished only if situated in such a way that they can be minutely studied; therefore the name *incrustans* is here preferred.

#### WIGGINSIA, new genus

This genus of the family Myxillidae is here established to have as genotype the following new species, *Wigginsia wigginsi*. The external appearance is much like that of *Higginsia higgini*, rather than like that of other Myxillidae. The generic diagnosis should emphasize that this is for sponges with smooth ectosomal diactines, smooth or spiny monactinal spicules coring the tracts or fibers, and (significantly) spiny diactinal spicules echinating the tracts or fibers. Diactinal echinators are very uncommon in the whole order Poecilosclerina. The microscleres of *Wigginsia* are palmate isochelas, a type that is seldom found in the family Myxillidae.

The name is given in recognition of the services to science of the eminent biologist Dr. I. L. Wiggins, director of the Arctic Research Laboratory.

#### WIGGINSIA WIGGINSI, new species

A single specimen of this unique sponge (U.S.N.M. No. 23222) was obtained by G. E. MacGinitie, September 9, 1949, at 143 meters (469 feet), from a bottom revealed by the dredge as consisting of worm tubes and a few rocks, located 15 miles (24 km.) north of the base.

This species is basically lamellate, but on the original wall, side walls are placed at right angles, and yet smaller ones abut against them. The

whole is covered with elevations about 1 mm. high, each of which is in turn ornamented with smaller elevations. This elaborate structure is rare in the family Myxillidae, but is found in the Axinellidae, especially in such beautiful species as *Higginsia higgini*. Our Arctic poriferan is 3 mm. high, 5 cm. wide, with walls up to 3 mm. thick, but chiefly thinner.

Sponges of the *Higginsia* type are often of a lovely red color. The field collector placed this *Wigginsia* in the same jar with an extremely different sponge, a *Polymastia*. He also placed in the bottle a field note: "Rose red sponge." *Polymastia* species are usually gray to white! Perhaps it was the *Wigginsia* that had the lovely color as well

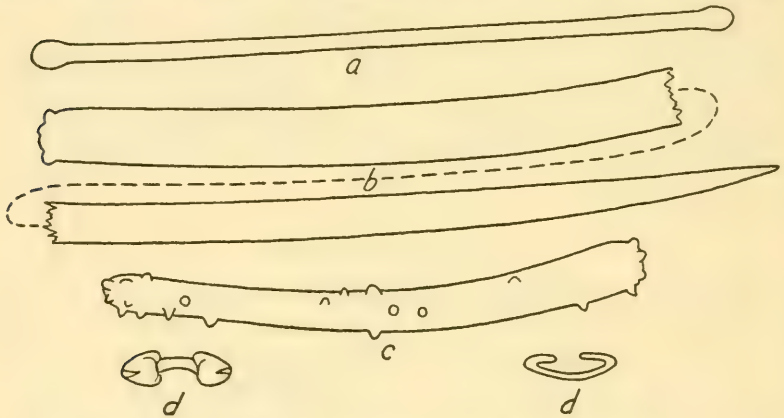


FIG. 4.—Spicules of *Wigginsia wigginsii*,  $\times 435$ . A, Dermal tornote; B, coring style; C, echinating spicules, acanthostrongyles; D, palmate isochelas. Camera lucida drawing.

as the interesting structure, and *Wigginsia* is in all ways as beautiful as *Higginsia*.

The inhalant and exhalant openings of the specimen were either closed or else as minute as in *Higginsia*, and the consistency is like that of the latter genus. We have here a species with principal skeleton as in the family Myxillidae, but in general appearance, while not like that of typical axinellids, it is very much like that of one particular genus of the Axinellidae.

The skeleton includes abundant special ectosomal spicules, usually tangentially placed. These tornotes are rather tylote than strongylate, and their ends are only very minutely spined if at all. They are typically about 18 by 390 microns in size. There are thin, vague ascending tracts of large styles, some smooth, some with a few spines near the blunt end. This combination, together with spiny echinating

spicules, is usual in the Myxillidae, but in *Wigginsia* the echinators are acanthostrongyles. They are very abundant, making up the vast bulk of the skeleton. They are often so placed that parallel groups form walls to microscopic cavities which are only a little larger than the flagellate chambers. This, which I have called "log cabin" architecture, is common in the genus *Myxilla* itself. These echinating diacts are about 13 by 162 microns in size. There seems to be only one sort of microsclere present; it is abundant, a palmate isochela, usually 35 microns long.

The species name also honors Dr. I. L. Wiggins, and its choice is obviously inspired by the interesting comparisons to *Higginsia higgini* Dendy.

#### Family OPHLITASPONGIIDAE

#### Genus ECHINOCLATHRIA Carter

#### ECHINOCLATHRIA BERINGENSIS (Hentschel)

This is the most conspicuous and one of the most abundant sponges in the American Arctic. It is frequently thrown on the beach as a result of wave action, and it is often dredged.

In the MacGinitie material it is represented by numerous specimens taken from 6 to 12 miles (9.5-19 km.) off the Point Barrow base from a stone, rock, and worm-tube bottom at 104 to 226 meters (341-741 feet), August and October 1949, and in Eluitkak Pass, Elson Lagoon, Point Barrow, at 9 to 12 meters (30-40 feet), from gravel, stone, and mud bottom, August 10 and 30, 1948. I dredged this species on three occasions from 2 miles (3 km.) north of Point Barrow, at 80 meters (263 feet), and 6 miles (10 km.) west of Point Barrow, at 26 and 50 meters (85 and 164 feet), in July 1951, and also found it cast up on the beach.

The specimen described below is one of a lot taken at 26 meters (85 feet), from gravel bottom, July 29, 1951 (U.S.N.M. No. 23215).

It is stalked, with a body wall 5 mm. thick and so curved as to form almost a complete inverted cone, yet the edges do not quite meet. The whole specimen is 13 cm. high, stem about 4 cm. long and 1 cm. thick. There are conspicuous root processes below. (A few specimens, probably merely fragments, appeared simply lamellate; many were completely conical, stalked, and very symmetrical.)

The color is pale brown, the consistency flexible, easily torn. The surface is smooth or punctiform, with evidence of pores quickly closed, about one for each square mm. Probably those on the concave side are exhalant, those on the outside inhalant.

The spicules are styles of two size ranges. The smaller are all close to 7 by 220 microns; the larger are often about 12 by 520 but range up to 22 by 710 microns in size.

The surfaces are covered by a dense ectosome, 0.5 mm. thick, packed with spicules of both sizes, all with their points outward. Under this is a subdermal cavity, 0.7 mm. from floor to ceiling. The latter is supported by fascicular columns of the larger styles, the columns 100 microns in diameter and about 250 microns apart, on centers. The endosome is formed of rather dense flesh, permeated by spicular tracts, of only the larger styles, diameter 75 to 150 microns. The smaller

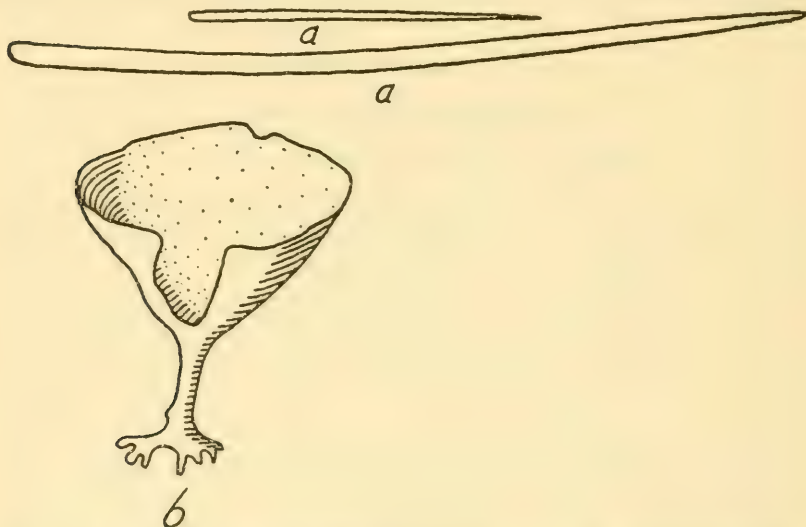


FIG. 5.—A, Spicules of *Echinoclathria beringensis*,  $\times 210$ . Camera lucida drawing. B, Sketch of the sponge,  $\times \frac{1}{4}$ . Freehand drawing.

spicules are loose in the flesh between the tracts, or in many cases appear to be echinating the tracts but not so as to render them plumose.

This species was first described by Lambe (1893, p. 76) from St. Matthew Island and identified as being *Phakellia papyracea* Ridley and Dendy. This latter species was transferred to *Phakettia* by de Laubenfels (1936, p. 131). Lambe in 1895 (p. 124) reallocated his species, this time identifying it as *Phakellia ventilabrum* (Johnston). This latter sponge does indeed have the stalked, vaselike shape, but it has a skeleton that comprises axial cores of diacts, echinated by large styles. Hentschel (1929, p. 975) recognized that Lambe's material represented a new species but still used the same genus. He called this *Phakellia beringensis*. I had a bit of this species, just part of the

wall, from Foxe Basin, and described it in my 1942 paper (p.264) as *Echinoclathria schmitti*, new species. The skeletal structure is clearly that of *Echinoclathria*, but in this latter genus no other species has the funnel or vase shape. *Echinoclathria* belongs in the family Ophlitaspongiidae, whereas *Phakellia* is in the Axinellidae, a family characterized by skeletons that have axial specializations, surrounded by contrasting structures, and that are typically very plumose in architecture. The sponge under discussion (*beringensis*) is even less plumose than *Ophlitaspongia* itself, as well as being devoid of axial specializations; it therefore appears certain that it should not be in the Axinellidae. On the other hand, the genus *Phakellia* is not typical of the Axinellidae; hence the classification of these various sponges is still far from certain or settled. It is possible that a new genus may be needed for *beringensis*.

The sponge described as *Echinoclathria favus* by Carter (1885, p. 292) is not properly placed, because of its microscleres; it is here transferred to *Axociella*.

#### Genus HALICHONDRIA Fleming

#### HALICHONDRIA LAMBEI Brøndsted

This species is abundant near Point Barrow. Nearly every one of my dredge hauls on gravel bottom in July and August 1951 fetched several specimens.

MacGinitie's records reveal the species as equally common during his earlier dredging efforts in August 1948, August and October 1949, and August 1950. His specimens were obtained 2.8 to 8 miles (4.4-13 km.) off the Point Barrow base on bottoms of gravel, stones, and rocks in various proportions with, in two instances, some admixture of mud and shells, in depths of from 36 to 138 meters (118-453 feet). The description below is based on a specimen from a lot I dredged in 50 meters (164 feet), 6 miles (10 km.) west of Point Barrow (U.S.N.M. No. 23216).

This specimen consists of about half a dozen digitate processes of various sizes, up to 2.4 mm. in diameter and 80 mm. high. The color is drab and the consistency fragile. The surface is smooth, with pores 50 to 100 microns in diameter, in places four or five per square millimeter, but apparently absent from large patches here and there. The oscules are about 0.3 mm. in diameter, without raised rims. In some specimens they are as much as 3 mm. in diameter. On about half the surface they are absent, but in other places there are as many as one

per square centimeter. The larger ones are much farther apart. Each small oscule is surrounded by many large spicules radially arranged.

There is a conspicuous ectosome, about 30 to 70 microns thick, over a continuous subdermal cavity. The pillars or columns supporting the dermis are about 1.5 to 2 mm. apart and are conspicuously visible through the ectosome, as viewed with the naked eye from without. The endosome has the architecture commonly and appropriately known as "crumb of bread." It is permeated by very vague spicular tracts, elsewhere with spicules in confused arrangement. The endosomal spicules in general are much larger than those of the ectosome, the

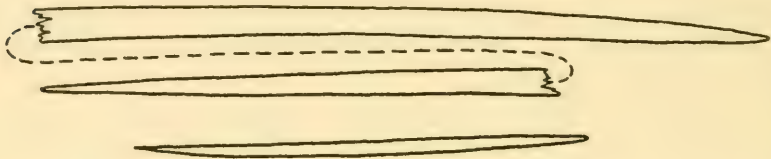


FIG. 6.—Spicules of *Halichondria lambei*,  $\times 158$ . Camera lucida drawing.

latter being usually tangentially located. The flagellate chambers are about 40 to, occasionally, as much as 50 microns in diameter. The spicules are exclusively oxeas. Those of the dermis are often about 12 by 400 microns, those of the interior about 20 by 1,100, but in each location there is considerable variation in size.

This species was first described by Lambe (1893, p. 75) from St. Matthew Island and identified as *Halichondria panicea*. Brøndsted (1933, p. 15) appropriately gave it the species name *lambei*, as it is quite different from *panicea*. Brøndsted described it from near Ellesmere Land; thus it appears to be confined to the American Arctic, but to be widespread there, all the way from Bering Strait to Greenland.

## Order HADROMERINA

### Family CHOANITIDAE

#### Genus CHOANITES Mantell

#### CHOANITES LÜTKENII (Schmidt)

This species occurred in dredge hauls on two different occasions in July 1951. It had previously been taken by MacGinitie on three occasions, August of 1948 and 1950 and October 1949. His specimens are from 2.8 to 8 miles (4.5-13 km.) off the base and from 36 to 138

meters (118-138 feet), on mud, sand, shell, gravel, stone, and rock bottom. The following description is of a specimen from a gravel bottom, at a depth of 72 meters (236 feet), 2 miles (3 km.) north of Point Barrow, July 26, 1951 (U.S.N.M. No. 23213).

This is a flattened but rounded subspherical sponge, 2 by 6 by 6 cm. in size. The color is gray with yellowish tinges, and the consistency is like cheese. The surface is smooth, with pores about 60 microns in diameter, in places only 100 microns apart, center to center, but absent from considerable areas. The exhalant openings are not differentiated, or else are closed.

The ectosome is distinct, with a thin outer layer, only 50 microns thick, packed with microscleres. Under it are many subdermal cavities, about 150 microns in diameter. The megascleres at or near the surface

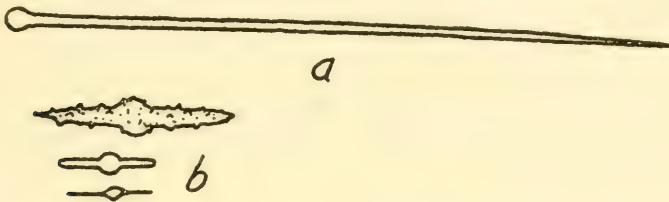


FIG. 7.—Spicules of *Choanites lütkenii*. A, Megasclere,  $\times 210$ ; B, microscleres,  $\times 780$ . Camera lucida drawing.

are all erect, points outward, but are not conspicuously smaller than the endosomal spicules. It was to be expected that they would be much smaller.

The endosome is dense, with spicules chiefly in confusion, but showing vague traces of a fundamentally radiate arrangement. The flagellate chambers are 30 to 35 microns in diameter, spherical, and grouped in spherical clusters about the beginnings of exhalant canals.

The megascleres are straight tylostyles, about 8 by 420 microns in size. The very abundant microscleres include numerous centrotylate acanthoxeas, often about 36 microns long, also centrotylate smooth microstrongyles, a little smaller and less common, also centrotylate smooth oxneas, only about 18 microns long.

This species was first described as *Suberites lütkenii* by Schmidt (1870, p. 47) from the far northern Atlantic. It has since been found to be common and widespread throughout the whole Arctic.

## Family SUBERITIDAE

## Genus POLYMASTIA Bowerbank

## POLYMASTIA ANDRICA de Laubenfels

A single specimen of this species was dredged by G. E. MacGinitie, August 17, 1949, from a bottom of stones in 162 meters (522 feet), 12 miles (19 km.) out from the Point Barrow base.

It is a rounded cake, 2 cm. thick and 5 by 8 cm. in horizontal measurement. The consistency is toughly cartilaginous. The surface is beset with smooth fistules about 3 mm. in diameter, 7 mm. high, about one such fistule per square centimeter. The abundant minute pores are on these elevations. There are also five exhalant elevations, each 6 mm. in diameter, 11 mm. high, each with an apical oscule about 4 mm. in diameter. The sides of these elevations are longitudinally fluted. In between the fistules and elevations the surface is densely hispid, a characteristic not common in this genus.

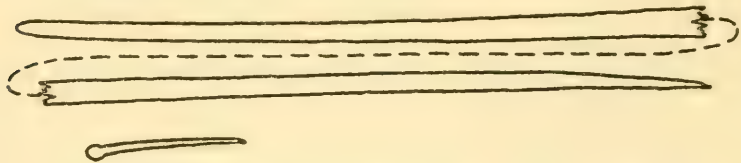


FIG. 8.—Spicules of *Polymastia andrica*,  $\times 160$ . Camera lucida drawing.

The thin ectosome is characterized by the palisade of erect spicules. The endosome is only a little less dense and is permeated by numerous spicular tracts or columns, running all the way from the base of the sponge to the surface. The spicules are chiefly tylostyles, usually about 4 by 150 microns in size. The larger ones were often centrally swollen, so that there the diameter of the shaft exceeds that of the head. Large smooth styles are also present, much less numerous, but conspicuous in the dermal hispidation and in the tracts; these are often some 20 by 1,200 microns, but exhibit great variation in size.

This name was established, in my study of the sponges of Woods Hole and vicinity (de Laubenfels, 1949, p. 22), for polymastias from eastern Canada and New England, with coarse, conspicuous surface hispidations and three or more size ranges of spicules. The present specimen is unlike typical *andrica* in the fact that its larger spicules are styles rather than tylostyles, but I hesitate to erect any more names in this rather crowded genus. Brøndsted (1933, p. 9) identified a sponge from west of Greenland as *Polymastia robusta* (Bowerbank), but this name is a junior synonym of *boletiformis* (Lamarck).



Brøndsted did not describe his specimen, and it may be that he had *andrica* but assumed that its differences from *boletiformis* fell within the range of variation of that European species.

## Order EPIPOLASIDA

### Family JASPIDAE

#### Genus TOPSENTIA Berg

#### TOPSENTIA DISPARILIS (Lambe) Burton

This was a very common species occurring in most of the dredgings made in 1948, 1949, and 1951 over bottoms of stones or gravel occurring in 38 to 45 meters (125-150 ft.) of water, 4 to 5 miles (7-8 km.) off the Point Barrow base.

The species *Halichondria lambei* has already been described, but sponges clearly of that species warrant discussion in connection with

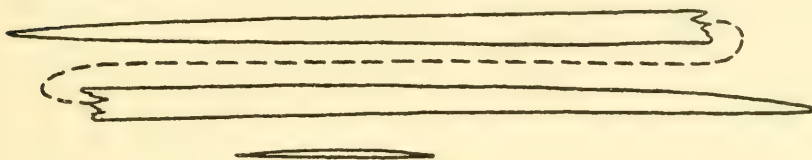


FIG. 9.—Spicules of *Topsentia disparilis*,  $\times 210$ . Camera lucida drawing.

*disparilis*. Both have only oxeas as spicules, and these are of great variation in size. Externally they may also be perplexing. Nearly every Arctic sponge is a sort of yellowish, pale drab color. Both types now being dealt with had this same color and the same fragile consistency. Each had small pores and oscules. Small specimens, say less than 3 cm. in diameter, sometimes could not be differentiated without microscopic study. Large ones showed some field recognition marks, as follows: *Halichondria lambei* evidently tends to become quite fistulose as it enlarges; in fact it verges strongly toward the structure of such genera as *Ciocalypta*, and especially *Cioxeamastia*. It may well be argued that *lambei* belongs in *Cioxeamastia*. The sponges that are here regarded as being *disparilis* never produce these tall, sharp-pointed fistules but instead are more or less covered with low, small tubercles, less than 1 mm. high, 2 or 3 mm. in diameter. These are confined to scattered areas, however, and may be missing from small specimens.

The ectosome of the sponge now being described was less conspicuously separated than that of *lambei*, and its spicules were usually erect, even bristling, rather than horizontal or tangent, as in *lambei*.

The endosomal skeleton was chiefly confused, but vaguely radiate. This latter trait, with the erect ectosomal spiculation, suggests an epipolasid rather than a halichondrid classification. The principal criterion as here relied upon for separating *disparilis* was that it had spicules of two radically different size ranges, as is diagnostic of the genus *Topsentia*. The larger oxeas were about 20 by 900 microns in size; the smaller, perhaps to be regarded as microscleres, were about 8 by 130 microns.

Sponges of this type were described by Fristedt (1887, p. 426) from the Arctic (east of Greenland) as *Amorphina fibrosa*. Their larger spicules were not so much larger than the smaller category as is true of the Point Barrow *Topsentia*, yet *fibrosa* should be transferred to *Topsentia*, and is probably related to the present species. In 1942 I recorded, with some hesitation, a sponge from west of Greenland as being *fibrosa*.

Lambe (1894, p. 25) described a sponge from the west coast of Canada as *Halichondria disparilis*, and Burton (1935, p. 77) recorded it from Japan, correctly transferring it to the genus *Topsentia*. Its spicules are not quite so large as those of the Point Barrow *Topsentia*, but it is here considered likely that the two are conspecific.

Lundbeck (1902, p. 27) described a sponge from the Arctic east of Greenland as *Halichondria colossea*. This has specifications almost identical with those of the Point Barrow *Topsentia*, but slightly different dermal structures and shape. It is here transferred definitely to the genus *Topsentia*, and (with some hesitation) also to synonymy with *disparilis*.

## Order CHORISTIDA

### Family CRANIELLIDAE

#### Genus CRANIELLA Schmidt

#### CRANIELLA CRANIANA, new species

The type of this new species (U.S.N.M. No. 23233) was dredged by G. E. MacGinitie from a depth of 225 meters (741 feet), August 17, 1949, 12.1 miles (19.5 km.) north of Point Barrow. Two other specimens were obtained the same day in the same general vicinity, one from 225 meters (741 feet), the other from 133 meters (438 feet); the type and the first of these other two are preserved dry, the third and less typical one is an alcoholic specimen; all three are from a worm-tube and mud bottom. It is of interest to recall that *Craniella* is one of the rather few sponges capable of living in or on mud.

The type is subspherical, about 4 cm. in diameter. The spirit specimen has a similar shape, but is slightly smaller (3 cm.). The other dry specimen is elongate oval, 4 cm. in diameter, but 8 cm. high. The color is the usual drab, the consistency cartilaginous.

The surface of all three specimens is hairy on the lower half, or the dermis may be missing from the lower half as a result of the dredge impact. The upper surface of each, especially the dry specimens, is covered with conspicuous cone-shaped projections, much larger and more acute than the structures (probably not homologous) that are customarily termed "conules." These projections on *craniana* are 3 mm. in diameter at the base, 6 to 8 mm. high, tapering steadily to a termination that is only slightly blunted. They are so crowded that

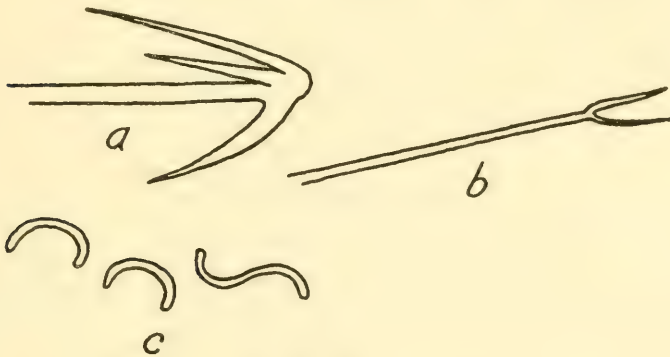


FIG. 10.—Spicules of *Craniella craniana*. A, Cladome of anatriaene,  $\times 150$ ; B, cladome of prodiaene,  $\times 150$ ; C, microscleres (sigmas),  $\times 650$ . Camera lucida drawing.

their bases touch one another. Neither pores nor oscules show, doubtless being closed during the dredge haul.

The architecture is typical choristid, with huge fascicular columns, which arise from a point near the center of the base of the sponge, and continue clear to the surface. These are each about 1 mm. in diameter, and either touch one another, side by side, or (near the surface) have spaces of flesh between them as much as 1 mm. wide.

The commonest megasclere is a large oxea, often over 100 microns thick and several millimeters long. As usual in the order Choristida, the longest specimens were broken before they could be subjected to microscopic study, and there was great variation in size. There are anatriaenes, also of great variation. Some have clads about 200 microns long and rhabs 16 microns in diameter. There are probably the usual protriaenes, too, but all that I happened to find were merely

prodiaenes. The microscleres are abundant sigmas with blunted ends, chord measurement 17 to 22 microns, often 18 microns.

There are at present some 58 species names left in the genus *Craniella*. More than 50 of these have spiculation practically identical with one another and with the genotype, *Craniella crania* (Lamarck). The great majority, in fact nearly all of these 50, should probably be dropped in synonymy to *crania*, but a few may be retained for their peculiar architecture.

The present species has this typical craniellid skeleton, its only unique trait being its astonishing surface. The species *crania* is characterized by a felted or hispid surface, not always even, but never raised in such striking elevations. Therefore a means of referring by name to the Point Barrow specimens seems indicated.

## Class CALCISPONGEA

### Order SYCONIDA

#### Family LEUCONIIDAE

#### Genus LEUCONIA Gray

#### LEUCONIA ANANAS (Montagu)

This species frequently turned up in the dredge hauls made by G. E. MacGinitie in September 1948 and August-October 1949, over a bottom of gravel and stones, in 53 meters (175 feet), about 4 miles (6.5 km.) out from the Point Barrow base. Only a single specimen was found in July 1951, in 50 meters (164 feet), about 6.2 miles (10 km.) west of Point Barrow.

This sponge has the narrow cylindrical shape of a *Grantia*. The representative specimen is 9 mm. in diameter, 22 mm. in length. Others were even narrower and longer. The color is dirty white (doubtless actually dirty), and the consistency is fragile. The surface is astonishingly smooth, but there is a rim of coronal oxeads around the apical oscule, which is 5 mm. in diameter. The cloaca extends nearly the whole length of the sponge, a little less than 5 mm. in diameter.

The flagellate chambers are subspherical, about 50 microns in diameter. The spiculation includes many regular triaxons, rays 16 by 240 to 16 by 320 microns, and fairly numerous oxeads, 16 by 720 microns. These, like the triaxons, are chiefly confused in arrangement, not particularly oriented. There are some tetraxons, especially on the cloacal surface. Their rays are also 16 microns in diameter but vary greatly in length in the same spicule, say from 100 to 300 microns long.

This species was first described by Montagu (1818, p. 97) as *Spongia ananas*, from the extreme northern Atlantic, almost Arctic, and has since been found widespread throughout the Arctic. I recorded it in 1942 (p. 267) from just west of Greenland. Our Point Barrow specimens have oxeas much smaller than other recorded members of this species, and lack the curved hypocloacal rays of the spicules lining the cloaca. Its surface is astonishingly smooth. Perhaps it deserves a new name, but there are so many names now in *Leuconia* that many need to be reduced to synonymy. In spite of this, one sort of specimen of

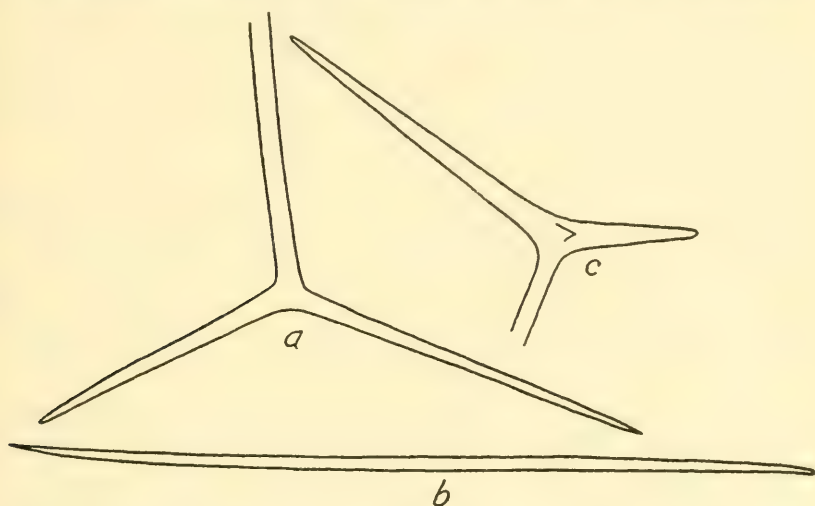


FIG. 11.—Spicules of *Leuconia ananas*,  $\times 155$ . A, Triaxon; B, oxea; C, tetraaxon. Camera lucida drawing.

*Leuconia* from Point Barrow does seem to warrant a new name, as follows:

#### LEUCONIA ALASKENSIS, new species

The type (U.S.N.M. No. 23220) and some five other specimens were dredged by G. E. MacGinitie, 5 miles (8 km.) off the Point Barrow base, August 30, 1949, from a stony bottom, in 55 meters (181 feet). The other five specimens are in poor condition and are identified with doubts.

This is a sprawling, repent, ramose sponge. At the base the type is 2 mm. in diameter. Four branches maintain this diameter and are respectively 7, 8, 9, and 22 mm. long. The fifth or main stem is nearly 30 mm. long (or high), and its distal or apical half attains a diameter of nearly 3 mm. It certainly terminates in an oscule of nearly its full diameter. It is not clear whether the other branches so terminate.

Perhaps their much smaller oscules closed, as some *Leuconia* oscules are certainly known to do (see de Laubenfels 1932, p. 13). The apical portion of this main branch is flattened, that is to say, compressed. The cloaca extends throughout the whole body, nearly to the base. Thus the architecture may be described as tubular, with walls only some 250 microns thick. This thinness is most remarkable in the genus *Leuconia*, and like the thin, tubular shape, is rather to be found in the genus *Grantia*.

The color is dirty white, the consistency fragile. The surface is smooth, except for the peculiar diactinal spicules to be described below. There is no conspicuous fringe about the oscule, and all or many of the pores are closed.

The flagellate chambers are oval, about 50 microns in diameter, 70 microns long.



FIG. 12.—Spicules of *Leuconia alaskensis*,  $\times 150$ . A, Triaxons; B, diactines. Camera lucida drawing.

The spicules are chiefly regular triaxons, in great abundance but confused arrangement in the body wall. Many have rays only 4 by 40 microns in size. Some have rays as large as 6 by 50 to 6 by 60 microns. Much searching revealed not a single tetraxon. Throughout the body wall, at distances of about 300 microns from one another in all directions, are peculiar diactinal spicules, about 30 by 300 microns, half of this length embedded in the chamber layer, half protruding from the outer surface. These spicules are cylindrical, that is to say, of the same diameter throughout nearly their entire length. The ends are often as bluntly rounded as in strongyles or styles. More commonly one or both ends are obtusely or hastately pointed. Each is strongly curved, somewhat like an Australian boomerang.

This is a well-marked species, with no very close relatives.

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SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 121, NUMBER 7

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Charles D. and Mary Vaux Walcott  
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(WITH 24 PLATES)

BY

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U. S. National Museum

AND

HELEN TAPPAN

U. S. Geological Survey



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(WITH 24 PLATES)

INTRODUCTION

The present study was originally begun with the hope of learning more about the Arctic foraminiferal faunas and their ecology. Increased interest in these Arctic faunas had been stimulated by a study of the fossil faunas of northern Alaska obtained in the course of petroleum exploration in Naval Petroleum Reserve No. 4.

During 1950 a grant was obtained by the writers from the Office of Naval Research for the collection of samples from the ocean bottom off northern Alaska. Dredged samples were collected by Alfred R. Loeblich, Jr., during July and August, 1950, with the aid of Dr. G. E. MacGinitie, then director of the Naval Arctic Research Laboratory at Point Barrow, Alaska.

Unfortunately, bad weather conditions during the summer of 1950 somewhat limited the number of trips for the collection of samples. We have therefore added to this study some dredged samples collected by the *Albatross* in the Arctic and sub-Arctic, and others collected by Capt. Robert A. Bartlett from the Greenland and Canadian Arctic areas.

PREVIOUS WORK AND SCOPE OF THE PRESENT  
STUDY

It was intended at first to make a strictly ecologic study, as various earlier papers had described Arctic faunal assemblages. After a very short time it became quite evident that no comparisons could be made of the Alaskan foraminiferal faunas with those of other regions without first making a complete taxonomic study of the species concerned.

The Arctic faunas had been studied by many authors over the past century, but the later authors almost invariably followed the original identifications of Parker and Jones and Brady, from the days when it was thought that no evolutionary changes could be observed in such simple creatures as protozoans.

For example, Parker and Jones (1865, p. 346) stated: "It is impossible to fix on any distinctive character, or set of characters, sufficiently limited in development to be of real importance in dividing the Lagenae into even two *species*" (italics supplied by the original authors). In contrast, modern workers have separated Parker and Jones's single species (and 10 varieties) into 4 distinct *genera* and recognize hundreds of species of these unilocular Foraminifera.

These authors stated further (p. 335): "In comparing our specimens with figured forms, we have been satisfied when a near approach to identity is shown; minute differences are ignored, such differences not being of essential value."

Nearly a century later, authors are still following the identifications of Parker and Jones, who admitted they were satisfied with a *near* approach, although these more modern workers apparently have considered these identifications to be as detailed and accurate as the type of work now done on fossil faunas. If such wide latitude were allowed in fossil species there would be no economic micropaleontologists, as the "minute differences," upon which oil-field correlations are based, would be completely ignored.

The wide use of micropaleontology by the oil industry in the identification of strata demonstrates the completely different approach of the present day to the study of fossil faunas. Yet these living Arctic species are still being referred to species described originally from beds as old as the Cretaceous, and from environments as different as the tropical Pacific, the Red Sea, and the West Indies. Even a cursory examination of the literature shows the great variation in character of forms all referred to the same "classic living species." Even more surprises result from the examination of type specimens in the various collections, where sometimes representatives of three or four *genera* have been included under a single specific name. There are many more instances where a number of quite distinct species have been labeled with the same name. In some of the more recent literature authors have remarked that certain "species" seem to include a variety of forms, but in all too many instances no attempt has been made to rectify the situation, and the old all-inclusive names are used again and again. As one example we might cite the species herein



made the type for the new genus *Pateoris*. Although possessing characters that would exclude it from these genera, it has nevertheless been frequently referred in the literature to the *genotype species* of three different genera, *Quinqueloculina*, *Miliolinella*, and *Massilina*. Although differing from those three species in nearly every character of generic importance, only after about 80 years had passed was it finally given a separate name. Even then it was considered a *forma* of one of these earlier genotype species, and not given even varietal or subspecific rank.

One recent work on Arctic faunas to which these remarks do not apply is that of Höglund (1947), for he made an extremely detailed taxonomic study and revised a number of the old "species." However, he could not include all the Arctic species and many problems remain.

In general, the careless identification of Arctic forms with tropical species, fossil species, etc., no matter how distinct they might appear, has made it impossible to learn much about the actual present-day distribution of species. A compilation of the depths, temperature, bottom conditions, etc., at which a single species has been recorded in the literature would imply that almost no Foraminifera are even moderately affected by their environment. Even a glance at assemblages from different regions or varying depths will show how false is this impression.

Correlations previously made on the basis of "species," in large part are based on occurrences of a number of misidentified forms, and identical published lists of names will, upon examination of the specimens themselves, prove to refer to astonishingly distinct faunas. It is comparable to basing correlations on the presence of all quadrupeds with black eyes, for example, although that would include not only many different species, but also representatives of different genera and families. Such are the identifications upon which foraminiferal ecologic studies have been based, specimens which belong to quite distinct genera, and even different families as well, having been referred to one specific name.

This is not to say, however, that no comparisons can be made. An examination of publications that have described and illustrated the specimens they obtained (regardless of the names assigned to them), and a study of the types when available, shows a marked similarity among all the Arctic faunas. A few distinct species occur, which are limited to a small geographic area or to certain ocean depths, but on the whole, the Arctic fauna is a circumpolar one. Identical forms are

found in the Arctic Ocean and adjoining regions, i.e., Alaska, the Greenland area, Canadian Arctic, north of the British Isles, the coasts of Sweden and northern Germany, and from off the Russian and Siberian coasts.

Unfortunately, this method of interpretation of the earlier works upon the basis of their figures and descriptions is greatly hampered by the fact that all too many authors have not adequately described their material. Many references make use of faunal lists (obviously questionable in view of the wide variation in the concept of the different species by the various writers). Many other references have recorded a species, but in place of figures and descriptions of the material at hand, the original figures and descriptions have been copied (to save time and effort). A comparison of the type specimens of these later authors with the meager descriptions given by them (and either quoted verbatim from the original author or paraphrased in some way) shows the descriptions often to be at considerable variance with the specimens actually found.

In some cases species have been recorded and important characters described as present, under the erroneous supposition that the specimens at hand were like those from other areas, seen in the literature. Closer examination of the types shows that the true characters are quite different, sometimes even requiring transfer of the species to another genus.

We have therefore changed the point of emphasis for our present study, so that it is largely a taxonomic one, and we have tried to straighten out some of the tangled problems that have been uncovered. Admittedly, other problems still exist, some of which require a first-hand examination of the original types of Brady, Parker and Jones, and other European workers for solution, but as this was impossible for the present, these problems are stated as such under the appropriate specific descriptions.

A redescription of all genotype species of the smaller Foraminifera is in progress by the writers and a proposed study of the original types in Europe will undoubtedly settle many more of these taxonomic problems. Only then will a detailed ecologic study be possible.

The present study is not intended as a monographic treatment, and not all species that were obtained have been included. A few of the lagenids, some of the polymorphinids and rotalids, and a few of the arenaceous species have been left for later study because of the questions arising as to their correct identification. It is hoped that future studies will allow us to complete the descriptions of the Arctic faunas.

## LIST OF STATIONS

### Station

1. 3.2 miles off Point Barrow, northern Alaska, at a depth of 48.6 m. Bottom: mud, gravel, stones, small rocks. Dredged February 18, 1950, through ice with a dog team.
2. 7.0 miles offshore at Point Barrow, northern Alaska, at a depth of 126 m. Bottom: stones and gravel. Dredged August 9, 1949.
3. 12.1 miles off Point Barrow, northern Alaska, at a depth of 223.2 m. Bottom: worm tubes. Dredged August 8, 1949.
4. 4.0 miles off Point Barrow Base Camp, northern Alaska, at a depth of 52.2 m. Bottom: gravel and small stones, sea urchins. Dredged October 14, 1949.
5. 5.0 miles off Point Barrow, northern Alaska, at a depth of 55.8 m. Bottom: stones, *Psolus*, and many sea urchins. Dredged August 30, 1949.
6. 8.0 miles off Point Barrow, northern Alaska, at a depth of 136.8 m. Bottom: rocks and small amount of gravel, and *Psolus*. Dredged October 11, 1949.
7. 4.0 miles off Point Barrow, northern Alaska, at a depth of 64.8 m. Bottom: gravel and mud. Dredged October 6, 1949.
8. 16.0 miles off Point Barrow, northern Alaska, at a depth of 144 m. Bottom: worm tubes and few rocks. Dredged September 6, 1949.
9. 5.0 miles off Point Barrow, northern Alaska, at a depth of 84.2 m. Bottom: rocks, stones, gravel, and *Psolus*. Dredged October 6, 1949.
10. 6.0 miles off Point Barrow, northern Alaska, at a depth of 104.4 m. Bottom: few rocks, stones, gravel, and sea urchins. Dredged October 11, 1949.
11. 150 yards offshore at Point Barrow, northern Alaska. Plankton haul touching bottom at a depth of 9.1 m. Collected July 13, 1950.
12. 4.0 miles off Point Barrow Base Camp, northern Alaska, at a depth of 64.8 m. Bottom: gravel and mud. Dredged October 6, 1949.
13. 1.75 miles off Point Barrow, northern Alaska, at a depth of 21.6 m. Bottom: mud, clams, worms, hermit crabs, and a few gastropods. Collected July 21, 1950.
14. Along shore opposite Point Barrow Base Camp, northern Alaska, at a depth of 3.2 m. Collected October 11, 1949.
15. 3.0 miles off Point Barrow Base Camp, northern Alaska, at a depth of 43.2 m. Bottom: mud. Collected July 22, 1950.
16. 2.6 miles off Point Barrow Base Camp, northern Alaska, at a depth of 39.6 m. Bottom: mud. Collected July 22, 1950.
17. 3.5 miles off Point Barrow Base Camp, northern Alaska, at a depth of 42 m. Bottom: mud, sand, gravel, cobbles, octocorals, sponges, pelecypods, gastropods, and isopods. Collected August 1, 1950.
18. 3.0 miles offshore between Point Barrow Base Camp and Barrow village, northern Alaska, at a depth of 37 m. Bottom: mud, sand, gravel, cobbles, and shells. Collected August 1, 1950.

*Station*

19. 5.5 miles off Point Barrow Base Camp, northern Alaska, at a depth of 61.2 m. Collected August 5, 1950.
20. Lat.  $63^{\circ}25'N.$ , long.  $68^{\circ}19'W.$  (approximate), about 2.0 miles east of Cape Rammelsburg, west side of Frobisher Bay, Baffin Land, at a depth of 100.5 m. Collected August 23, 1943. Bartlett Collection.
21. Lat.  $63^{\circ}10'N.$ , long.  $67^{\circ}45'W.$  (approximate), close to the south end of Gletcher Island, east end of Cincinnati Press Channel, Frobisher Bay, at a depth of 54.9 m. Collected August 22, 1943. Bartlett Collection.
22. Just to the southwest of the first island within Kneeland Bay, west shore of Frobisher Bay, at a depth of 31.1 m. Collected August 26, 1942. Bartlett Collection.
23. Off North Wolstenholme Island, northwest Greenland, in 23.8 to 45.7 m. Bartlett Collection.
24. Winter Harbor, Lyon Inlet, Melville Peninsula, Fox Channel. Collected August 27, 1933. Bartlett Collection.
25. North shore of Lyon Inlet, Melville Peninsula, Fox Channel. Collected August 24, 1933. Bartlett Collection.
26. North Omenolu, near North Star Bay, north Greenland, at a depth of 31.1 m. Collected July 28, 1932. Bartlett Collection.
27. Disko Island, Vaigat, west Greenland. Muddy bottom. Collected August 16, 1937. Bartlett Collection.
28. Off Akpatok Island, Ungava Bay, at a depth of 47.6 m. Collected August 9, 1943. Bartlett Collection.
29. 20.0 miles off Akpatok Island, Ungava Bay, at a depth of 65.9 m. Collected August 9, 1943. Bartlett Collection.
30. Off Akpatok Island, Ungava Bay, lat.  $60^{\circ}8'N.$ , long.  $67^{\circ}47'W.$ , at a depth of 73.2 m. Collected August 9, 1943. Bartlett Collection.
31. Between Parker Snow Bay and Conical Rocks, northwest Greenland, at a depth of 45.7 to 82.3 m. Collected July 22, 1940. Bartlett Collection.
32. Lat.  $63^{\circ}34'N.$ , long.,  $68^{\circ}14'W.$  (approximate), about 1.0 mile off An Island, mouth of Porter Inlet, east side of Frobisher Bay, Baffin Land, at a depth of 142.6 m. Collected August 23, 1943. Bartlett Collection.
33. Cape Stosch, Gotthaob Island, Hudson Land, northeast Greenland, at a depth of 12.8 m. Collected 1931. Bartlett Collection.
34. Lat.  $66^{\circ}43'N.$ , long.  $80^{\circ}07'W.$ , Fox Basin. Collected August 1927. Bartlett Collection.
35. Between Shannon and Hochstetter Islands, northeast Greenland. Collected August 13, 1931. Bartlett Collection.
36. Lat.  $74^{\circ}21'N.$ , long.  $16^{\circ}30'W.$ , at a depth of 201.2 m. Bartlett Collection.
37. 5.0 miles off Cape Borlase Warren, northeast Greenland, at a depth of 12.8 m. Collected August 13, 1931. Bartlett Collection.
38. Murray Harbor, Lyon Inlet, Melville Peninsula, Fox Channel. Collected August 27, 1933. Bartlett Collection.
39. Off north shore of an island in harbor of Crystal 2 Base, Frobisher Bay, at a depth of 23.8 m. Collected July 28, 1942. Bartlett Collection.
40. Lat.  $54^{\circ}15'N.$ , long.  $57^{\circ}45'W.$ , Hamilton Inlet, Labrador, at a depth of 54.9 m. Bottom: mud and stones. D. C. Nutt Collection.
41. North Gabriola Island, east side of Vancouver Island, British Columbia, at a depth of 91.4 m. Collected October 1900 by J. W. Taylor.

## Station

42. Lat.  $63^{\circ}11'N.$ , long.  $67^{\circ}50'W.$ , near a small island at the east end of Cincinnati Press Channel, at a depth of 146.3 m. Collected August 22, 1943. Bartlett Collection.
43. *Albatross* station D. 2859, lat.  $55^{\circ}20'00''N.$ , long.  $136^{\circ}20'00''W.$ , at a depth of 2869.7 m. Bottom: gray ooze. Collected August 29, 1888.
44. *Albatross* station D. 3600, lat.  $55^{\circ}06'00''N.$ , long.  $163^{\circ}28'00''W.$ , at a depth of 16.5 m. Bottom: fine dark volcanic sand. Collected June 26, 1895.
45. Off Village Pingikalik, Fury and Hecla Straits, northeast Melville Island. Collected September 6, 1933. Bartlett Collection.
46. Lat.  $63^{\circ}18'N.$ , long.  $68^{\circ}05'W.$ , Bartlett Collection.
47. *Blue Dolphin* station 51-2, Nain Bay, Labrador, at a depth of 82.3 m. Bottom: mud. D. C. Nutt Collection.
48. *Blue Dolphin* station 51-1, Nain Bay, Labrador, at a depth of 65 m. Bottom: mud. D. C. Nutt Collection.
49. Lat.  $71^{\circ}29.4'N.$ , long.  $156^{\circ}53.4'W.$ , at a depth of 148.1 m. Collected August 13, 1951.
50. 3.0 miles off Point Barrow Base Camp, northern Alaska, at a depth of 36.6 m. Bottom: gravel, large stones, and mud. Collected August 8, 1949.
51. Off Clavering Island, northeast Greenland, at a depth of 91.4 to 104.2 m. Collected August 13, 1931. Bartlett Collection.
52. Off south end of the Humboldt Glacier, northwest Greenland, at a depth of 201.2 m. Bottom: mud and sand. Collected August 3, 1940. Bartlett Collection.
53. Off Kushiro, Hokkaido, Japan, at a depth of 200 m. Collected by Hiroshi Niino.
54. Off Clavering Island, northeast Greenland, at a depth of 18.3 to 65 m. Bartlett Collection.
55. *Albatross* station D. 2251, lat.  $40^{\circ}22'17''N.$ , long.  $69^{\circ}51'30''W.$ , at a depth of 78.7 m. Bottom: green mud and fine sand. Collected September 27, 1884.
56. *Albatross* station D. 2453, lat.  $47^{\circ}10'00''N.$ , long.  $51^{\circ}02'00''W.$ , at a depth of 150 m. Bottom: green mud and fine sand. Collected June 26, 1885.
57. *Albatross* station D. 2242, lat.  $40^{\circ}15'30''N.$ , long.  $70^{\circ}27'00''W.$ , at a depth of 106 m. Bottom: green mud. Collected September 26, 1884.
58. *Albatross* station D. 2465, lat.  $45^{\circ}35'00''N.$ , long.  $55^{\circ}01'00''W.$ , at a depth of 122.5 m. Bottom: black, gray sand. Collected July 3, 1885.
59. *Albatross* station D. 2240, lat.  $40^{\circ}27'30''N.$ , long.  $70^{\circ}29'00''W.$ , at a depth of 80.5 m. Bottom: green mud. Collected September 26, 1884.
60. *Albatross* station D. 2253, lat.  $40^{\circ}34'30''N.$ , long.  $69^{\circ}50'45''W.$ , at a depth of 58.6 m. Bottom: gray sand, black specks. Collected September 27, 1884.
61. Hudson Bay, Richmond Gulf (about 3.0 miles from entrance), at a depth of 27.4 to 36.6 m. Bottom: sand and stones. Collected August 23, 1920, by Frits Johansen.
62. Bay at (north of) southeast point of South Twin Island, James Bay, at a depth of 7.3 to 9.1 m. Bottom: sand, gravel, and stones. Collected July 27, 1920 by Frits Johansen.

*Station*

63. Off Camp David Gray, Shannon Island, northeastern Greenland, at a depth of 122.5 m. Collected by Capt. Robert A. Bartlett.
64. Bay inside boat opening, Manitousk Sound, east coast of Hudson Bay, at a depth of 9.1 to 12.8 m. Bottom: clay with sand and stones. Collected August 27, 1920, by Frits Johansen.
65. Bay between Black Whale and Olaska Harbors, east coast of Hudson Bay (about lat. 55°N.), at a depth of 18.3 m. Bottom: sandy mud with many loose algae. Collected August 28, 1920, by Frits Johansen.
66. Between Clavering Island and Holmes Foreland, near glacier, northeastern Greenland, at a depth of 12.8 m. Collected by Capt. Robert A. Bartlett.
67. Off Shannon Island, northeastern Greenland, at a depth of 18.3 to 65 m. Collected by Capt. Robert A. Bartlett.
68. *Albatross* station D. 3604, lat. 54°54'00"N., long. 168°59'00"W., at a depth of 2562.4 m. Bottom: green ooze.
69. *Albatross* station D. 3608, lat. 55°19'00"N., long. 168°11'00"W., at a depth of 504.8 m. Bottom: gray sand.
70. *Discoverer* station 27-N, lat. 36°41.5'N., long. 122°05'W., at a depth of 1494.3 m.
71. *Guide* station 22 (24), lat. 43°12'N., long. 125°01'W., at a depth of 1086.4 m.
72. *Guide* station 13 (24), lat. 43°15'N., long. 124°53'W., at a depth of 415.2 m.
73. *Guide* station 13 (25), lat. 33°17'N., long. 117°55'W., at a depth of 724.3 m.
74. Off Clavering Island, near glacier, northeastern Greenland. Collected by Capt. Robert A. Bartlett.
75. Between Shannon Island and Hochstetter Foreland, northeastern Greenland. Collected by Capt. Robert A. Bartlett.
76. Off Shannon Island, northeastern Greenland, at a depth of 12.8 m. Collected by Capt. Robert A. Bartlett.
77. Southeast corner of the Fox Basin, lat. 66°46' N., long. 79°15'W., at a depth of 62.2 to 67.7 m. Collected by Capt. Robert A. Bartlett.
78. Bight of Shannon Island, northeastern Greenland. Collected by Capt. Robert A. Bartlett.

## ACKNOWLEDGMENTS

The field work for the present project was sponsored by a contract (ONR 02200) between the Office of Naval Research, Department of the Navy, and the Smithsonian Institution. The writers are indebted to both of these agencies for their splendid cooperation during the course of this work.

Dr. G. E. MacGinitie, former director of the Arctic Research Laboratory, Point Barrow, Alaska, aided in collecting samples and in providing material collected prior to 1950. Jacob Stalker and Miles Itta, Eskimo guides employed by the Arctic Laboratory, gave valuable assistance in collecting the material. Dr. Ira L. Wiggins, present

director of the Arctic Research Laboratory, supplied one sample collected during the 1951 season.

Mrs. Sally D. Lee, scientific illustrator, Smithsonian Institution, prepared the camera-lucida drawings of Foraminifera.

## THE FORAMINIFERAL FAUNA GENERAL STATEMENT

In the present report, 110 species of Foraminifera from the Arctic and sub-Arctic regions, representing 20 families and 56 genera, are described and illustrated. There are 6 new genera, 21 new species, and 1 new specific name proposed for a homonym. Many of the previously described species are placed in genera other than that under which they were originally described or have since been recorded.

The genus *Alvecolophragmium* Stschedrina is redefined, and the name *Labrospira* Höglund is suppressed as a synonym. The new genus *Ammotium* is separated from *Ammobaculites* Cushman on the basis of chamber arrangement. The genus *Miliolinella* Wiesner is discussed, and because of the congeneric genotype species the generic name *Triloculinella* Riccio is suppressed as a synonym. A study of apertural characters and plan of chamber arrangement has led to the naming of the new genera *Scutuloris* and *Pateoris*, both belonging to the family Miliolidae.

In the Polymorphinidae, two new genera, *Laryngosigma* and *Eso-syrinx*, are proposed because of their distinctive apertural characters, which separate them respectively from *Sigmomorphina* Cushman and Ozawa and *Polymorphina* d'Orbigny.

Because of the apertural characters of the genotype species of *Elphidium* Montfort, the generic name *Cribrroelphidium* Cushman and Bronnimann is suppressed as a synonym. An examination of the genotype species of *Discorinopsis* Cole has shown that genus to be an agglutinated form, and not a representative of the calcareous Rotaliidae. Hyaline, calcareous species formerly placed in *Discorinopsis* are now placed in the new genus *Trichohyalus*.

## THE BARROW AREA CHARACTER OF THE BARROW FAUNA

In all, 74 species were found in the Barrow area, representing 40 genera. Only 14 of the species are agglutinated forms, and 10 are calcareous imperforate. The remaining 50 species are calcareous ones, belonging mainly to the Lagenidae, Polymorphinidae, Nonionidae,

Elphidiidae, Buliminidae, and Cassidulinidae. These forms were also most abundant in number of individuals, especially *Oolina costata* and *O. melo*, and the 3 species representative of the Nonionidae, as well as *Elphidium* and *Cassidulina*.

Of the agglutinated forms *Eggerella*, *Spiroplectammina*, *Alveolphragmium*, and *Ammotium* were often abundant in individuals, although represented by only a few species.

*Quinqueloculina agglutinata*, *Pyrgo williamsoni*, and *Pateoris hauerinoides* also were abundant in most of the samples.

#### LOCAL LIMITING FACTORS IN THE FORAMINIFERAL DISTRIBUTION

A total of 74 species of Foraminifera are here recorded from the 21 dredge samples taken from the vicinity of Point Barrow, Alaska. A range table has been prepared, showing the samples in order of increasing distance from shore. The depths in meters are also given, for in general the depths increase steadily with greater distance from shore. Station 3, from a distance of 12.1 miles offshore and a depth of 223 meters does not represent a normal depth, however, as it was taken from one of the submarine canyons.

*Depth and distance offshore.*—These must be treated as one in this discussion, as with increased distance, the depths also increase. Therefore, only depth is mentioned here, and the range in distance can be easily determined from the table. Among these 21 samples, there is a range from a minimum of 3 species to a maximum of 55 species in a single sample. The samples range in depth from 3 to 223 meters and from a dredging made along shore to a distance of 16 miles offshore.

As can be readily seen from the chart, the extremely shallow samples are less populated, but a total of 69 of the 74 species are found in the dredgings between the depths of 20 and 50 meters. Some of the species occur throughout the entire depth and distance range, but others are more restricted.

In particular, the Miliolidae, some of the species of *Oolina* and *Fissurina*, the Nonionidae, Elphidiidae, and Rotaliidae all tend to occur at all depths sampled. In a single genus there may be variation also, for *Cassidulina islandica* and *C. teretis* are both widespread, but *C. norcrossi* was found only in three samples, between 40 and 50 meters in depth.

Species found only in depths less than 50 meters include *Reophax scorpiurus*, *Adercotryma glomeratum* (only in one sample at 48 meters), *Quinqueloculina stalkerii*, *Gordiospira arctica*, *Trochammina*









*rotaliformis*, *Astacolus* sp., *Dentalina ittai*, *Lagena apiopleura*, *L. flatulenta*, *L. gracillima*, *L. mollis*, *L. semilineata*, *L. setigera*, *Oolina hexagona*, *O. lineato-punctata*, *Glandulina laevigata*, and *Elphidiella groenlandica*.

In addition, *Bulimina exilis* is found only at depths of less than 65 meters, *Fissurina semimarginata* from a single sample at 61 meters, and *Laryngosigma williamsoni* from three samples ranging from 37 to 64 meters in depth. Three species were found only in the deepest sample, at 223 meters, namely, *Hippocrepina indivisa*, *Fissurina cucurbitasema*, and *Fissurina lucida*.

Thus the factor of depth is of some importance, the extremely shallow samples being comparatively barren and some species being restricted to certain depths, although no very marked change is evident.

*Temperature*.—Although of regional importance, in that all faunas studied are Arctic faunas, the temperature is definitely not a local factor here, as the bottom temperature varies only between  $-1.8^{\circ}\text{C}$ . and  $-2.9^{\circ}\text{C}$ . throughout the year, within the Barrow area.

*Light*.—The amount of light also has little effect on the foraminiferal populations as, with the single exception of station 3, from a submarine canyon, all stations are less than 150 meters in depth, and thus well within the littoral zone (the lighted zone of the benthos). Possibly the light fluctuation in the Arctic from summer to winter would have an effect, but no samples were available to determine the seasonal variation, if any, in the faunas.

*Character of the bottom*.—Probably the most important factor in the distribution of Foraminifera is the character of the bottom. Adjacent to the shore line is a narrow zone of sand (the beach) which is very sparsely populated. This zone is represented by stations 11 and 14. Beyond this narrow sandy zone is a mud zone, and farther out is a zone of coarse gravel. In the offshore gravel zone is found the most diversified invertebrate fauna, and a varied foraminiferal fauna, whereas the mud zone has fewer species.

The character of the bottom is very important to these benthonic forms, for there is no vegetation in the near-shore zone to offer protection for the minute benthonic forms, and the movement of the sand and gravel by wave or current action destroys all life.

The mud zone also contains fewer Foraminifera, probably because of a lack of oxygen, for the decaying organic matter consumes the supply of oxygen. Where the mud is mixed with gravel and cobbles

the population increases, for here the heterogeneous bottom allows a better supply of oxygen so that many benthonic invertebrates are present.

The boundaries of these zones are not static in the Barrow area. Records of earlier dredgings show that the gravel zone extended much farther inshore in previous years, and even in 1949 gravel and stones with associated invertebrates (clams, gastropods, worms, and echinoids) were found as close as 4 miles from shore. However, heavy storms during the winter of 1949-50 carried large quantities of mud out over the shell banks and gravel zones of earlier years. Dredgings showed a mixture of mud and gravel or mud, sand, and cobbles, as far offshore as collections were made that year (5.5 miles), and a single sample obtained in 1951 contained mud at a depth of 148 meters, approximately 11 miles offshore. This extension of the mud zone made a considerable change in the character of the fauna. In large part only dead shells of the invertebrates were obtained in collections made in 1950 from the former gravel zones, for all the animals were killed by the influx of mud to which they were not accustomed.

There was also a considerable effect on the foraminiferal populations. Station 5 (1949) at a distance of 5 miles offshore and a depth of 55 meters contained 34 species of Foraminifera along with echinoids and *Psolus*. Station 19 (1950) from 5.5 miles offshore at a depth of 61 meters contained only 26 species. In general, the species that dropped out belonged to the Lagenidae and Buliminidae, although a single species each of *Pyrgo*, *Elphidium*, *Buccella*, and *Cassidulina* also were present in station 5 and absent from station 19.

Records of the foraminiferal population have not been made for a sufficient length of time to determine in detail the effect of the changing environment. It is probable that a much greater change would eventually take place, providing the mud zone continued to extend farther offshore. Very little is known of the degree of tolerance of Foraminifera of a temporarily unfavorable environment. It is also possible that some mixing of assemblages also was caused by the same strong currents that carried the muds out over the gravel zone.

About the only conclusion that can be reached on the basis of the limited amount of material and the short time interval represented is that the temperature, light, and depth all seem of minor importance in the local Arctic area in the vicinity of Point Barrow, and the character of the ocean bottom itself is the most effective limiting influence on the foraminiferal assemblage.

## SYSTEMATIC DESCRIPTIONS

## Family RHIZAMMINIDAE

Genus BATHYSIPHON M. Sars, 1872

## BATHYSIPHON RUFUS de Folin

Plate 1, figure 1

*Bathysiphon rufum* DE FOLIN, 1886, Act. Soc. Linn. Bordeaux, vol. 40 (ser. 4, vol. 10), p. 283, pl. 6, figs. 8a-c.—GOËS, 1896, Bull. Mus. Comp. Zool., vol. 29, p. 23, pl. 1, fig. 10.—FLINT, 1899, Ann. Rep. U. S. Nat. Mus. for 1897, p. 267, pl. 7.

*Bathysiphon rufus* de Folin, CUSHMAN, 1910, U. S. Nat. Mus. Bull. 71, pt. 1, p. 32, text fig. 22; 1918, U. S. Nat. Mus. Bull. 104, pt. 1, p. 29.

Test free, large, consisting of an extremely elongate and somewhat tapering hollow tube, occasionally somewhat arcuate, with irregular constrictions at varying intervals, possibly representing growth stages; wall fairly thick, finely arenaceous, with siliceous cement, surface smooth and polished, color white, yellow, or reddish brown; aperture at the open end of the tube.

Length of figured hypotype 8.66 mm., greatest breadth of tube 0.42 mm., least diameter at early portion of tube 0.16 mm. Other specimens range in length from 2.86 to 7.05 mm., and in width from 0.29 to 0.49 mm.

*Types and occurrence.*—Figured hypotype (U.S.N.M. No. P2146) and unfigured hypotypes from station 43.

## Family SACCAMMINIDAE

Genus PELOSINELLA Parr, 1950

## PELOSINELLA DIDERA Loeblich and Tappan, new species

Plate 1, figure 2

Test free, unilocular, with a single ovate chamber, and two elongate necks at opposite ends of the test; wall arenaceous, of medium-sized to coarse grains, with a chitinous base; apertures at the open ends of the two tubular necks.

Length of holotype 1.35 mm., length of chamber 0.60 mm., greatest breadth of chamber 0.44 mm., diameter of neck 0.10 mm. Length of paratype 0.60 mm.

*Remarks.*—The genus *Pelosphaera* was described by Heron-Allen and Earland, 1932, from the Antarctic, as consisting of a spherical test usually with two hollow conical projecting processes, which do not possess external openings at their ends. *Pelosinella*, 1950, also

from the Antarctic, was defined as having definite apertures at the ends of the tubes. It seems very probable that the two may be congeneric and either the latter has broken ends rather than true apertures, or apertures may be present on *Pelosphaera* but concealed by sediment. However, as it is impossible to determine this definitely without examination of the types, the present species is placed in *Pelosinella*, as it appears to have definite apertures.

The present species is very similar in appearance to *Pelosinella bicaudata* Parr, the genotype species from the Antarctic. It differs in being about one-fourth as large and in having somewhat more elongate necks.

*Types and occurrence.*—Holotype (U.S.N.M. No. P2062) and unfigured paratype from station 43.

Genus THURAMMINA Brady, 1879

THURAMMINA ALBICANS Brady

Plate 1, figure 3

*Thurammia albicans* BRADY, 1879, Quart. Journ. Micr. Soc., vol. 19, p. 46; 1884, Rep. Voy. Challenger, vol. 9 (Zoology), p. 323, pl. 37, figs. 2-7.—CUSHMAN, 1910, U. S. Nat. Mus. Bull. 71, pt. 1, p. 58, text figs. 67-72; 1918, U. S. Nat. Mus. Bull. 104, pt. 1, p. 71, pl. 28, figs. 4-8.

Test free, unilocular, nearly globular; wall thin, finely arenaceous, surface smoothly finished; about 5 to 6 apertures, nearly equidistant, and situated upon mammillate protuberances.

Greatest diameter of figured hypotype 0.73 mm.

*Remarks.*—*T. albicans* Brady differs from *Thurammia papillata* Brady in being smaller in size and in having much more infrequent apertures. Typical *T. papillata* is covered with numerous protruding orifices. An atypical specimen of *Thurammia papillata* Brady (1884, pl. 36, fig. 7) is very similar in the relatively smooth appearance and few apertures, but is larger than the usual specimens of *T. albicans*.

*Type and occurrence.*—Figured hypotype (U.S.N.M. No. P2063) from station 43.

Genus THOLOSINA Rhumbler, 1895

THOLOSINA BULLA (Brady)

Plate 1, figure 4

*Placopsilina bulla* BRADY, 1881, Quart. Journ. Micr. Soc., vol. 21, p. 51; 1884, Rep. Voy. Challenger, vol. 9 (Zoology), p. 315, pl. 35, figs. 16, 17.

*Tholosina bulla* (Brady) CUSHMAN, 1910, U. S. Nat. Mus. Bull. 71, pt. 1, p. 49, text fig. 55; 1918, U. S. Nat. Mus. Bull. 104, pt. 1, p. 63, pl. 25, fig. 6; 1920, Rep. Canadian Arctic Exped. 1913-1918, vol. 9, pt. M, p. 5, pl. 1, figs. 1, 2.—CUSHMAN and McCULLOCH, 1939, Allan Hancock Pacific Exped., vol. 6, No. 1, p. 49, pl. 2, fig. 6.—CUSHMAN, 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 15, pl. 1, fig. 13.

*Pseudoplacopsilina bulla* (Brady) EIMER and FICKERT, 1899, Zeitschr. wiss. Zool., vol. 65, No. 4, p. 672.

Test attached, a hemispherical undivided chamber; wall finely arenaceous, whitish in color, surface smooth, but granular in appearance; aperture small, rounded, adjacent to the substratum.

Greatest diameter of figured hypotype 0.65 mm., height of test 0.29 mm. Other specimens range from 0.96 to 1.77 mm. in diameter.

*Types and occurrence.*—Figured hypotype (U.S.N.M. No. P1099) from station 3; unfigured hypotype recorded from station 30.

Genus **AMMOPEMPHIX** Loeblich, 1952

**AMMOPEMPHIX ARCTICA** (Cushman)

Plate 1, figure 5

*Urnula arctica* CUSHMAN, 1933, Smithsonian Misc. Coll., vol. 89, No. 9, p. 1, pl. 1, figs. 1, 2; 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 17, pl. 2, figs. 1, 2.

Test attached, but generally loosened from the attachment, nearly circular in outline, flat on the attached side, convex above; consisting of four or more chambers, usually symmetrically arranged, with a few chambers (4 or 5) in a single whorl, occasionally with a second outer ring of chambers surrounding the first, chambers of nearly equal size; sutures distinct, depressed, the septa visible from the base on unattached specimens, straight, of a thickness nearly equal to that of the outer wall; outer wall finely arenaceous, white to yellowish in color, wall adjacent to the attachment very thin, delicate and translucent, and may be broken off when loosened from the attachment, leaving the chambers open ventrally; a rounded aperture at the center of each chamber.

Greatest breadth of figured hypotype 0.36 mm., height of test from attachment 0.08 mm.

*Types and occurrence.*—Figured hypotype (U.S.N.M. No. P1061) from station 50; unfigured hypotypes are recorded from stations 51 and 67.



## Family HYPERAMMINIDAE

Genus HYPERAMMINA Brady, 1878

## HYPERAMMINA ELONGATA Brady

Plate 1, figure 6

*Hyperammina elongata* BRADY, 1878, Ann. Mag. Nat. Hist., ser. 5, vol. 1, p. 433, pl. 20, figs. 2a,b.—CUSHMAN, 1910, U. S. Nat. Mus. Bull. 71, pt. 1, p. 60, text fig. 73 (74<sup>?</sup>); 1918, U. S. Nat. Mus. Bull. 104, pt. 1, p. 74, pl. 29, fig. 4.—HÖGLUND, 1947, Zool. Bidrag Uppsala, vol. 26, p. 66, text figs. 22-25.—CUSHMAN, 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 18.—F. PARKER, 1952, Bull. Mus. Comp. Zool., vol. 106, No. 9, p. 395, pl. 1, fig. 10.

Test free, narrow, elongate, cylindrical; consisting of a bulbous proloculus and long, slender, tubular second chamber of diameter somewhat less than that of the proloculus; wall rather coarsely arenaceous, of many angular quartz fragments with a small amount of ferruginous stained cement, surface rough; aperture terminal, but broken from the single specimen found.

Length of figured hypotype 1.59 mm., greatest breadth of proloculus 0.26 mm., greatest breadth of tubular chamber 0.18 mm.

*Remarks.*—Only a single specimen was observed and its terminal portion was broken. According to Höglund (1947, p. 66), "round the aperture, which is constricted to half or a third of the diameter of the tubular chamber, a circular, crater-like vallum is constructed of only fine-grained mortar-mass, without intermixture of larger grains of sand. . . . The ring encircling the aperture loosens very readily from the rest of the test, which explains the erroneous statement of Cushman and other authors: Aperture at the distal end of the tube, circular without a lip or other modification."

*Type and occurrence.*—Figured hypotype (U.S.N.M. No. P2033) from station 51.

## HYPERAMMINA SUBNODOSA Brady

Plate 1, figures 7-12

*Hyperammina subnodosa* BRADY, 1884, Rep. Voy. Challenger, vol. 9 (Zoology), p. 259, pl. 23, figs. 11-14.—GOËS, 1894, Svenska Vet.-Akad. Handl., vol. 25, No. 9, p. 16, pl. 3, fig. 42-53 (not fig. 54).—CUSHMAN, 1918, U. S. Nat. Mus. Bull. 104, pt. 1, p. 76, pl. 29, figs. 7, 8; 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 19, pl. 2, fig. 7.

Test very large, elongate and narrow, subcylindrical; proloculus large and rounded to elongate, later tubular chamber may be of slightly less diameter with somewhat irregular constrictions, and rarely (about 2 percent of the specimens examined) bifurcating (fig.

9); wall thick and fairly coarsely arenaceous, but containing clear quartz grains well sorted as to size, which give the surface a sugary appearance because of the relatively small amount of cement, color yellowish, because of the ferruginous stained cement; aperture circular, at the somewhat constricted distal end of the tube.

Length of hypotype of figure 8, 9.0 mm., breadth of proloculus 1.46 mm., greatest breadth of tubular chamber 1.38 mm., least breadth of tubular chamber 0.86 mm. Length of hypotype of figure 10, 3.17 mm., breadth 1.90 mm.

*Types and occurrence.*—Figured hypotypes (U.S.N.M. Nos. P1069a-f) from station 40; unfigured hypotypes are recorded from stations 40, 47, and 48.

**Genus HIPPOCREPINA Parker, 1870**

**HIPPOCREPINA INDIVISA Parker**

Plate I, figure 13

*Hippocrepina indivisa* PARKER, 1870, in Dawson, Can. Nat., n. s., vol. 5, p. 176, fig. 2.—CUSHMAN, 1918, U. S. Nat. Mus. Bull. 104, pt. 1, p. 57, pl. 23, figs. 3-7; 1944, Cushman Lab. Foram. Res. Spec. Publ. 12, p. 6, pl. 1, fig. 5; 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 21, pl. 2, figs. 4, 5.—F. PARKER, 1952, Bull. Mus. Comp. Zool., vol. 106, No. 9, p. 394, pl. 1, fig. 5.

Test free, consisting of a single elongate, tapering chamber which is contracted and broadly rounded at the top; wall finely arenaceous, reddish to yellowish in color, the apertural portion somewhat lighter in color, smoothly finished, but with occasional slight transverse constrictions, which are not related to any structural features as there are no internal divisions into chambers; aperture small, terminal, central, usually circular, sometimes surrounded by a slightly raised lip.

Length of figured hypotype 0.91 mm., greatest breadth 0.39 mm. Other specimens range from 0.47 to 1.04 mm. in length.

*Types and occurrence.*—Figured hypotype (U.S.N.M. No. P1045) from station 3; unfigured hypotypes are recorded from stations 27, 29, 30, and 47.

**Genus SACCORHIZA Eimer and Fickert, 1899**

**SACCORHIZA RAMOSA (Brady)**

Plate I, figures 14, 15

*Hyperammina ramosa* BRADY, 1879, Quart. Journ. Micr. Soc., vol. 19, p. 33, pl. 3, figs. 14, 15; 1884, Rep. Voy. *Challenger*, vol. 9 (Zoology), p. 261, pl. 23, figs. 15-19.—FLINT, 1899, Ann. Rep. U. S. Nat. Mus. for 1897, p. 270, pl. 11, fig. 1.

*Saccorhiza ramosa* (Brady) EIMER and FICKERT, 1899, Zeitschr. wiss. Zool., vol. 65, No. 4, p. 670.—CUSHMAN, 1910, U. S. Nat. Mus. Bull. 71, pt. 1, p. 65, text fig. 81; 1918, U. S. Nat. Mus. Bull. 104, pt. 1, p. 81, pl. 30, figs. 3, 4.

Test free, with a subglobular proloculus and long dichotomously branching tubular undivided chamber of nearly uniform diameter throughout; wall thick, agglutinated, consisting of medium to fine sand grains, with an abundance of sponge spicules fastened almost at right angles to the outer surface, giving a very spinose and bristling appearance, color white or yellowish, with frequent dark mineral grains sometimes giving a very speckled appearance; apertures formed by the open ends of the tubes.

Length of hypotype of figure 15, 5.77 mm., breadth of tube varying from 0.44 to 0.65 mm. Length of hypotype of figure 14, 3.93 mm.

*Types and occurrence.*—Figured hypotypes (U.S.N.M. Nos. P2067a,b) and unfigured hypotypes from station 43.

### Family REOPHACIDAE

Genus REOPHAX Montfort, 1808

#### REOPHAX ARCTICA Brady

Plate I, figures 19, 20

*Reophax arctica* BRADY, 1881, Ann. Mag. Nat. Hist., ser. 5, vol. 8, p. 405, pl. 21, figs. 2a,b; 1882, Denkschr. Akad. Wiss. Wien, math.-nat. Kl., vol. 43, p. 99, pl. 2, figs. 2a,b.—F. PARKER, 1952, Bull. Mus. Comp. Zool., vol. 106, No. 9, p. 395, pl. 1, figs. 6, 7.

*Bigenerina arctica* (Brady) CUSHMAN, 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 31, pl. 3, fig. 9 (not figs. 10, 11).

Test free, small, elongate, somewhat compressed and slightly tapering at the base, later portion with nearly parallel margins; chambers numerous, uniserially arranged throughout, early ones low and broad, increasing in relative height as added, final chambers of nearly equal breadth and height, last chamber somewhat produced toward the aperture; sutures distinct, slightly depressed, later ones somewhat constricted so that the margin is somewhat lobulate in appearance; wall finely arenaceous, with occasional larger grains, white to gray in color, rather smoothly finished; aperture terminal, rounded.

Length of hypotype of figure 20, 0.55 mm., breadth 0.13 mm. Length of hypotype of figure 19, 0.39 mm.

*Remarks.*—Cushman (1948b, p. 31) mixed specimens of this species with those of *Textularia torquata* Parker, considering the present form as the megalospheric generation with a much-reduced biserial

stage and indistinct early chambers. He stated that the microspheric stage was biserial for a considerable portion of the test and that young specimens may not reach the uniserial stages. However, the associated *Textularia torquata* is not related to this species and never reaches a uniserial stage. Cushman's figure (1948b, pl. 3, fig. 9) is definitely misinterpreted and the test is actually uniserial down to the base rather than biserial as drawn. Cushman also stated that the size and color of the wall show the two forms to be the same. However, the *Textularia* which is often but not always associated with *R. arctica* is characteristically reddish in color as are so many of these Arctic agglutinated forms. Furthermore, the uniserial form is more slender and elongate, and the biserial form shorter and more flaring. After this separation had been made in manuscript by the present writers, Parker's paper (1952a) appeared in which she also separated the two forms and described the biserial form as a distinct species.

*Types and occurrence.*—Figured hypotype (U.S.N.M. No. P1054) from station 1; figured hypotype (U.S.N.M. No. P1055) from station 12; unfigured hypotypes are also recorded from the following stations: 1, 2, 8, 12, 13, 15, 16, 18, 20, 21, 22, 23, 26, 27, 29, 30, 31, 32, 33, 37, 38, 40, 42, 46, 47, 48, 51, 52, and 72.

### REOPHAX CURTUS Cushman

Plate 2, figures 1-4

*Reophax curtus* CUSHMAN, 1920, U. S. Nat. Mus. Bull. 104, pt. 2, p. 8, pl. 2, figs. 2, 3; 1922, Contr. Can. Biol., No. 9 (1921), p. 139.—CUSHMAN and McCULLOCH, 1939, Allan Hancock Pacific Exped., vol. 6, No. 1, p. 58, pl. 2, fig. 12.—CUSHMAN, 1944, Cushman Lab. Foram. Res. Spec. Publ. 12, p. 10, pl. 1, figs. 15, 16; 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 24, pl. 2, figs. 13, 14.—F. PARKER, 1942, Bull. Mus. Comp. Zool., vol. 106, No. 9, p. 395.

*Reophax subfusiformis* Earland, HÖGLUND, 1947 (part), Zool. Bidrag Uppsala, vol. 26, p. 82, pl. 9, figs. 1, 2, 4 (not 3), pl. 26, figs. 1-36, pl. 27, figs. 1-19, text figs. 43-50.

Test free, large, elongate, usually slightly arcuate, tapering at the base; consisting of 3 to 4 chambers, increasing rapidly in size, slightly inflated, final chamber pyriform in outline, tapering to form a neck; sutures obscured, later ones somewhat constricted, horizontal; wall coarsely arenaceous, with occasional black or dark green mineral grains among the usual clear quartz ones, little cement, mostly white or light in color, except for the occasional dark grains; aperture rounded, terminal, upon the slightly produced last chamber.

Length of specimen of figure 4, 2.05 mm., breadth 0.68 mm. Length

of specimen of figure 2, 2.34 mm., breadth 0.65 mm. Length of specimen of figure 3, 1.66 mm., breadth 0.60 mm. Other specimens range from 0.81 to 2.78 mm. in length.

*Remarks.*—The specimens figured by Höglund (1947) as *R. subfusiformis* Earland are apparently identical with the present species. However, Earland's types were from the Antarctic and thus may be distinct, hence we have not placed this species in the above synonymy. Höglund stated that *R. curtus* was described as lacking a neck and that *R. subfusiformis* had a definite neck. As Parker (1952a) noted, *R. curtus* may have a definite neck, but this may be broken because of its fragile character. Specimens we have found bear out this conclusion.

*Types and occurrence.*—Figured hypotypes (U.S.N.M. Nos. P1046a-d) from station 35; unfigured hypotypes are recorded from the following stations: 1, 2, 12, 16, 18, 20, 22, 26, 29, 30, 31, 35, 36, 40, 50, and 51.

#### REOPHAX PILULIFERA Brady

##### Plate 2, figure 6

*Reophax pilulifera* BRADY, 1884, Rep. Voy. *Challenger*, vol. 9 (Zoology), p. 292, pl. 30, figs. 18-20.—FLINT, 1899, Ann. Rep. U. S. Nat. Mus. for 1897, p. 273, pl. 18, fig. 1.

*Reophax pilulifer* Brady, CUSHMAN, 1910, U. S. Nat. Mus. Bull. 71, pt. 1, p. 85, figs. 117, 118; 1920, U. S. Nat. Mus. Bull. 104, pt. 2, pp. 7-8, pl. 2, fig. 1.—CUSHMAN and McCULLOCH, 1939, Allan Hancock Pacific Exped., vol. 6, No. 1, p. 68, pl. 4, fig. 6.

*Reophax subfusiformis* Earland, HÖGLUND, 1947 (part), Zool. Bidrag Uppsala, vol. 26, p. 82, pl. 9, fig. 3 only.

Test free, straight and somewhat elongate, consisting of a series of rounded or globular chambers with each additional chamber much larger than the preceding, the final chamber may be somewhat elongate and produced into a neck: sutures distinctly constricted between the nearly separated chambers; wall arenaceous, of medium-sized clear quartz grains, and occasional dark mineral grains, color white, surface fairly smooth; aperture terminal, rounded, on a slight necklike elongation of the final chamber.

Length of figured hypotype 1.09 mm., greatest breadth of first chamber 0.13 mm., greatest breadth of second chamber 0.23 mm., greatest breadth of final chamber 0.42 mm.

*Remarks.*—The specimen figured by Cushman (1944) from the New England coast seems closer to *R. curtus* than to the present species. The specimen shown by Höglund (1947, pl. 9, fig. 3) and one or

two of his text figures (not numbered) are apparently this species. They differ from *R. curtus* Cushman in having more regular and more globular chambers, and are more constricted between chambers. Höglund commented concerning these specimens which he referred to as "extreme variant No. 2" of *Reophax subfusiformis* Earland: "Individuals can be met with that I think show quite as much similarity to the original figures of *R. pilulifer*. . . . In saying this, however, I do not mean to assert that there is identity. An opinion on that problem can only be formed by someone having access to a sufficiently large material from Brady's original localities." Nevertheless, these figured specimens seem much closer to Brady's types than to the types of *R. subfusiformis*, which is an Antarctic species, or of *R. curtus* Cushman, to which the majority of Höglund's specimens of "*R. subfusiformis*" most probably belong.

*Type and occurrence*.—Figured hypotype (U.S.N.M. No. P1058) from station 43.

#### REOPHAX SCORPIURUS Montfort

Plate 2, figures 7-10

*Reophax scorpiurus* MONTFORT, 1808, Conchyliologie systematique . . . , vol. 1, p. 330.—CUSHMAN, 1910, U. S. Nat. Mus. Bull. 71, pt. 1, p. 83, figs. 114-116; 1920, U. S. Nat. Mus. Bull. 104, p. 6, pl. 1, figs. 5-7; 1944, Cushman Lab. Foram. Res. Spec. Publ. 12, p. 10, pl. 1, fig. 19.—(?) HÖGLUND, 1947, Zool. Bidrag Uppsala, vol. 26, p. 81, pl. 9, figs. 9, 10, pl. 26, figs. 52-55, text figs. 51, 52.

Test free, small, narrow, elongate, nearly straight or arcuate; consisting of a few chambers which increase rapidly in height as added, but less rapidly in breadth; sutures nearly horizontal, obscure to moderately constricted; wall agglutinated, largely composed of medium-sized clear quartz grains with a few scattered dark mineral grains and comparatively little cement, surface rough; aperture terminal, rounded, at the end of a distinct tubular neck.

Length of specimen of figure 10, 1.14 mm., breadth 0.39 mm. Other specimens range from 0.52 to 1.09 mm. in length.

*Remarks*.—This species is similar in appearance to *R. curtus* Cushman, but differs in being much smaller, more slender, with less-incised sutures, and is less coarsely arenaceous.

*Types and occurrence*.—Figured hypotypes (U.S.N.M. Nos. P1043a-c) from station 14; figured hypotype (U.S.N.M. No. P1044) from station 43; unfigured hypotypes are recorded from stations 14, 17, 33, 35, and 51.

Genus **PROTOSCHISTA** Eimer and Fickert, 1899**PROTOSCHISTA FINDENS** (Parker)

Plate 1, figures 16-18

- Lituola findens* PARKER, 1870, in Dawson, Can. Nat., n. s., vol. 5, p. 176, pl. fig. 1.  
*Reophax findens* (Parker) SIDDALL, 1879, Catalogue of British Recent Foraminifera, p. 4.—CUSHMAN, 1921, U. S. Nat. Mus. Bull. 100, vol. 4, p. 71, pl. 13, fig. 4.  
*Protoschista findens* (Parker) EIMER and FICKERT, 1899, Zeitschr. wiss. Zool., vol. 65, No. 4, p. 677.—GALLOWAY, 1933, Manual of the Foraminifera, p. 176, pl. 15, fig. 19.  
*Dendrophrya? findens* (Parker) CUSHMAN, 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 22, pl. 3, figs. 1, 2.

Test free, consisting of a series of chambers which are usually regularly uniserial, occasionally branching and forming 2 or 3 uniserial series of chambers from the proloculus; chambers somewhat broader than high, slightly inflated, of nearly equal size throughout; wall arenaceous, with comparatively little cement, surface rough, color yellowish to white; aperture circular at the ends of the series of chambers.

Length of hypotype of figure 16, 1.04 mm., breadth 0.23 mm.; length of hypotype of figure 18, 0.49 mm., breadth 0.18 mm.

*Types and occurrence*.—Figured hypotype (U.S.N.M. No. P1041a,b) from station 3; figured hypotype (U.S.N.M. No. P1042) from station 12; unfigured hypotypes are also recorded from stations 3, 6, 26, 52, 54, and 66.

Family **AMMODISCIDAE**Genus **TURRITELLELLA** Rhumbler, 1903**TURRITELLELLA SHONEANA** (Siddall)

Plate 2, figure 5

- Trochammina shoncana* SIDDALL, 1878, Proc. Chester Soc. Nat. Sci., pt. 2, p. 46, figs. 1, 2.  
*Ammodiscus shoneanus* Siddall, SIDDALL, 1879, Catalogue of British Recent Foraminifera, p. 5.—BALKWILL and WRIGHT, 1882, Proc. Roy. Irish Acad., vol. 3, p. 546; 1884, Journ. Micr., vol. 3, p. 25, pl. 1, fig. 4.—BRADY, 1884, Rep. Voy. *Challenger*, vol. 9 (Zoology), p. 335, pl. 38, figs. 17-19.—HERON-ALLEN and EARLAND, 1913, Proc. Roy. Irish Acad., vol. 31, No. 64, p. 49, pl. 3, fig. 6; 1916, Trans. Linn. Soc. London, vol. 11, pt. 13, p. 227.  
*Turritellopsis shoneanus* Siddall, RHUMBLER, 1895, Nachr. Ges. Wiss. Göttingen, p. 85; 1902, Zeitschr. allg. Phys., vol. 2, p. 284, fig. 103.  
*Turritellella shoneana* (Siddall) RHUMBLER, 1903, Arch. Prot., vol. 3, p. 283, fig. 135.—CUSHMAN, 1910, U. S. Nat. Mus. Bull. 71, pt. 1, p. 79, figs. 107-109; 1918, U. S. Nat. Mus. Bull. 104, pt. 1, p. 102, pl. 38, figs. 5-7.—HÖGLUND, 1947, Zool. Bidrag Uppsala, vol. 26, p. 129, text fig. 102.

Test free, elongate, narrow, consisting of a proloculus and long, undivided tubular second chamber increasing very slowly in diameter and coiled in a very high close spire, of approximately 10 volutions; spiral suture slightly depressed; wall finely arenaceous, of a reddish or yellowish color, grading from a more deeply colored proloculus to a lighter terminal portion; aperture consists of the open end of the tube.

Length of figured hypotype 0.31 mm., greatest breadth 0.10 mm. Length of unfigured hypotypes ranges from 0.23 to 0.26 mm.

*Types and occurrence*.—Figured hypotype (U.S.N.M. No. P1059) from station 20; unfigured hypotypes (U.S.N.M. No. P1060) are recorded from station 26.

### Family LITUOLIDAE

Genus *ADERCOTRYMA* Loeblich and Tappan, 1952

#### *ADERCOTRYMA GLOMERATUM* (Brady)

Plate 8, figures 1-4

*Lituola glomerata* BRADY, 1878, Ann. Mag. Nat. Hist., ser. 5, vol. 1, p. 433, pl. 20, figs. 1a-c.

*Haplophragmium glomeratum* (Brady) GOËS, 1894, K. Svenska Vet.-Akad. Handl., vol. 25, No. 9, p. 23, pl. 5, figs. 134-139.

*Haplophragmoides glomeratum* (Brady) CUSHMAN, 1910, U. S. Nat. Mus. Bull. 71, pt. 1, p. 104, figs. 158-161; 1920, U. S. Nat. Mus. Bull. 104, pt. 2, p. 47, pl. 9, fig. 6.—HÖGLUND, 1947, Zool. Bidrag Uppsala, vol. 26, p. 135, pl. 10, figs. 3, 4, text fig. 112.—CUSHMAN, 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 28, pl. 2, fig. 16.

*Adercotryma glomeratum* (Brady) LOEBLICH and TAPPAN, 1952, Journ. Washington Acad. Sci. vol. 42, p. 141, figs. 1-4.

Test free, subglobular to slightly ovate, planispiral but somewhat asymmetrical, with about two whorls present, greatest dimension in the axis of coiling, periphery broadly rounded; chambers few in number, only the four of the final whorl visible, very broad and low, slightly inflated, somewhat wedge-shaped with the narrower portion on the side with the aperture; sutures distinct, rather straight, slightly constricted; wall rather coarsely arenaceous, with considerable cement between the grains; aperture may be indistinct or lacking, or consist of a short slit or low arch at the inner margin of the final chamber, about one-half to two-thirds the distance from the periphery to the umbilicus, on the narrower side of the test.

Greatest diameter of hypotype of figure 2, 0.26 mm., thickness 0.26 mm. Other specimens range in diameter from 0.13 to 0.36 mm.



*Remarks.*—In describing this species, Brady (1878, p. 433) stated: "Aperture at the inner margin of the terminal chamber, near the exterior of the corresponding segment of the previous convolution, simple, often obscure." Cushman (1948b, p. 28) stated that the aperture is "a short slit at the base of the chamber, often obscured by sand grains." It remained for Höglund (1947, p. 135, pl. 10, fig. 4) to clearly demonstrate the position of this aperture, and he described it as "interio-marginal, forming a short slit at the margin of the last chamber, near the narrow end of the oviform test, most frequently indistinct or even lacking." In any large series of specimens, apertures are occasionally seen. These may be either of two types, a low arch about halfway between the periphery and the umbilicus (figs. 2, 3, 4b), or a slit which extends along the inner margin of the final chamber to the umbilicus (fig. 1b). Höglund suggested that specimens lacking an aperture might be in a growth stage in which it had not yet been developed. It is possible that different stages of growth may account for the two variations of apertures here mentioned.

*Types and occurrence.*—Figured hypotypes (U.S.N.M. Nos. P829a-c) from station 52; figured hypotype (U.S.N.M. No. P831) from station 51; unfigured hypotypes are recorded from stations 1, 22, 23, 26, 31, 32, 35, 36, 51, 52, and 53.

Genus **RECURVOIDES** Earland, 1934

**RECURVOIDES TURBINATUS** (Brady)

Plate 2, figure 11

*Haplophragmium turbinatum* BRADY, 1881, Quart. Journ. Micr. Soc., n. s., vol. 21, p. 50; 1884, Rep. Voy. *Challenger*, vol. 9 (Zoology), p. 312, figs. 9a-c.

*Trochammina turbinata* (Brady) CUSHMAN, 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 43, pl. 5, figs. 2a,b.

*Recurvoides turbinatus* (Brady) F. PARKER, 1952, Bull. Mus. Comp. Zool., vol. 106, No. 9, p. 402, pl. 2, figs. 23, 24.

Test free, streptospiral, with the later portion coiled in a different plane than the early portion, periphery broadly rounded; chambers numerous, increasing gradually in size as added, 5 to 8 in the final whorl, the majority with 6 chambers, later ones slightly inflated; sutures distinct, slightly depressed, nearly straight; wall finely arenaceous, with occasional larger quartz grains, smoothly finished, color yellowish to reddish brown; aperture interio-areal, ovate to somewhat elongate.

*Remarks.*—Cushman (1948b, p. 44) describes this species as having an aperture at the base of the ventral side of the chamber, but in

reality the aperture is interio-areal. Brady (1884, p. 312) stated the chambers in the final whorl numbered about 6. Cushman states (1948b, p. 44) there are 5 to 8 in the final whorl and Parker (1952a, p. 402) says her specimens have 6 in the final whorl and considered that Cushman might have confused another species with this form. The Arctic specimens examined by the writers have 5 to 8 chambers in the final whorl, with the majority having 6, however.

*Types and occurrence.*—Cushman (1948b) stated that this species occurred in a single station off Greenland, and that “as this seems to be the only record for it in this cold water, it is probably not to be included among typical Arctic species.” However, we have it at four stations off Point Barrow, Alaska, as well as other Arctic locations.

Figured hypotype (U.S.N.M. No. P2023) from station 23; unfigured hypotypes are recorded from stations 3, 8, 12, 15, 22, 23, 26, 27, 31, 35, 36, 51, and 52.

#### Genus *ALVEOLOPHRAGMIUM* Stschedrina, 1936

The nomenclature involving this genus is somewhat complicated and perplexing and involves several generic names including *Labrospira*, *Cribrostomoides*, and *Haplophragmoides*. Norman (1892, p. 17) describes the species *Haplophragmium crassimargo*, which later became the genotype species of the genus *Labrospira* Höglund. Höglund (1947, p. 144) in his discussion of *Labrospira* includes the species *L. subglobosa* (G. O. Sars) but in addition placed in the synonymy of this latter species *Cribrostomoides bradyi* Cushman. *Cribrostomoides bradyi* is the genotype species of the genus *Cribrostomoides* and if a new generic name were needed to distinguish such forms as *Labrospira*, certainly *Cribrostomoides* Cushman was available and should not have been placed in synonymy. The writers therefore agree with Frizzell and Schwartz (1950, pp. 1, 4) in rejecting *Labrospira* as a synonym, although not of *Cribrostomoides* Cushman. The writers feel that, in spite of the criticism of Earland (1935, p. 89), Höglund (1947, p. 145), Frizzell and Schwartz (1950, p. 3), and Maync (1952, p. 44), *Cribrostomoides* is a valid genus based on the generic characters enumerated by Cushman (1910, p. 108) and is distinct from forms called *Labrospira* by Höglund.

Höglund's *Labrospira* is a synonym of *Alveolophragmium* Stschedrina and in reality is based on the same species. In describing *Alveolophragmium*, Stschedrina based it on the new species *A. orbiculatum* from the Russian Arctic and sub-Arctic waters, and differentiated it from *Haplophragmoides* as possessing an alveolar wall structure.

However, this species is without doubt the same as the common Arctic species *Haplophragmium crassimargo* Norman. The original description of the latter makes no mention of an interior-aperture and to be sure many specimens do not clearly show this feature (Höglund, 1947, p. 144). However, Stschedrina's illustrations of *A. orbiculatum* var. *typica* (1936, p. 315) show a well-developed upper lip, and the figures of *A. orbiculatum* var. *caraensis* (p. 318) show both upper and lower lips, so that it is identical in this character with *H. crassimargo* Norman. The writers do not regard the alveoles in the wall as true alveolar structures, but merely the gaps left between the coarse fragments used in constructing the test. Specimens of *H. crassimargo* Norman from the American Arctic show this identical pseudoalveolar structure. Thus the writers are suppressing the name *Labrospira* as a junior synonym of *Alveolophragmium*.

#### ALVEOLOPHRAGMIUM CRASSIMARGO (Norman)

##### Plate 3, figures 1-3

*Haplophragmium crassimargo* NORMAN, 1892, Museum Normanianum, pt. 8, p. 17.

*Haplophragmium canariense* (d'Orbigny) BRADY (part), 1884, Rep. Voy. Challenger, vol. 9 (Zoology), p. 310, pl. 35, fig. 4 (not figs. 1-3, 5).

*Haplophragmoides major* CUSHMAN, 1920, U. S. Nat. Mus. Bull. 104, pt. 2, p. 39, pl. 8, fig. 6; 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 27, pl. 2, fig. 17.

*Alveolophragmium orbiculatum* var. *typica* STSCHEDRINA, 1936, Zool. Anz., vol. 114, Heft 11/12, p. 315, text figs. 2a,b.

*Alveolophragmium orbiculatum* var. *ochotonensis* STSCHEDRINA, 1936, *ibid.*, p. 316, text figs. 2a,b.

*Alveolophragmium orbiculatum* var. *caraensis* STSCHEDRINA, 1936, *ibid.*, p. 318, text figs. 3a,b.

*Labrospira crassimargo* (Norman) HÖGLUND, 1947, Zool. Bidrag Uppsala, vol. 26, p. 141, pl. 11, fig. 1, text figs. 121-125.—F. PARKER, 1952, Bull. Mus. Comp. Zool., vol. 106, No. 9, p. 400, pl. 2, figs. 16a,b.

Test free, planispiral, but slightly asymmetrical, biumbilicate, varying from completely involute to slightly evolute, so that a portion of the earlier whorls are visible around the umbilicus, robust, of medium to large size, the very large specimens being rather rare, periphery broadly rounded; chambers numerous, increasing gradually in size as added, later chambers somewhat inflated and occasionally somewhat off center, 7 to 10 in the last whorl, but most commonly 8 or 9; sutures distinct, radial, slightly depressed or constricted in the later portion; wall arenaceous, consisting of many clear quartz grains in a somewhat

granular and fine-grained matrix, smoothly finished, yellowish to reddish in color, sometimes nearly white; aperture in the face of the last formed chamber, interio-areal in position, forming an arched linear slit which parallels the base of the chamber face, but is completely surrounded by a distinct raised lip in well-preserved specimens.

Greatest diameter of hypotype of figure 3, 1.17 mm., thickness 0.65 mm. Greatest diameter of hypotype of figure 1, 2.65 mm., thickness 1.74 mm.

*Remarks.*—This species has been given three different specific names, and referred to four separate genera, being considered the genotype species of two of the genera.

Cushman described *H. major* as a typical *Haplophragmoides*, stating (1920b, p. 39), "aperture an elongate semicircular slit at the base of the final chamber, the upper portion forming a thin lip." Examination of Cushman's original material shows that his species has an elongate semicircular aperture extending across the apertural face and nearly to the umbilicus, the upper portion forming a thin lip and the lower portion also forming a thin but prominent lip, so that the aperture is interio-areal and not interio-marginal as described. Höglund (1947, p. 143) stated that he could not determine the character of the aperture from Cushman's indistinct figure of this species, but hypothesized that if the aperture were proved to be interio-areal the name should be a synonym of *Labrospira crassimargo* (Norman). Cushman stated in his original description that *Haplophragmoides major* was very similar to the specimen figured by Brady in the *Challenger* report (pl. 35, fig. 4), but he did not state how they agreed or differed. This figure of Brady's was also referred to by Norman (1892, p. 17) in describing *Haplophragmium crassimargo*.

*Alveolophragmium* was described as having alveoles in the wall; broken fragments were pictured showing these "pores." Fragments of typical specimens of *Haplophragmoides major* Cushman show an identical appearance, but the majority of these so-called alveoles are merely the cavities left between some of the larger grains on the rough interior surface of the wall. The different "varieties" of *Alveolophragmium* are probably entirely due to minor fluctuations in the character of the sea bottom, the coarsely arenaceous and thick-walled tests being built in sandy areas, while along the silty mud bottoms the same species has a finer-grained and thinner wall. This is not so much due to a selective habit which would be of varietal importance, as it is to mere utilization of whatever material was available for building the test.

The type specimens differ slightly in some features, the type of *Haplophragmoides major* having a more semicircular aperture which extends across the face of the last chamber nearly to the umbilicus. The type of *Alveolophragmium orbiculatum* is almost identical with Cushman's types of *H. major* in apertural characters and external appearance. The type of *Haplophragmium crassimargo* has a shorter aperture extending only across the terminal face. These seem merely to be variations, however, and all gradations in extent of aperture occur between them.

The types of *Alveolophragmium* were from the Arctic and sub-Arctic, in the Sea of Okhotsk, the Kara Sea, and the Sea of Japan. The types of *Haplophragmium crassimargo* Norman were from East Finmark and Greenland, the types of *Haplophragmoides major* Cushman were from the Gulf of St. Lawrence, and Höglund, in describing the genus *Labrospira*, also recorded it from Sweden. Thus this species has been reported from the seas adjacent to three continents, but all lie within the circumpolar region, and the Arctic fauna of which this is a representative is the same within this region regardless of the longitude.

As the genotype species of *Alveolophragmium* is thus conspecific with the genotype species of *Labrospira*, the latter name is a junior synonym and must be suppressed. However, the specific name *crassimargo* was the first to be described for the species and thus takes precedence over *orbiculatum* and *major*. The species thus is now referred to *Alveolophragmium crassimargo* (Norman).

*Types and occurrence.*—Figured hypotype (U.S.N.M. No. 10673, paratype of *Haplophragmoides major* Cushman) from station 56; figured hypotype (U.S.N.M. No. P1038) from station 49; figured hypotype (U.S.N.M. No. P1039) from station 22; unfigured hypotypes are recorded from the following stations: 2, 3, 6, 7, 8, 9, 10, 12, 19, 20, 21, 22, 23, 26, 27, 29, 30, 31, 32, 35, 36, 37, 40, 41, 49, 50, 51, 52, 54, 55, 56, 57, 58, 59, and 60.

#### ALVEOLOPHRAGMIUM JEFFREYSI (Williamson)

Plate 3, figures 4-7

*Nonionina jeffreysii* WILLIAMSON, 1858, Recent Foraminifera of Great Britain, p. 34, figs. 72-73.

*Haplophragmoides canariense* (d'Orbigny) CUSHMAN, 1920, Rep. Canadian Arctic Exped., 1913-1918, vol. 9, pt. M, p. 6; 1922, Contr. Can. Biol., No. 9 (1921), p. 140; 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 26, pl. 2, fig. 15.

*Labrospira jeffreysi* (Williamson) HÖGLUND, 1947, Zool. Bidrag Uppsala, vol. 26, p. 146, pl. 11, fig. 3, text figs. 128, 129.—F. PARKER, 1952, Bull. Mus. Comp. Zool., vol. 106, No. 9, p. 401, pl. 2, figs. 15, 17-20.

Test free, planispiral, and involute, but occasionally somewhat trochoid so that earlier whorls may be visible in the umbilical region on one side, somewhat compressed, biumbilicate, margin lobulate, periphery rounded; 6 or 7 chambers in the final whorl, increasing rapidly in size, the final chamber occasionally somewhat more inflated or tending to uncoil slightly; sutures distinct, slightly depressed; wall very thin and fragile, arenaceous, with many glassy-appearing grains in a finer ground mass, surface smoothly finished; aperture oval, interio-areal, usually very near the base of the final chamber, but may be slightly above the base (fig. 6) with a definite lower lip visible on well-preserved specimens or on the earlier chambers when broken or sectioned; color usually reddish or yellowish in the early portion, with the final chambers lighter in color and frequently white.

Greatest diameter of hypotype of figure 7, 0.91 mm., thickness of test 0.36 mm. Other specimens range in diameter from 0.29 to 1.04 mm.

*Remarks.*—Cushman consistently identified this species as *Haplophragmoides canariense* which he had designated as the genotype species of *Haplophragmoides*. However, the well-defined interio-areal aperture places the present form in the genus *Alveolophragmium* Stschedrina. As no worker has subsequently studied the types of *Haplophragmoides canariense*, it may be found that it also possesses an interio-areal aperture and then the genus *Alveolophragmium* would become a synonym of *Haplophragmoides* Cushman. This case clearly emphasizes the fact that writers should designate as types specimens at hand, and should not rely on figures of so-called classical species, for these invariably become items of doubt to later students. As new structures and internal characters are observed, different criteria are used for differentiating species and genera, and often in the past such features were erroneously assumed to be lacking on early species merely because they had not been mentioned in the original description, and no further study of the types was made.

*Types and occurrence.*—Figured hypotypes (U.S.N.M. Nos. P1040a-d) from station 3; unfigured hypotypes are recorded from stations 1, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 15, 17, 18, 19, 20, 21, 22, 23, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 37, 44, 49, 50, 51, and 52.

**AMMOTIUM**<sup>1</sup> Loeblich and Tappan, new genus

Synonym: *Ammobaculites* (part) of authors.

Genotype (type species): *Lituola cassis* Parker.

Test free, compressed, ovate in outline, chambers planispirally coiled and evolute with later chambers tending to uncoil, but reaching backward toward the coil at the inner margin; wall agglutinated; aperture simple, rounded and terminal, at the dorsal angle of the final chamber.

*Remarks.*—This genus is erected for species that differ considerably from the genotype species of *Ammobaculites* Cushman, in that they do not become completely uncoiled. It differs from *Ammobaculites* in the same way that *Astacolus* differs from *Marginulina* or *Marginulinopsis*, the later portion being flattened rather than rounded in section, and the chambers reaching far back toward the coil at the inner margin. Other species that can be placed here include *Ammobaculites auricularis* Loeblich and Tappan (Kiowa formation, Lower Cretaceous of Kansas), *A. braunsteini* Cushman and Applin ("marine shale of the Tuscaloosa," Upper Cretaceous of Mississippi), *A. pseudocassis* Cushman and Bronnimann (Recent of Trinidad), *A. salsus* Cushman and Bronnimann (Recent of Trinidad), and *A. salsus* var. *distinctus* Cushman and Bronnimann (Recent of Trinidad).

*Range.*—Lower Cretaceous to Recent.

**AMMOTIUM CASSIS** (Parker)

Plate 2, figures 12-18

*Lituola cassis* PARKER, 1870, in Dawson, Can. Nat., n. s., vol. 5, pp. 177, 180, fig. 3.

*Ammobaculites cassis* (Parker) CUSHMAN, 1920, U. S. Nat. Mus. Bull. 104, pt. 2, p. 63, pl. 12, fig. 5.—CUSHMAN and McCULLOCH, 1939, Allan Hancock Pacific Exped., vol. 6, No. 1, p. 83, pl. 7, figs. 7, 8.—CUSHMAN, 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 29, pl. 3, figs. 4-6.—F. PARKER, 1952, Bull. Mus. Comp. Zool., vol. 106, No. 9, p. 398, pl. 2, figs. 8-10.

Test free, large, robust, somewhat flattened, early portion planispiral, later uncoiling and flattened, extremely variable in degree of coiling and breadth of uncoiled portion, periphery broadly rounded; chambers numerous, low and broad, increasing gradually in the size as added and increasing in relative breadth in most specimens, with uncoiled chambers reaching back at the inner margin, thickest at the ventral margin, and flattened out toward the dorsal margin, final chamber somewhat higher and may be nearly circular in section, somewhat produced to form a slight neck; sutures obscure in the early por-

<sup>1</sup> From Gr. *ammos*, sand; *otion*, dim. of *ous*, ear.

tion and moderately depressed and distinct between the uncoiled chambers; wall medium to coarsely arenaceous, later portion with progressively larger grains incorporated; aperture terminal at the dorsal angle, large, rounded to oval in shape.

Length of hypotype of figure 17, 1.82 mm., greatest breadth 0.94 mm.; length of hypotype of figure 15, 1.51 mm., greatest breadth 0.57 mm.; length of hypotype of figure 13, 0.88 mm., greatest breadth 0.29 mm.

*Types and occurrence.*—Figured hypotypes (U.S.N.M. Nos. P1047 a-f) from station 3; figured hypotype (U.S.N.M. No. P1048) from station 18; unfigured hypotypes are recorded from stations 1, 2, 3, 4, 8, 9, 10, 12, 13, 15, 17, 18, 22, 26, 27, 30, 50, and 51.

### Family TEXTULARIIDAE

#### Genus SPIROPLECTAMMINA Cushman, 1927

#### SPIROPLECTAMMINA BIFORMIS (Parker and Jones)

#### Plate 4, figures 1-6

*Textularia agglutinans* d'Orbigny var. *biformis* PARKER and JONES, 1865, Philos. Trans. Roy. Soc. London, vol. 155, p. 370, pl. 15, figs. 23, 24.

*Textularia biformis* Parker and Jones, BRADY, 1878, Ann. Mag. Nat. Hist., ser. 5, vol. 1, p. 436, pl. 20, fig. 8.

*Spiroplecta biformis* (Parker and Jones) BRADY, 1884, Rep. Voy. *Challenger*, vol. 9 (Zoology), p. 376, pl. 45, figs. 25-27.

*Spiroplectamina biformis* (Parker and Jones) CUSHMAN, 1927, Contr. Cushman Lab. Foram. Res., vol. 3, pt. 1, p. 23, pl. 5, fig. 1.—HÖGLUND, 1947, Zool. Bidrag Uppsala, vol. 26, p. 163, pl. 12, fig. 1, text figs. 140, 141.—CUSHMAN, 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 30, pl. 3, figs. 7, 8.—F. PARKER, 1952, Bull. Mus. Comp. Zool., vol. 106, No. 9, p. 402, pl. 3, figs. 1, 2.

Test free, small, narrow, elongate, parallel-sided, early planispiral coil of 5 to 6 chambers with the later biserial portion of a breadth approximately equal to that of the coil, periphery rounded; chambers numerous, 5 to 6 in the coil, followed by as many as 8 pairs of biserially arranged chambers of nearly equal size, slightly inflated; sutures distinct, straight and radial in the coil, slightly oblique, highest at the midline in the biserial portion; wall finely arenaceous, but granular in appearance, with grains of nearly equal size, surface smoothly finished; aperture a low arch at the inner margin of the last-formed chamber.

Length of hypotype of figure 1, 0.44 mm., breadth of coil 0.10 mm., breadth of biserial portion 0.16 mm., thickness 0.09 mm. Length of hypotype of figure 3, 0.70 mm., breadth of coil 0.21 mm., breadth of



biserial portion 0.21 mm. Other hypotypes range from 0.16 to 0.75 mm. in length.

*Remarks.*—It seems probable that two species are included here, one considerably smaller than the other, although otherwise very similar. The small form is here shown in figure 1, the larger type in figures 2 to 6. However, the original description of Parker and Jones gave no measurements for their specimens, hence it is uncertain with which of the two forms they dealt. The magnification given by Parker and Jones for their illustrations would seem to suggest that they were concerned with the larger form. However, F. Parker (1952a) has referred the larger form to *S. typica* Lacroix, and the smaller form to *S. biformis*. Only an examination of the types can settle this problem, and we have been unable to determine this satisfactorily through correspondence. Therefore, the two forms are here described as one species with the reservation that one will probably later be removed.

*Types and occurrence.*—Figured hypotypes (U.S.N.M. Nos. P2103 a-e) from station 13; figured hypotype (U.S.N.M. No. P2104) from station 52; unfigured hypotypes are recorded from stations 1, 2, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 26, 27, 29, 30, 31, 32, 33, 42, 46, 50, 51, and 52.

Genus *TEXTULARIA* DeFrance, 1824

*TEXTULARIA TORQUATA* F. Parker

Plate 2, figures 19-21

*Textularia torquata* F. PARKER, 1952, Bull. Mus. Comp. Zool., vol. 106, No. 9, p. 403, pl. 3, figs. 9-11.

Test free, tiny, flattened, flaring from a pointed or bluntly rounded base, early portion occasionally somewhat twisted, biserial throughout; chambers increasing rapidly in size as added, low and broad over most of the test, the final pair comparatively higher, slightly inflated, somewhat overlapping earlier chambers at the periphery; sutures straight, somewhat oblique, slightly depressed in the later portion; wall finely arenaceous, but of rather large grains for the size of the test, roughly finished; aperture narrow, slitlike, extending up into the apertural face.

Length of hypotype of figure 21, 0.34 mm., breadth 0.18 mm. Other figured hypotypes are 0.29 and 0.34 mm. in length.

*Remarks.*—A comment seems necessary as to the wall texture. The original description stated that the species was "coarsely arenaceous." However, as can be seen from the measurements, the entire test is nowhere near as large as a single grain found in the wall of certain larger

species. The terms "finely" or "coarsely" arenaceous as commonly used may thus be quite misleading. Actually the grains in this species are very small, but seem rather larger as compared to the size of the minute test.

*Types and occurrence.*—This species was originally described from off Portsmouth, N. H., and was also recorded from near Greenland, in samples from Baffin Bay and the Kane Basin. Figured hypotypes (U.S.N.M. Nos. P1051a-c) from station 23; unfigured hypotypes are recorded from the following stations: 8, 13, 16, 18, 21, 22, 23, 26, 29, 30, 31, 32, 35, 36, 37, 38, 46, 47, 48, and 52.

### Family VALVULINIDAE

Genus *EGGERELLA* Cushman, 1933

*EGGERELLA ADVENA* (Cushman)

Plate 3, figures 8-10

*Verneuilina advena* CUSHMAN, 1922, Contr. Can. Biol., No. 9 (1921), p. 141.

*Eggerella advena* (Cushman) CUSHMAN, 1937, Cushman Lab. Foram. Res.

Spec. Publ. No. 8, p. 51, pl. 5, figs. 12-15; 1948, Cushman Lab. Foram. Res.

Spec. Publ. No. 23, p. 32, pl. 3, fig. 12.

*Eggerella arctica* HÖGLUND, 1947, Zool. Bidrag Uppsala, vol. 26, p. 193, pl. 16, fig. 4, text figs. 166-168.

not *Verneuilina advena* Cushman, HÖGLUND, 1947, *ibid.*, p. 185, pl. 13, fig. 11, text fig. 169.

Test free, elongate, somewhat tapering, early portion with 4 to 5 chambers to a whorl, later portion triserial; chambers numerous, low and broad in the early portion, increasing in relative height as added, those of the final whorl being approximately equal in height and breadth; sutures distinct, depressed; wall finely arenaceous, with occasional larger grains, rather smoothly finished, reddish to yellowish in color, with the final whorl much lighter in color and nearly white; aperture small, central, a low arch at the base of the final chamber.

Length of hypotype of figure 10, 0.68 mm., breadth 0.21 mm.  
Length of hypotype of figure 8, 0.39 mm., breadth 0.21 mm.

*Remarks.*—This species was originally described by Cushman from the Hudson Bay Expedition, but no figures were given then or later of the types. Furthermore, the original description of the species stated, in part, "Test minute, elongate, triserial, tapering," which would imply that it was a true *Verneuilina*. To add to the confusion, Cushman stated that he had recorded the same species as *V. poly-stropha* from the Canadian Arctic (1920a, p. 8m, pl. 1, fig. 5) and that

Heron-Allen and Earland recorded it as a dwarfed *V. polystropha*. The first illustrations given by Cushman under the name *V. advena* were those in the Atlantic Foraminifera monograph (1922a, pl. 9, figs. 7-9), which were copies of the figures of Heron-Allen and Earland.

In 1933 Cushman defined the genus *Eggerella* for the species which began with more than three chambers to a whorl, and in 1937 placed his species *Verneuilina advena* in the genus *Eggerella*, for the first time illustrating the typical Arctic forms.

An examination of the original types in the Cushman collection from the four localities where it was first recorded shows them to be true *Eggerella*, and despite Cushman's original description, references to the British forms and copies of the British figures, *Verneuilina advena* Cushman is a true *Eggerella*, and the British triserial form which is a typical *Verneuilina* is not only a distinct species, but belongs to a different genus and family.

Höglund (1947) noted that Cushman (1937) had included under *E. advena* typical *Eggerella* with an early whorl of 4 to 5 chambers, but also placed in his synonymy the British form of Heron-Allen and Earland. As he had no opportunity to examine Cushman's types, Höglund based his interpretation of Cushman's species on the incorrect original description and the first illustrations published by Cushman (the copies of the British figures), and thus erroneously assumed that the typical *V. advena* was a true *Verneuilina*, and that the specimens of *Eggerella* figured later by Cushman (1937) should be given a distinct specific name. He therefore proposed that *Verneuilina advena* be restricted to the forms with a triserial base (the Swedish and British forms) and gave the name *Eggerella arctica* to Cushman's Arctic species illustrated in the 1937 monograph. Unfortunately, Cushman's type specimens from the Arctic are all true *Eggerella* and according to the rules of nomenclature the specific name *advena* must be restricted to those forms like the original types. Thus the name *Eggerella arctica* Höglund must be suppressed as a synonym of *E. advena* Cushman, and the European form is in need of a new name.

*Types and occurrence.*—Lectotype (here designated) (Cushman Coll. No. 1138), the specimen figured by Cushman (1937, pl. 5, figs. 13a,b) from station 65; figured hypotypes (U.S.N.M. Nos. P1053a-c) from station 2; unfigured hypotypes are also recorded from stations 1, 2, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 18, 19, 20, 21, 22, 23, 24, 26, 27, 28, 29, 30, 31, 32, 38, 39, 42, 44, 46, 50, 51, 52, 61, 62, 64, and 65.

## Family SILICINIDAE

Genus SILICOSIGMOILINA Cushman and Church, 1929

## SILICOSIGMOILINA GROENLANDICA (Cushman)

Plate 4, figures 7-9

*Quinqueloculina fusca* Brady var. *groenlandica* CUSHMAN, 1933, Smithsonian Misc. Coll., vol. 89, No. 9, p. 2, pl. 1, fig. 4.

? *Quinqueloculina groenlandica* Cushman, NØRVANG, 1945, Zoology of Iceland, vol. 2, pt. 2, p. 6.

*Quinqueloculina groenlandica* Cushman, CUSHMAN, 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 34, pl. 3, fig. 18.

not *Quinqueloculina fusca* Brady, CUSHMAN, 1944, Cushman Lab. Foram. Res. Spec. Publ. 12, p. 14, pl. 2, fig. 21.

Test free, oblong, length about twice the width, sigmoidine in plan, with chambers a half a coil in length, added slightly more than 180° apart rather than in a single plane so that in cross section the chambers are aligned in a sigmoid curve of two continuously revolving spirals; chambers elongate, inflated, somewhat thicker at the base and narrower toward the aperture; early sutures somewhat obscure, later ones distinct and slightly depressed; wall insoluble in acid, finely arenaceous, with a large proportion of siliceous cement, surface smoothly finished, and almost porcelaneous in appearance; aperture terminal, a curved slit, due to the infolding of a portion of the inner edge of the chamber wall so that it forms a broad flap.

Length of hypotype of figure 9, 0.75 mm., greatest breadth 0.44 mm., thickness 0.26 mm. Other hypotypes range from 0.29 to 0.70 mm. in length.

*Remarks.*—This species has never been completely described. The complete original definition of this form as a variety of *Q. fusca* stated only, "Variety differing from the typical in the much smoother test with a much larger proportion of cement of a light gray color, and the test usually more compressed." Nørvang (1945, p. 6) separated the variety as a distinct species of *Quinqueloculina*, but as he neither figured nor described the species it is impossible to be certain whether or not he actually had the same form as was described by Cushman.

Parker (1952a, p. 405) stated "In connection with the study of *M. fusca* at the Cushman Laboratory, specimens of '*Quinqueloculina groenlandica*' Cushman were examined and found to belong to the genus *Miliammina*."

The present species is insoluble in acid, showing that it should be placed in the Siliciniidae, but a section of the test (fig. 8) shows that it

is not triloculine or quinqueloculine in plan, as is *Miliammina*, but has the successive chambers added on opposite sides in continuously revolving spirals, as in *Silicosigmoilina*.

Thus, this species was described as a variety of an existing species, later separated as a distinct species, and still later removed to a different genus, without a complete description of its characters ever being published. Finally, the actual description of this species necessitates its being placed in a third genus, *Silicosigmoilina*.

*Types and occurrence.*—Figured hypotypes (U.S.N.M. Nos. P1052 a-c) from station 35; unfigured hypotypes are recorded from stations 32, 35, 36, 40, 52, and 75.

### Family MILIOLIDAE

Genus QUINQUELOCULINA d'Orbigny, 1826

#### QUINQUELOCULINA AGGLUTINATA Cushman

Plate 5, figures 1-4

*Quinqueloculina agglutinata* CUSHMAN, 1917, U. S. Nat. Mus. Bull. 71, pt. 6, p. 43, pl. 9, fig. 2.—CUSHMAN and TODD, 1947, Contr. Cushman Lab. Foram. Res., vol. 23, pt. 1, p. 61, pl. 14, figs. 12, 13.—CUSHMAN, 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 33, pl. 3, fig. 13.

Test free, ovate in outline, of medium to large size and robust appearance; 5 chambers visible in the adult, chambers elongate and somewhat angular, but with the angles rounded, broadest at the base, narrowing toward the aperture; sutures distinct, depressed; wall finely arenaceous, smoothly finished, although surface is granular in appearance, yellowish to reddish in color, the chambers being progressively lighter in color as added; aperture terminal, circular to oval, with a small but broad flattened tooth projecting from the inner margin.

Length of hypotype of figure 2, 1.04 mm., breadth 0.73 mm., thickness 0.55 mm. Length of larger hypotype of figure 1, 1.40 mm., breadth 1.04 mm. Length of hypotypes of figures 4 and 3, 0.99 mm. and 0.83 mm.

*Types and occurrence.*—Figured hypotypes (U.S.N.M. Nos. P1049a,b) from station 4; figured hypotypes (U.S.N.M. Nos. P1050a,b) from station 26; unfigured hypotypes are also recorded from stations 1, 2, 4, 5, 6, 7, 8, 9, 10, 13, 15, 18, 19, 22, 23, 26, 29, 31, 32, 35, 39, 40, 42, 45, 49, and 50.

**QUINQUELOCULINA ARCTICA** Cushman

Plate 5, figures 11, 12

*Quinqueloculina arctica* CUSHMAN, 1933, Smithsonian Misc. Coll., vol. 89, No. 9, p. 2, pl. 1, figs. 3a-c; 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 35, pl. 4, figs. 2a-c.—F. PARKER, 1952, Bull. Mus. Comp. Zool., vol. 106, No. 9, p. 405, pl. 3, figs. 19a,b.

Test free, of medium size, robust, ovate in outline, subtriangular in section, periphery truncate; chambers typically quinqueloculine in plan and distinctly angled; sutures distinct, slightly depressed; wall calcareous, imperforate, surface smooth; aperture large, semicircular, at the end of the final chamber, no projecting neck present, a thin and delicate bifid tooth projecting into the aperture from the margin adjacent to the preceding chamber.

Length of hypotype of figure 11, 1.33 mm., breadth 1.04 mm., thickness 0.83 mm. Length of hypotype of figure 12, 0.94 mm., breadth 0.73 mm. Other specimens range from 0.39 to 1.25 mm. in length.

*Types and occurrence.*—Figured hypotypes (U.S.N.M. Nos. P2035a,b) from station 4; unfigured hypotypes are recorded from stations 2, 4, 5, 7, 9, 13, 18, 19, 21, 22, 23, 26, 27, 35, 40, 50, 51, 63, 66, 67, 75, 76, and 78.

**QUINQUELOCULINA STALKERI** Loeblich and Tappan, new species

Plate 5, figures 5-9

*Quinqueloculina fusca* Brady, CUSHMAN, 1948 (not Brady, 1870), Cushman Lab Foram. Res. Spec. Publ. 23, p. 33, pl. 3, figs. 16, 17.

Test free, small, ovate in outline, rounded in section, periphery rounded; chambers quinqueloculine in plan, of nearly equal diameter throughout; sutures distinct, depressed; wall calcareous, imperforate, soluble in hydrochloric acid, with a very finely grained agglutinated surface; aperture ovate to rounded, somewhat elevated on a short neck and surrounded by a distinct lip, a small bifid tooth based on the margin adjacent to the preceding chamber.

Length of holotype 0.57 mm., breadth 0.31 mm., thickness 0.23 mm. Length of paratype of figure 8, 0.44 mm., breadth 0.23 mm. Length of paratype of figure 6, 0.34 mm., breadth 0.16 mm. Length of paratype of figure 5, 0.36 mm., breadth 0.18 mm. Other paratypes range from 0.26 to 0.52 mm. in length.

*Remarks.*—This Arctic species was referred to *Quinqueloculina fusca* Brady by Cushman, but it differs in having a higher percentage of the wall calcareous, with a smaller amount of agglutinated material,

and in possessing a small bifid tooth. *Q. fusca* was described as being a characteristic brackish-water form and the writers doubt that the same species would be found in the more or less normal marine Arctic waters. *Q. stalker*, new species, resembles *Q. nitida* Nørvang, but has a more prominent lip around the aperture and differs in possessing a small bifid tooth, which is lacking in *Q. nitida* Nørvang. This species is named in honor of Jake Stalker, Eskimo guide employed by the Naval Arctic Research Laboratory, Point Barrow, Alaska.

*Types and occurrence.*—Holotype (U.S.N.M. No. P2036) from station 33; figured paratypes (U.S.N.M. Nos. P2037a,b) from station 13; figured paratypes (U.S.N.M. Nos. P2038a,b) from station 18; unfigured paratypes are recorded from stations 16, 18, 23, 27, 33, and 78.

#### SCUTULORIS<sup>2</sup> Loeblich and Tappan, new genus

Synonyms: *Miliolinella* (part) Wiesner, 1931; Cushman, 1933.

*Quinqueloculina* (part) of authors (not d'Orbigny, 1826).

Genotype (type species); *Scutuloris tegminis* Loeblich and Tappan, new species.

Test free, chambers in a quinqueloculine arrangement; wall calcareous, imperforate; aperture at the end of the chamber and nearly filled by a broad, low flap.

*Remarks.*—Species of this genus have been previously referred to *Miliolinella* Wiesner because of the erroneous subsequent designation of *Quinqueloculina lamellidens* Reuss as the genotype species for *Miliolinella*. As *Verniculum subrotundum* Montagu was selected as the genotype by original designation by Wiesner, no later change is permissible. *Scutuloris* differs from *Miliolinella* in having a quinqueloculine chamber arrangement, and from *Quinqueloculina* in having a broad flap filling the aperture, in place of the bifid tooth characteristic of the latter.

#### SCUTULORIS TEGMINIS Loeblich and Tappan, new species

Plate 5, figure 10

Test free, robust, ovate in section, with rounded periphery; chambers in a quinqueloculine arrangement, increasing rapidly in size as added, inflated; sutures distinct, slightly depressed; wall calcareous, imperforate, white and porcelaneous in appearance, surface smooth; aperture at the end of the chamber, semicircular, and nearly filled by a broad flap, which leaves open only a slitlike crescent.

<sup>2</sup> From *L. scutum*, dim. *scutulum*, an oblong shield; *oris*, mouth, oral.

Length of holotype 0.75 mm., breadth 0.55 mm., thickness 0.34 mm. Paratypes range from 0.31 to 0.60 mm. in length.

*Remarks.*—This species differs from *Quinqueloculina lamellidens* Reuss in being somewhat more compressed and ovate rather than sub-triangular in section; and in the final chambers being more inflated and occupying a larger proportion of the test.

*Types and occurrence.*—Holotype (U.S.N.M. No. P2101) from station 3; unfigured paratypes from stations 6, 26, 28, 33, and 50.

### PATEORIS<sup>3</sup> Loeblich and Tappan, new genus

Synonyms: *Massilina* (part) of authors (not Schlumberger, 1893).

*Miliola* (part) of authors (not Lamarck, 1804).

*Miliolina* (part) of authors (not Williamson, 1858).

*Quinqueloculina* (part) of authors (not d'Orbigny, 1826).

*Sigmoilina* Martinotti, 1921 (not Schlumberger, 1887).

Genotype (type species): *Quinqueloculina subrotunda* (Montagu) forma *hauerinoides* Rhumbler.

Test quinqueloculine in the early portion, later chambers added in a single plane, usually two to a coil, but as many as three to a coil in the later stages; wall calcareous, imperforate; aperture at the open end of the chamber, without a tooth or flap.

*Remarks.*—This genus differs from *Massilina* Schlumberger and *Quinqueloculina* d'Orbigny in lacking an apertural tooth, and in the later stage having more than two chambers to a coil. It differs from *Quinqueloculina* and *Miliola* Lamarck also in having the later chambers in a single plane. It differs from *Sigmoilina* Schlumberger in having the later chambers in a single plane and more than two to a coil, and in lacking the apertural tooth, and differs from *Hauerina* and *Miliola* in lacking the cribrate aperture.

The following species, in addition to the genotype species, apparently belong in *Pateoris*: *Massilina agglutinans* Keijzer, *M. australis* Cushman, *M. obliquestriata* Cushman and Valentine, *M. pacificensis* Cushman, and *Sigmoilina sidebottomi* Martinotti.

### PATEORIS HAUERINOIDES (Rhumbler)

Plate 6, figures 8-12; text figures 1A, B

*Miliolina seminulum* (Linné) var. *disciformis* (Macgillivray) WILLIAMSON, 1858 (not *Vermiculum disciforme* Macgillivray, 1843), Recent Foraminifera of Great Britain, p. 86, pl. 7, figs. 188, 189.

<sup>3</sup> From L. *pateo*, to lie open; *os, oris*, mouth, opening.



*Miliola (Quinqueloculina) subrotunda* (Montagu) PARKER and JONES, 1865 (not *Vermiculum subrotundum* Montagu, 1803), Philos. Trans. Roy. Soc. London, vol. 155, p. 411, pl. 15, figs. 38a,b (erroneously numbered 28a,b on the plate).

? *Massilina secans* (d'Orbigny) CUSHMAN, 1929, U. S. Nat. Mus. Bull. 104, pt. 6, p. 37, pl. 7, figs. 3, 4.

*Quinqueloculina subrotunda* (Montagu) forma *hauerinoides* RHUMBLER, 1936, Foram. der Kieler Bucht, Teil II-Ammodisculinidae bis Textulinidae, vol. 1, No. 1, pp. 206, 217, 226, text figs. 167 (p. 205), 208-212 (p. 225).

*Quinqueloculina subrotunda* (Montagu)? CUSHMAN, 1948 (not *Vermiculum subrotundum* Montagu, 1803), Cushman Lab. Foram. Res. Spec. Publ. 23, p. 35, pl. 3, figs. 20, 21, pl. 4, fig. 1.

*Quinqueloculina subrotunda* (Montagu) F. PARKER, 1952, Bull. Mus. Comp. Zool., vol. 106, No. 9, p. 406, pl. 4, figs. 4a,b.

Test free, ovate to subcircular in outline, somewhat compressed, with a rounded periphery; chambers quinqueloculine in arrangement in the early portion, later chambers added in a single plane and becoming more embracing although shorter in length so that in the later portion there may be  $2\frac{1}{2}$  to 3 chambers to a coil; wall calcareous, imperforate, porcelaneous surface smooth and polished, the later chambers sometimes with transverse wrinkles; aperture at the open end of the chamber, consisting of a low arch on the periphery in the early stages, later opening slightly to one side of the periphery and developing a slight reentrant, the gerontic form having an elongate, almost slitlike extension of the aperture (fig. 11c).

Greatest diameter of hypotype of figure 11, 0.49 mm., thickness 0.29 mm. Greatest diameter of hypotype of figure 8, 0.65 mm., thickness 0.42 mm. Greatest diameter of hypotype of figure 10, 0.68 mm., thickness 0.34 mm. Greatest diameter of hypotype of figure 12, 0.75 mm., thickness 0.39 mm. Greatest diameter of hypotype of figure 9, 0.96 mm., thickness 0.42 mm. Other hypotypes range from 0.18 to 0.91 mm. in diameter.

*Remarks.*—Although recorded under many names, this species has been most often confused with *Vermiculum subrotundum* Montagu, the genotype species of *Miliolinella*, and *Quinqueloculina secans* d'Orbigny, the genotype species of *Massilina*. It seems difficult to believe that they could have been so confused, for *V. subrotundum* is triloculine, rather than quinqueloculine, does not become massiline or hauerine in the later stages, and it has a broad flap partially covering the aperture, rather than a completely open aperture.

*Quinqueloculina secans* is a larger species, and, in addition to having an elongate, strongly bifid tooth, is much more compressed, distinctly keeled and with oblique transverse ribs.

Williamson referred the present species to *Miliolina seminulum* (Linné) var. *disciformis* (Macgillivray), thus referring it to a variety of the genotype species of *Quinqueloculina*, but Macgillivray defined his form as having a "medial, erect tooth, extending to more than half the height of mouth," and in being carinate.

The first time the present form was recognized as distinct was when Rhumbler described it as the forma *hauerinoides* of *subrotunda*. As *V. subrotundum* is the genotype species of *Miliolinella*, the present form cannot be its "forma," and hence is here raised to specific rank, and placed in the new genus *Pateoris*. Rhumbler described this species from the Kieler Bucht, north of Germany, and it occurs through-

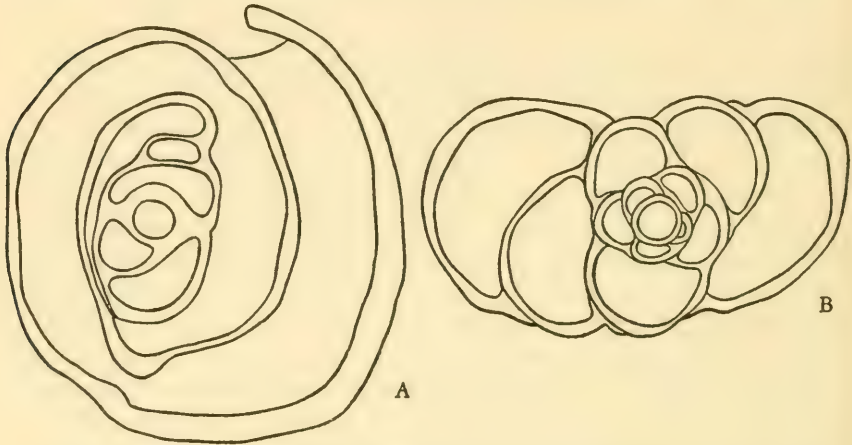


FIG. 1.—*Pateoris hauerinoides* (Rhumbler). A, Longitudinal section cut in plane of adult coiling. B, Transverse section showing early quinqueloculine stage and *Massilina*-like arrangement of the later chambers.  $\times 100$ .

out the Arctic regions from Alaska, Canada, and Greenland, and also is found on the coasts of Great Britain.

*Massilina agglutinans* Keijzer is similar in having more than 2 chambers to a coil in the later stages, but has an agglutinated wall, and is more compressed. *Massilina australis* Cushman is similar in the character of coiling, and in lacking a tooth, but is much more compressed. *Massilina pacificensis* Cushman is also similar, but more compressed and with a subacute periphery, and has prominent, obliquely transverse crenulations on the chambers. *Massilina obliquestriata* Cushman and Valentine is more ovate in outline and ornamented by longitudinal, slightly oblique ribs.

It differs from *Sigmoilina sidebottomi* Martinotti in being more evolute so that the earlier chambers are visible in the center and more

compressed, and Martinotti's species lacks the transverse ridges of *P. hauerinoides*.

*Types and occurrence*.—Figured hypotypes (U.S.N.M. Nos. P2105a-e) and thin-sectioned hypotypes (U.S.N.M. Nos. P2106a,b) from station 17; unfigured hypotypes are recorded from stations 2, 3, 4, 5, 6, 7, 8, 9, 12, 15, 16, 17, 18, 19, 22, 23, 24, 25, 26, 28, 29, 30, 31, 33, 34, 35, 37, 38, 40, 45, 47, 48, 50, and 51.

Genus **TRILOCULINA** d'Orbigny, 1826

**TRILOCULINA TRIHEDRA** Loeblich and Tappan, new species

Plate 4, figure 10

Test free, small, triangular in section with subacute angles and nearly flat to slightly convex sides; chambers triloculine in plan, slightly inflated; wall calcareous, imperforate, vitreous, surface smooth and polished; aperture terminal, ovate, with a short and broad bifid tooth.

Length of holotype 0.60 mm., breadth 0.49 mm., thickness 0.47 mm. Other paratypes range from 0.23 to 1.04 mm. in length.

*Remarks*.—This species differs from *Triloculina tricarinata* d'Orbigny, from the Red Sea, in having less-excavated sides, more-rounded angles and in the chambers being more enveloping. *Miliolites trigonula* Lamarck, from the Paris Basin, France, differs in being almost circular in section, and more ovate in side view. *Triloculina gibba* d'Orbigny from the Pliocene and Recent of Italy is more elongate-ovate in side view and with more-inflated chambers.

It is probable that the majority of Arctic and other northern references to the Mediterranean species of d'Orbigny and Lamarck should be included in the present species, but as many of the references show no figures, or only copy the original figures, this can be determined only from a study of the types.

*Types and occurrence*.—Holotype (U.S.N.M. No. P2110) from station 3; unfigured paratypes are recorded from stations 13, 15, 18, 21, 22, 23, 26, 39, 45, and 50.

Genus **MILIOLINELLA** Wiesner, 1931

Genotype (type species): *Vermiculum subrotundum* Montagu. Original designation by Wiesner (1931, p. 63).

*Miliolinella*, as described by Wiesner (1931, p. 107), included biloculine, triloculine, and quinqueloculine forms—in most cases those forms characterized by large flaplike extensions covering the aperture.

Cushman (1933b, p. 148) designated *Quinqueloculina lamellidens* Reuss as a genotype and most later authors have apparently followed Cushman in this type designation. However, this was in error as Wiesner (1931, p. 63) by original designation had made *Vermiculum subrotundum* Montagu the type species.

The species *Vermiculum subrotundum* as figured by Montagu has a triloculine test, but unfortunately the aperture was not figured and it would be difficult now to determine what species Montagu originally had. Wiesner evidently based his concept of *V. subrotundum* on Brady's figures (1884, pl. 5, figs. 10, 11), of which one specimen was quinqueloculine (?) and one specimen shows five chambers in a lateral view and the apertural view shows a large flap which nearly covers the aperture. Incidentally, this is not the same type of test as illustrated by Cushman (1948b, pl. 3, figs. 20, 21) as *Quinqueloculina subrotunda* (Montagu) (?). Thus neither Brady's nor Cushman's figured specimens of *V. subrotundum* are conspecific, or even congeneric with those of Montagu. The genus *Miliolinella* can only include species agreeing in character with the genotype species and as Montagu's illustration shows a distinctly triloculine test, the biloculine and quinqueloculine species should be excluded.

Parr subdivided Wiesner's genus in 1950, describing the new genus *Planispirinoides* (1950, p. 287) with the genotype *Miliolina bucculenta* Brady having an adult "triloculine" stage and possessing a broad lip. This species of Brady's had been included in *Miliolinella* by Wiesner (1931, p. 107), but placed in the synonymy of *Miliolinella subrotunda* var. *trigonina* Wiesner. This latter was erroneous as noted by Parr, for if it were to be classed only as a variety, Brady's name would nevertheless have been available, and the varietal name *trigonina* is thus suppressed as a synonym. Parr placed the genus *Planispirinoides* in the Ophthalmitidae as it had an early *Cornuspira* stage, and is thus distinct from *Miliolinella*, although both genera have a triloculine adult.

Riccio (1950, p. 90) named another triloculine genus and, following Cushman's genotype designation, he stated that his new genus *Triloculinella* (genotype *T. obliquinodus* Riccio) differed from *Miliolinella* in being triloculine rather than quinqueloculine. *Triloculinella* Riccio is here suppressed as a junior synonym of *Miliolinella* Wiesner, as both genera have triloculine genotype species.

It is unfortunate that Montagu's species was selected as the genotype for it was neither well figured nor described in the original publication, and various distinct species have since been referred to it. The main character differentiating these forms from *Triloculina* is

the apertural flap, and as the apertural characters are not shown by Montagu this genotype species is thus somewhat doubtful. It would have caused much less confusion if Wiesner had selected a species from his own material as the genotype rather than a so-called classic species. This practice of using "classic" species as genotypes whenever possible has been followed by many authors, but time after time has proved to be an unfortunate choice, for almost invariably these classic species are incompletely known, from the too brief descriptions and small and generalized original figures. Furthermore, many of the type specimens were in private collections and have since been lost or destroyed, and as geologic age and type localities are not always exactly known it is sometimes impossible to obtain a reliable specimen on which to base a redefinition of the species.

**MILIOLINELLA CHUKCHIENSIS** Loeblich and Tappan, new species

Plate 6, figure 7

Test free, ovate in outline, triloculine in chamber arrangement, periphery rounded; chambers inflated, increasing rather rapidly in size as added, final chamber somewhat wider at the base and tapering toward the aperture on the side where three chambers are visible; sutures distinct, depressed, slightly oblique; wall calcareous, imperforate, white and porcelaneous in appearance, surface smooth; aperture at the open end of the chamber, partially covered by a broad, low flap which leaves only a crescentic opening.

Length of holotype 0.75 mm., breadth 0.55 mm., thickness 0.42 mm.; paratypes range in length from 0.34 to 0.83 mm.

*Remarks.*—This species differs from *Triloculina valvularis* Reuss in being about one-fourth as large, more ovate in outline, and with slightly inclined sutures. It differs from *Triloculina circularis* Bornemann in being ovate rather than circular in outline.

*Types and occurrence.*—Holotype (U.S.N.M. No. P2098) from station 6; unfigured paratypes are recorded from stations 3, 6, 9, 17, 18, 21, 26, 45, and 47.

Genus **PYRGO** Defrance, 1824

**PYRGO ROTALARIA** Loeblich and Tappan, new species

Plate 6, figures 5, 6

*Biloculina murrhyna* Schwager, CUSHMAN (part), 1917 (not Schwager, 1886), U. S. Nat. Mus. Bull. 71, pt. 6, p. 75, pl. 29, figs. 1a-c (not pl. 28, figs. 3a,b.)

Test free, circular in outline, much inflated, but with a distinctly carinate border, slightly produced at the aboral end; chamber devel-

opment typically biloculine; wall calcareous, imperforate, surface smooth; aperture nearly circular, with a broad tooth that is slightly notched to give a bifid appearance.

Length of holotype 0.55 mm., greatest breadth 0.52 mm., thickness 0.31 mm. Length of figured paratype 0.57 mm., breadth 0.52 mm. Other specimens range from 0.47 to 0.86 mm. in length.

*Remarks.*—This species resembles *Pyrgo murrhyna* (Schwager) of some authors, but the type specimen of Schwager has two strong spines on either side of an indentation on the basal margin, and the peripheral margin of the test is grooved.

It resembles *Biloculina bradyi* Fornasini, 1886, in general appearance, but is more inflated, and has a slight elongation of the basal margin, rather than an indentation. Furthermore, the tooth is broader in *P. rotalaria*, new species, and not as strongly bifurcate.

*Types and occurrence.*—Holotype (U.S.N.M. No. P2064), figured paratype (U.S.N.M. No. P2065), and unfigured paratypes all from station 43.

#### PYRGO WILLIAMSONI (Silvestri)

Plate 6, figures 1-4

*Biloculina ringens* (Lamarck) *typica* WILLIAMSON, 1858 (not *Miliolites ringens* Lamarck, 1804), Recent Foraminifera of Great Britain, p. 79, pl. 6, figs. 169, 170, pl. 7, fig. 171.

*Biloculina williamsoni* SILVESTRI, 1923, Atti Accad. Pont. Romana Nuovi Lincei, vol. 76 (1922-23), p. 73.

*Pyrgo elongata* (d'Orbigny) CUSHMAN, 1948 (not *Biloculina elongata* d'Orbigny, 1826), Cushman Lab. Foram. Res. Spec. Publ. 23, p. 39, pl. 4, figs. 7, 8.

Test oval in outline, inflated; chambers oval in outline, the last extending beyond the previous one on all margins, the young specimens somewhat more elongate, the larger ones nearly circular; sutures distinct, depressed; wall calcareous, white, imperforate and vitreous in appearance, surface smooth; aperture ovate with a small, broad, and bifid tooth projecting from the inner and lower margin of the aperture, the tooth more strongly bifid in the older specimens.

Length of hypotype of figure 1, 0.57 mm., breadth 0.44 mm., thickness 0.42 mm. Length of hypotype of figure 2, 0.29 mm., breadth 0.18 mm., thickness 0.21 mm. Length of hypotype of figure 3, 0.83 mm., breadth 0.78 mm., thickness 0.65 mm. Length of hypotype of figure 4, 0.44 mm., breadth 0.34 mm., thickness 0.31 mm.

*Remarks.*—This species varies somewhat in outline with age, the young forms being more narrow and elongate with a nearly circular aperture and spatulate tooth, and the tests gradually become more

rounded in outline with increase in size, the aperture becoming more ovate and the tooth more distinctly bifid. This species has been recorded from the Arctic as *P. elongata* (d'Orbigny), but d'Orbigny's species does not have the last chamber surrounding the penultimate one on all sides and is not as broad.

*Types and occurrence.*—Figured hypotypes (U.S.N.M. Nos. P2114a-d) from station 50; unfigured hypotypes are recorded from stations 1, 2, 3, 5, 6, 7, 8, 12, 13, 16, 18, 22, 23, 26, 28, 29, 30, 33, 35, 47, and 50.

#### Family OPTHALMIDIIDAE

Genus *CORNUSPIRA* Schultze, 1854

#### *CORNUSPIRA INVOLVENS* (Reuss)

Plate 7, figures 4, 5

*Operculina involvens* REUSS, 1850, Denkschr. Akad. Wiss. Wien, vol. 1, p. 370, pl. 46, fig. 30.

*Cornuspira involvens* (Reuss) BRADY, 1884, Rep. Voy. *Challenger*, vol. 9 (Zoology), p. 200, pl. 11, figs. 1-3.—FLINT, 1899, Ann. Rep. U. S. Nat. Mus. 1897, p. 303, pl. 48, fig. 3.—CUSHMAN, 1917, U. S. Nat. Mus. Bull. 71, pt. 6, pp. 5, 25, pl. 1, fig. 2, pl. 2, fig. 2, text figs. 2-3; 1929, U. S. Nat. Mus. Bull. 104, pt. 6, p. 80, pl. 20, figs. 6-8.—WIESNER, 1931, Deutsche Südpolar-Exped., 1901-1903, vol. 20 (Zoology, vol. 12), p. 101, pl. 14, figs. 161, 162.

Test free, planispiral, evolute, periphery rounded; consisting of a globular proloculus and long undivided tubular second chamber which increases steadily in size as added; spiral suture distinct; wall calcareous, porcelaneous, surface smooth, except for various transverse growth lines; aperture at the open end of the tube.

Greatest diameter of hypotype of figure 5, 1.59 mm., thickness 0.29 mm. Greatest diameter of hypotype of figure 4, 1.48 mm., thickness 0.31 mm. Other hypotypes range from 0.21 to 2.05 mm. in diameter.

*Types and occurrence.*—Figured hypotype (U.S.N.M. No. P2091) from station 2; figured hypotype (U.S.N.M. No. P2092) from station 23; unfigured hypotypes are recorded from stations 3, 4, 5, 7, 13, 16, 17, 18, 19; 20, 21, 22, 23, 26, 27, 30, 31, 33, 34, 35, 37, 38, 42, and 51.

Genus *GORDIOSPIRA* Heron-Allen and Earland, 1932

#### *GORDIOSPIRA ARCTICA* Cushman

Plate 7, figures 1-3

*Gordiospira arctica* CUSHMAN, 1933, Smithsonian Misc. Coll., vol. 89, No. 9, p. 3, pl. 1, figs. 5-7; 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 41, pl. 4, figs. 11-13.

Test free, nearly planispiral, partially evolute so that previous coils are visible in the umbilical region, as many as  $3\frac{1}{2}$  whorls may be present; proloculus globular, followed by long undivided tubular second chamber, which is somewhat irregular in coiling in the early portion; wall calcareous, imperforate, surface marked by numerous ridges of growth; aperture large, formed by the open end of the tube.

Greatest diameter of hypotype of figure 1, 0.88 mm., greatest thickness 0.36 mm. Greatest diameter of hypotype of figure 2, 0.34 mm. Greatest diameter of hypotype of figure 3, 0.39 mm.

*Types and occurrence.*—Figured hypotype (U.S.N.M. No. P1072) from station 23; figured hypotype (U.S.N.M. No. P1073) from station 15; figured hypotype (U.S.N.M. No. P1074) from station 22; unfigured hypotypes are recorded from stations 15, 17, 20, 22, 23, 26, 33, and 34.

### Family TROCHAMMINIDAE

Genus TROCHAMMINA Parker and Jones, 1859

#### TROCHAMMINA NANA (Brady)

Plate 8, figure 5

*Haplophragmium nana* BRADY, 1881, Quart. Journ. Micr. Soc., vol. 21, p. 50; 1884, Rep. Voy. *Challenger*, vol. 9 (Zoology), p. 311, pl. 35, figs. 6-8.

*Trochammina nana* (Brady) CUSHMAN, 1920, U. S. Nat. Mus. Bull. 104, pt. 2, p. 80, pl. 17, fig. 1; 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 42, pl. 5, fig. 1.—PHLEGER, 1952, Contr. Cushman Found. Foram. Res., vol. 3, pt. 2, p. 86, pl. 13, figs. 31, 32.

Test free, small, trochoid, biconvex, ventrally umbilicate, margin lobulate; chambers numerous, increasing rapidly in size as added, later ones inflated, particularly on the ventral side, the complete  $2\frac{1}{2}$  whorls visible dorsally, only the 6 or 7 chambers of the final whorl visible ventrally; sutures distinct, nearly straight and radiate ventrally, curving backward to the periphery on the dorsal side; wall arenaceous, of medium-sized grains, with some larger clear quartz grains, surface rather smoothly finished; color yellowish to reddish brown, the early portion usually darker in color; aperture at the base of the apertural face on the ventral side.

Greatest diameter of hypotype of figure 5, 0.35 mm., thickness 0.16 mm. Other hypotypes range from 0.18 to 0.31 mm. in greatest diameter.

*Types and occurrence.*—Figured hypotype (U.S.N.M. No. P2013) from station 51; unfigured hypotypes are recorded from stations 35, 36, 51, and 52.



**TROCHAMMINA QUADRILOBA** Höglund

Plate 7, figure 8

*Trochammina pusilla* HÖGLUND, 1947 (not *Serpula pusilla* Geinitz, 1848), Zool.

Bidrag Uppsala, vol. 26, p. 201, pl. 17, figs. 4a-c, text figs. 183, 184.

*Trochammina quadriloba* HÖGLUND, 1948, Contr. Cushman Lab. Foram. Res.,

vol. 24, pt. 2, p. 46.

Test free, small, trochoid, high-spined, periphery rounded, margin lobulate; chambers increasing rapidly in size as added, strongly inflated, four in the final whorl; sutures fairly distinct, constricted; wall thin, finely arenaceous with medium-sized grains as well, surface usually rather smoothly finished, but occasional specimens have a rough exterior, color white to reddish brown, later chambers of lighter color than the early ones; aperture small, interio-marginal, an arched slit at the base of the last chamber.

Greatest diameter of figured hypotype 0.26 mm., height of spire 0.26 mm. Other hypotypes range from 0.16 to 0.23 mm. in maximum diameter.

*Types and occurrence.*—Figured hypotype (U.S.N.M. No. P2021) and unfigured hypotypes from station 36.

**TROCHAMMINA ROTALIFORMIS** Wright

Plate 8, figures 6-9

*Trochammina rotaliformis* WRIGHT, in Heron-Allen and Earland, 1911, Journ.

Roy. Micr. Soc., p. 309.—CUSHMAN, 1920, U. S. Nat. Mus. Bull. 104, pt.

2, p. 77, pl. 16, figs. 1, 2; 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 42, pl. 4, figs. 16a-c.

Test free, small to medium-sized, trochoid, concavo-convex, with low dorsal spire and excavated and umbilicate ventral side, periphery broadly rounded; chambers numerous, up to  $3\frac{1}{2}$  volutions visible dorsally, only the 5 to 6 of the last whorl visible ventrally with the final chamber occupying about one-third of the ventral side; sutures distinct, slightly depressed, radial and nearly straight ventrally, gently curved backward on the periphery on the dorsal side; wall finely arenaceous, with occasional larger grains, smoothly finished, white to reddish brown in color, the later chambers progressively lighter in color on each specimen; aperture an elongate ventral slit, at the base of the final chamber, extending from near the periphery into the umbilicus, partially covered by a flaplike covering from the final chamber.

Greatest diameter of hypotype of figure 8, 0.86 mm., height of spire 0.44 mm. Greatest diameter of hypotype of figure 6, 0.70 mm., height of spire 0.34 mm. Greatest diameter of hypotype of figure 9, 0.68

mm., and of hypotype of figure 7, 0.23 mm. Other hypotypes range from 0.44 to 0.81 mm. in maximum diameter.

*Types and occurrence.*—Figured hypotypes (U.S.N.M. Nos. P2121a,b) from station 17; figured hypotype (U.S.N.M. No. P2122) from station 27; figured hypotype (U.S.N.M. No. P2123) from station 35; unfigured hypotypes are recorded from stations 17 and 35.

Genus **TROCHAMMINELLA** Cushman, 1943

**TROCHAMMINELLA ATLANTICA** F. Parker

Plate 7, figures 6, 7

*Trochamminella atlantica* F. PARKER, 1952, Bull. Mus. Comp. Zool., vol. 106, No. 9, p. 409, pl. 4, figs. 17-19.—PHLEGER, 1952, Contr. Cushman Found. Foram. Res., vol. 3, pt. 2, p. 87, figs. 2, 4.

Test free, small, trochoid, ventrally umbilicate, periphery rounded, peripheral margin lobulate; chambers numerous, slightly inflated, increasing rapidly in size as added, 5-6 in the last whorl; sutures distinct, depressed, radial, nearly straight; wall thin, finely arenaceous, with occasional larger grains, smoothly finished, color yellowish to reddish brown, the later chambers progressively lighter in color; aperture ovate, interio-areal, slightly ventral in position with a distinct lip.

Greatest diameter of hypotype of figure 7, 0.34 mm., thickness 0.18 mm. Greatest diameter of hypotype of figure 6, 0.31 mm., thickness 0.18 mm. Other hypotypes range from 0.16 to 0.39 mm. in maximum diameter.

*Types and occurrence.*—Figured hypotypes (U.S.N.M. Nos. P2022a,b) from station 26; unfigured hypotypes are recorded from stations 26, 31, 35, 36, 51, and 52.

Family **LAGENIDAE**

Genus **ASTACOLUS** Montfort, 1808

**ASTACOLUS HYALACRULUS** Loeblich and Tappan, new species

Plate 9, figures 1-4

Test free, large, robust, somewhat compressed, early portion close-coiled about the large globular proloculus, later portion uncoiling, but with chambers reaching back toward the coil on the inner margin, final chambers may become completely uniserial, periphery subacute; chambers numerous, about 7 surrounding the proloculus, followed by 3 or 4 which do not reach the coil in well-developed specimens, sutures distinct, visible through the somewhat translucent wall, gently

curved, oblique in uncoiled portion; wall calcareous, finely perforate, radiate, surface smooth; aperture radiate, at the dorsal angle.

Length of holotype 1.40 mm., greatest diameter of coil 0.52 mm., greatest breadth of uncoiled portion 0.49 mm., thickness 0.31 mm. Length of paratypes of figure 3, 0.34 mm., of figure 4, 0.70 mm., and of figure 1, 1.04 mm., breadth 0.52 mm. Other specimens range from 0.31 to 1.43 mm. in length.

*Remarks.*—This species resembles *Cristellaria berthelotiana* d'Orbigny, from the Canary Isles, in size and general proportions, but the present species is more enrolled at the base, and the later sutures are more nearly horizontal and the test is narrower in the uncoiled portion, but much less compressed.

*Cristellaria crepidula* (Fichtel and Moll) of Parker and Jones (1865, pl. 13, figs. 15, 16) is very similar, although the magnification given by Parker and Jones suggests that it is much larger than the present species. *A. hyalacrulus*, new species, is quite distinct from Fichtel and Moll's type figure however, as it is less compressed and less enrolled, and the later chambers do not extend as far back on the inner margin, but are higher and narrower and more nearly rectilinear.

*Types and occurrence.*—Holotype (U.S.N.M. No. P2039) from station 18; figured paratypes (U.S.N.M. Nos. P2040a-c) from station 3; unfigured paratypes are recorded from stations 1, 3, 12, 18, 20, 21, 23, 24, 29, 30, 31, 32, 38, 39, 42, 45, and 50.

#### ASTACOLUS species

Plate 9, figures 5, 6

Test free, small, ovate in outline, slightly compressed, periphery rounded; chambers few in number, in a somewhat evolute spiral, later chambers extending back toward the base on the inner margin, increasing more rapidly in breadth than in height; sutures distinct, but not depressed; wall calcareous, finely perforate, translucent, surface smooth; aperture radiate, at the somewhat produced dorsal angle.

Length of specimen of figure 5, 0.62 mm., breadth 0.29 mm., thickness 0.23 mm. Length of specimen of figure 6, 0.52 mm., breadth 0.26 mm., thickness 0.17 mm.

*Remarks.*—This species is similar to *Astacolus etigoensis* Asano from the Pliocene of Japan, but is less enrolled at the base, has a more elongate proloculus, and a narrower test with higher chambers. It differs from *A. planulatus* Galloway and Wissler from the Pleisto-

cene of California in being less enrolled, less compressed, and with a more-produced aperture.

This species somewhat resembles *Cristellaria tenuissima* Heron-Allen and Earland, from the region of the Falkland Islands, but is larger, less compressed, and more ovate in outline, with fewer chambers, and these higher and narrower and not extending as far back on the inner margin of the coil. It closely resembles the early portion of *Astacolus crepidulus* (Fichtel and Moll) in size and proportions but that species is from the Mediterranean, and it seems unlikely that the identical form would be found in the Arctic.

The present form is represented by only two specimens, and as it is not possible to determine if these are adults or juveniles (the small number of chambers suggesting the latter), it is not here specifically identified.

*Types and occurrence.*—Figured specimens (U.S.N.M. Nos. P2034a,b) from station 18.

Genus DENTALINA d'Orbigny, 1826

DENTALINA BAGGI Galloway and Wissler

Plate 9, figures 10-15

*Nodosaria pauperata* BAGG, 1912 (not *Dentalina pauperata* d'Orbigny, 1846), U. S. Geol. Surv. Bull. 513, p. 57, pl. 16, figs. 2a-f.

*Nodosaria calomorpha* BAGG, 1912 (not Reuss, 1866), *ibid.*, p. 53, pl. 15, fig. 3.

*Dentalina baggi* GALLOWAY and WISSLER, 1927, Journ. Paleontol., vol. 1, p. 49, pl. 8, figs. 14, 15.—CUSHMAN and GRAY, 1946, Cushman Lab. Foram. Res. Spec. Publ. 19, p. 13, pl. 2, figs. 26, 27.—CUSHMAN and McCULLOCH, 1950, Allan Hancock Pacific Exped., vol. 6, No. 6, p. 313, pl. 41, figs. 13, 14.

Test free, very large, robust, base rounded and smooth; chambers up to 7 or 8 in number in the Arctic specimens, of nearly equal size throughout, sometimes slightly increasing in size as added, inflated centrally, lower than broad except for the final chamber which is of greater height than breadth; sutures distinct, nearly horizontal, slightly constricted; wall calcareous, finely perforate, opaque, smooth; aperture terminal, radiate, eccentric, slightly produced.

Length of hypotype of figure 10, 3.54 mm., breadth 0.70 mm. Length of hypotype of figure 11, 2.63 mm., breadth 0.62 mm. Length of hypotype of figure 12, 3.17 mm., breadth 0.81 mm. Length of hypotype of figure 13, 3.90 mm., breadth 0.91 mm. Length of hypotype of figure 14, 1.35 mm., breadth 0.68 mm. Length of hypotype of figure 15, 5.72 mm., breadth 0.88 mm. Other hypotypes up to 4.84 mm. in length.

*Remarks.*—The specimen figured by Bagg as *N. calomorpha* was a juvenile form similar to that shown in figure 14. The types of *D. baggi* were extremely long and well-developed specimens, those of Cushman and Gray were similar to the larger specimens here figured. It is also very similar to *D. pauperata* d'Orbigny, differing in the smooth, rounded base and absence of the apical spine of d'Orbigny's species.

*Types and occurrence.*—Figured hypotype (U.S.N.M. No. P2005) from station 3; figured hypotype (U.S.N.M. No. P2006) from station 4; figured hypotypes (U.S.N.M. Nos. P2007a-c) from station 21; figured hypotype (U.S.N.M. No. P2008) from station 31; unfigured hypotypes are recorded from stations 3, 12, 18, 21, 22, 26, 29, 31, 32, 39, 42, 49, and 56.

#### DENTALINA FROBISHERENSIS Loeblich and Tappan, new species

Plate 10, figures 1-9

*Nodosaria mucronata* (Neugeboren) CUSHMAN (part), 1923 (not *Dentalina mucronata* Neugeboren, 1856), U. S. Nat. Mus. Bull. 104, pt. 4, p. 80, pl. 12, figs. 5-7, pl. 13, figs. 7-9.

*Dentalina* sp. CUSHMAN, 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 45, pl. 5, fig. 6.

Test free, usually quite large, although small specimens occur which are similar in all other respects and may be megalospheric, straight to slightly arcuate, rounded in section; chambers numerous, up to about 15 in number, early ones very low and broad, increasing in proportionate height as added, later ones of equal height and breadth and slightly inflated and final chamber somewhat elongate, produced at the aperture; sutures distinct, horizontal to very slightly oblique, later ones slightly constricted; wall calcareous, perforate, smooth and translucent; aperture terminal, radiate, slightly eccentric, and toward the inner margin of the curved test.

Length of holotype of figure 9, 3.51 mm., breadth 0.65 mm. Length of paratype of figure 1, 1.87 mm., breadth 0.42 mm. Length of paratype of figure 6, 1.04 mm., breadth 0.23 mm. Length of paratype of figure 7, 0.81 mm., breadth 0.21 mm. Length of paratype of figure 8, 0.47 mm., breadth 0.13 mm. Length of paratype of figure 4, 2.25 mm., breadth 0.62 mm. Length of paratype of figure 3, 1.98 mm., breadth 0.44 mm. Length of paratype of figure 5, 1.43 mm., breadth 0.36 mm. Length of paratype of figure 2, 0.52 mm., breadth 0.13 mm. Other paratypes range from 0.81 to 4.73 mm. in length.

*Remarks.*—This species was recorded as *N. mucronata* (Neugeboren) by Cushman, 1923, but is more robust, with less-tapered base,

and a straight to slightly arcuate test rather than the sinuate one of Neugeboren's species from the Rumanian Tertiary. The chambers are lower and broader and the sutures horizontal in the present species rather than strongly oblique, and the apertural end is much less produced. Other Recent references to Neugeboren's species by Cushman, Brady, and Flint are apparently not the present species.

*Types and occurrence*.—Holotype (U.S.N.M. No. P2016) and figured paratypes (U.S.N.M. Nos. P2017a-d) from station 20; figured paratypes (U.S.N.M. Nos. P2018a,b) from station 3; figured paratype (U.S.N.M. No. P2019) from station 5; figured paratype (U.S.N.M. No. P2020) from station 21; unfigured paratypes are recorded from stations 4, 18, 20, 22, 26, 29, 32, 35, 39, and 42.

#### DENTALINA ITTAI Loeblich and Tappan, new species

Plate 10, figures 10-12

*Dentalina* cf. *calomorpha* (Reuss) CUSHMAN, 1948 (not *Nodosaria* (*Nodosaria*) *calomorpha* Reuss, 1866), Cushman Lab. Foram. Res. Spec. Publ. 23, p. 44, pl. 5, figs. 4, 5.

Test free, narrow, elongate, arcuate; consisting of 2 to 6 elliptical chambers, of nearly equal diameter, slightly overlapping; sutures distinct, constricted, straight; wall calcareous, finely perforate, translucent, so that the neck and aperture of earlier chambers may sometimes be seen through the wall of that following, surface smooth and unornamented; aperture radiate, terminal and central in position, very slightly produced.

Length of holotype of figure 11, 0.91 mm., greatest breadth 0.16 mm. Length of paratype of figure 10, 1.01 mm., greatest breadth 0.18 mm. Length of paratype of figure 12, 0.68 mm., greatest breadth 0.18 mm.

*Remarks*.—Brady (1884) and Cushman (1913) recorded *Nodosaria calomorpha* Reuss from the western Pacific, and later Cushman (1948b) recorded the present Arctic form as *Dentalina* cf. *calomorpha* (Reuss). The present species is smaller than the Pacific deep-water form and the Pacific form has a few hispid spines. Both Recent species are arcuate, however, and rounded at both ends, with no basal spine or apertural neck. Reuss's species from the German middle Oligocene is a true *Nodosaria*, rectilinear in growth, with an apical spine, more inflated chambers, more constricted sutures, and a pyriform final chamber tapering to a small neck.

*D. ittai*, new species, also is similar to *Dentalina baggi* Galloway and Wissler, in general appearance, but is very much smaller than

the 4 to 7 mm. length of *D. baggi* and the chambers are more elongate. The present species is apparently restricted to the Arctic.

This species is named in honor of Miles Itta, Eskimo guide employed by the Naval Arctic Research Laboratory, Point Barrow, Alaska.

*Types and occurrence.*—Holotype (U.S.N.M. No. P1096) from station 22; figured paratype (U.S.N.M. No. P1097) from station 1; figured paratype (U.S.N.M. No. P1098) from station 18; unfigured paratypes are recorded from stations 13, 18, 20, 21, 22, 23, 26, 27, 29, 30, 31, 33, 35, 38, and 39.

**DENTALINA MELVILLENSIS** Loeblich and Tappan, new species

Plate 10, figure 13

Test free, tiny, elongate, circular in section; chambers low and sub-cylindrical, very slightly inflated, 3 to 6 in number, closely appressed; sutures distinct, straight, very slightly constricted; wall calcareous, finely perforate, translucent, surface smooth; aperture terminal, central, round.

Length of holotype 0.47 mm., breadth 0.10 mm. Other specimens range from 0.29 to 0.39 mm. in length.

*Remarks.*—This species somewhat resembles *D. ittai*, new species, with which it is associated, but chambers of the present form have about one-half the diameter of those of *D. ittai*, and they are lower and more closely appressed. It is similar to *D. baggi* Galloway and Wissler in appearance, but has a less-produced aperture, more horizontal sutures, lower and less inflated chambers, and is very minute in size.

*Types and occurrence.*—Holotype (U.S.N.M. No. P2032) from station 30; unfigured paratypes are recorded from stations 20, 21, and 26.

**DENTALINA PAUPERATA** d'Orbigny

Plate 9, figures 7-9

*Dentalina pauperata* d'ORBIGNY, 1846, Foraminifères fossiles du bassin tertiaire . . . Vienne . . . , p. 46, pl. 1, figs. 57-58.

*Nodosaria (D.) pauperata* (d'Orbigny) BRADY, 1884, Rep. Voy. *Challenger*, vol. 9 (Zoology), p. 500, text fig. 14.

*Nodosaria pauperata* (d'Orbigny) CUSHMAN, 1923, U. S. Nat. Mus. Bull. 104, pt. 4, p. 72, pl. 14, fig. 13.

*Dentalina* cf. *roemeri* Neugeboren, CUSHMAN and GRAY, 1946 (not Neugeboren, 1856), Cushman Lab. Foram. Res. Spec. Publ. 19, p. 13, pl. 2, figs. 19-22.

*Dentalina* sp. CUSHMAN, 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 45, pl. 5, fig. 7.

Test free, large and robust, nearly cylindrical, but slightly curved; chambers of about equal breadth and height, inflated at the midline, proloculus with a distinct basal spine, final chamber somewhat produced to the aperture; sutures distinct, slightly constricted, nearly horizontal; wall calcareous, finely perforate, surface smooth; aperture terminal, radiate, eccentric.

Length of hypotype of figure 9, 4.16 mm., breadth 0.60 mm. Length of hypotype of figure 7, 1.17 mm., breadth 0.36 mm. Length of hypotype of figure 8, 0.60 mm., breadth 0.23 mm. Other hypotypes range from 0.86 to 3.12 mm. in length.

*Remarks.*—The present specimens are apparently identical with the Recent ones figured by Brady and Cushman and no distinction can be made between these and the Miocene type of d'Orbigny.

This species differs from *Dentalina roemeri* Neugeboren from the Tertiary in being larger and much more robust, subcylindrical rather than tapering, with horizontal rather than oblique sutures and with an apiculate instead of a smoothly rounded base. The specimen figured by Cushman (1948b) appears to be symmetrical, like a *Nodosaria*, in his illustration, but this is because the drawing was made from the front instead of from the side which would have shown its eccentric aperture.

*Types and occurrence.*—Figured hypotypes (U.S.N.M. Nos. P2009a,b) from station 20; figured hypotype (U.S.N.M. No. P2010) from station 35; unfigured hypotypes are recorded from stations 20, 21, 22, 26, 29, and 35.

#### Genus NODOSARIA Lamarck, 1812

#### NODOSARIA EMPHYSAOCYTA Loeblich and Tappan, new species

Plate 9, figures 16, 17

Test free, large and robust; proloculus rounded, followed by one or two additional subglobular chambers, all of nearly equal size, early chambers fairly closely appressed, third chamber of longer specimens frequently more distinctly separated, final chamber slightly produced at the aperture; sutures distinct, straight, that between second and third chambers much constricted; wall calcareous, finely perforate, surface smooth; aperture terminal, central, radiate.

Length of holotype 1.25 mm., breadth 0.39 mm. Length of figured paratype 0.78 mm., breadth 0.39 mm. Other paratypes range from 0.75 to 1.07 mm. in length.

*Remarks.*—This species is similar in appearance to *Dentalina subsoluta* (Cushman) but is rectilinear and not curved, the sutures are less



constricted, the basal spine is lacking and the neck less narrowed and produced. No specimens have been seen with more than three chambers and those with only two are more common.

*Types and occurrence.*—Holotype (U.S.N.M. No. P2011) from station 1; figured paratype (U.S.N.M. No. P2012) from station 3; unfigured paratypes are recorded from stations 1, 3, 5, 18, and 49.

Genus **LAGENA** Walker and Jacob, 1798

**LAGENA APIOPLEURA** Loeblich and Tappan, new species

Plate 10, figures 14, 15

*Lagena sulcata* (Walker and Jacob) PARKER and JONES (part), 1865 (not *Serpula (Lagena) sulcata* Walker and Jacob, 1798), Philos. Trans. Roy. Soc. London, vol. 155, p. 351, pl. 13, figs. 28-31.

*Lagena acuticosta* Reuss, BRADY (part), 1884 (not Reuss, 1862), Rep. Voy. Challenger, vol. 9 (Zoology), p. 464, pl. 58, fig. 2 (not pl. 57, figs. 31, 32, and not pl. 58, fig. 20).—CUSHMAN, 1913, U. S. Nat. Mus. Bull. 71, pt. 3, p. 23, pl. 8, fig. 9 (not fig. 10), pl. 23, fig. 2; 1923, U. S. Nat. Mus. Bull. 104, pt. 4, p. 5, pl. 1, figs. 1-3.—WIESNER, 1931, Deutsche Südpolar Exped., 1901-1903, vol. 20 (Zoology, vol. 12), p. 117, pl. 18, figs. 208-210.—CUSHMAN and McCULLOCH, 1950, Allan Hancock Pacific Exped., vol. 6, No. 6, p. 329, pl. 43, figs. 9, 10.

Test free, unilocular (but occasional freak twins occur), ovate to pear-shaped in outline, with a rounded base, circular in section; wall calcareous, hyaline, finely perforate, translucent, surface ornamented with a few longitudinal rounded ribs extending upward from a tiny ring at the base, and merging into a smooth collar a short distance below the apertural neck; aperture at the end of the short smooth neck, rounded.

Length of holotype 0.47 mm., width 0.29 mm. Length of two-chambered paratype of figure 15, 0.62 mm., breadth of basal chamber 0.27 mm., breadth of second chamber 0.16 mm. Other paratypes range from 0.31 to 0.47 mm. in length.

*Remarks.*—This species has often been referred to other ribbed lagenids, but is distinct. It differs from *Serpula (Lagena) sulcata* Walker and Jacob, 1798, in having fewer ribs and a more pear-shaped outline with a shorter neck. *Lagena acuticosta* Reuss is a Cretaceous species with a flattened base and subglobular form and does not have the pyriform appearance of the present species. Wiesner (1931, pl. 18, fig. 210) showed a two-chambered form similar to that here figured.

*Types and occurrence.*—Holotype (U.S.N.M. No. P2116) from station 18; figured paratype (U.S.N.M. No. P2117) from station 18; unfigured paratypes are recorded from stations 18, 23, and 30.

**LAGENA FLATULENTA** Loeblich and Tappan, new species

Plate II, figures 9, 10

*Lagena laevis* (Montagu) CUSHMAN, 1913 (not Montagu, 1803), U. S. Nat. Mus. Bull. 71, pt. 3, p. 5, pl. 38, fig. 5 (pl. 1, fig. 3 ?); 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 47, pl. 5, fig. 11.—CUSHMAN and McCULLOCH, 1950 (part), Allan Hancock Pacific Exped., vol. 6, No. 6, p. 341, pl. 45, fig. 15 (not figs. 14, 16).

*Lagena laevis* (Montagu) var. CUSHMAN and GRAY, 1946, Cushman Lab. Foram. Res. Spec. Publ. 19, p. 18, pl. 3, figs. 24, 25.

Test free, unilocular, flask-shaped, with an elongate, narrow and delicate neck; wall calcareous, hyaline, surface smooth; aperture terminal, rounded, surrounded by a slight lip.

Length of holotype 0.65 mm., breadth 0.31 mm. Length of paratype 0.55 mm., breadth 0.29 mm. Other specimens range in length from 0.49 to 0.68 mm.

*Remarks.*—This species has often been confused with *L. laevis* (Montagu), but has a nearly globular inflated chamber. Montagu's type is elongate and slender, almost fusiform in outline, and merges gradually into the neck. *Lagena flatulenta*, new species, has an almost globular chamber from which the long, slender neck is quite distinct.

The specimen figured by Cushman (1913, pl. 1, fig. 3) is similar, but shows only a short neck.

*Types and occurrence.*—Holotype (U.S.N.M. No. P2052) and figured paratype (U.S.N.M. No. P2053) from station 22; unfigured paratypes are recorded from stations 13, 20, 22, 23, 26, 39, and 45.

**LAGENA GRACILLIMA** (Seguenza)

Plate II, figures 1-4

*Amphorina gracillima* SEGUENZA, 1862, Descrizione dei foraminiferi monotalamici Marne mioceniche . . . Messina . . . , Diss. 2, p. 51, pl. 1, fig. 37.

*Amphorina distorta* SEGUENZA, 1862, *ibid.*, p. 52, pl. 1, fig. 38.

*Lagena gracillima* (Seguenza) BRADY, 1884, Rep. Voy. *Challenger*, vol. 9 (Zoology), p. 456, pl. 56, figs. 19-28.—CUSHMAN, 1913, U. S. Nat. Mus. Bull. 71, pt. 3, p. 11, pl. 1, fig. 4; 1923, U. S. Nat. Mus. Bull. 104, pt. 4, p. 23, pl. 4, fig. 5.

Test free, unilocular, narrow, elongate, fusiform, straight to slightly arcuate, with a long, apiculate base and a long, narrow neck at the opposite extremity; wall calcareous, hyaline, finely perforate, surface smooth; aperture terminal, rounded, at the end of the smooth, narrow, tubular neck and surrounded by a slight lip.

Length of hypotype of figure 1, 0.78 mm., breadth 0.18 mm. Length of hypotype of figure 4, 0.60 mm., breadth 0.21 mm. Length of hypo-

type of figure 2, 0.81 mm., breadth 0.26 mm. Length of hypotype of figure 3, 1.04 mm., breadth 0.29 mm. Unfigured hypotypes range from 0.52 to 1.01 mm. in length.

*Remarks.*—Seguenza described the symmetrical form as *Amphorina gracillima*, and an asymmetrical one (like fig. 1) as *A. distorta*. Both were from the same horizon and locality (upper Miocene of Sicily), the former described as common, the latter rare.

Brady placed two asymmetrical specimens with the symmetrical ones in *Lagena gracillima* (Seguenza). We have numerous asymmetrical specimens and they seem to grade imperceptibly into the symmetrical forms.

*Lagena distoma-polita* Parker and Jones is also similar, but has straighter sides and a more rhomboid side view. The present species is about one-third smaller.

This species resembles *Lagena laevis* (Montagu) var. *amphora* Williamson, 1848, but differs in having a more prominent basal spine. *Lagena clavata* (d'Orbigny) is also similar, but has a more inflated chamber and less extended basal spine.

*Types and occurrence.*—Figured hypotype (U.S.N.M. No. P2094) from station 20; figured hypotype (U.S.N.M. No. P2095) from station 32; figured hypotype (U.S.N.M. No. P2096) from station 46; figured hypotype (U.S.N.M. No. P2097) from station 50; unfigured hypotypes are recorded from stations 13, 15, 17, 18, 20, 21, 22, 23, 26, 30, 32, and 42.

### LAGENA LAEVIS (Montagu)

Plate 11, figures 5-8

*Vermiculium laeve* MONTAGU, 1803, Testacea Britannica, p. 524.

*Lagena vulgaris* WILLIAMSON, 1858, Recent Foraminifera of Great Britain, p. 3, pl. 1, figs. 5, 5a.—CUSHMAN and GRAY, 1946, Cushman Lab. Foram. Res. Spec. Publ. 19, p. 18, pl. 3, figs. 28-30.

*Lagena sulcata* Walker and Jacob var. *laevis* (Montagu) PARKER and JONES, 1865, Philos. Trans. Roy. Soc. London, vol. 155, p. 349, pl. 13, fig. 22 (called *Lagena laevis* on plate description).

*Lagena laevis* (Montagu) CUSHMAN and GRAY, 1946, Cushman Lab. Foram. Res. Spec. Publ. 19, p. 18, pl. 3, figs. 21-23.—CUSHMAN and McCULLOCH, 1950, Allan Hancock Pacific Exped., vol. 6, No. 6, p. 341, pl. 45, figs. 14, 16 (not fig. 15).

Test free, unilocular, flask-shaped, somewhat elongate, widest slightly below the midportion of the test, base rounded; wall calcareous, hyaline, finely perforate, surface smooth except occasionally very slightly and finely hispid at the base, but without distinct spines;

upper portion of the test tapering gradually to the very elongate and slender neck upon which is situated the rounded aperture.

Length of hypotype of figure 6, 0.83 mm., breadth 0.23 mm. Length of hypotype of figure 8, 0.65 mm., breadth 0.26 mm. Length of hypotype of figure 5, 0.70 mm., breadth 0.34 mm. Length of hypotype of figure 7, 0.86 mm., breadth 0.31 mm.

*Remarks.*—This species is more slender than *L. flatulenta*, new species, with which it is sometimes associated, and with which it has sometimes been confused in the past. *Lagena vulgaris* is an objective synonym of *L. laevis*, Williamson having proposed changing the name to *vulgaris* so as to include variously ornamented forms in the same species.

*Types and occurrence.*—Figured hypotype (U.S.N.M. No. P2077) from station 20; figured hypotype (U.S.N.M. No. P2078) from station 30; figured hypotypes (U.S.N.M. Nos. P2079a,b) from station 51; unfigured hypotypes are recorded from stations 3, 5, 12, 18, 20, 22, 29, 30, 38, 39, and 44.

#### LAGENA MERIDIONALIS Wiesner

Plate 12, figure 1

*Lagena caudata* (d'Orbigny) PARKER and JONES, 1865 (part) (not *Oolina caudata* d'Orbigny, 1839), Philos. Trans. Roy. Soc. London, vol. 155, p. 352, pl. 16, fig. 7.

*Lagena gracilis* Williamson, BRADY, 1884 (part), Rep. Voy. *Challenger*, vol. 9 (Zoology), p. 464, pl. 58, fig. 19 (not figs. 22-24).

*Lagena gracilis* Williamson var. CUSHMAN, 1913, U. S. Nat. Mus. Bull. 71, pt. 3, p. 25, pl. 8, fig. 7.

*Lagena gracilis* Williamson var. *meridionalis* WIESNER, 1931, Deutsche Südpolar-Exped. 1901-1903, vol. 20 (Zoology, vol. 12), p. 117, pl. 18, fig. 211.

Test free, unilocular, elongate-ovate, with rounded base, sometimes slightly bent and asymmetrical, lower three-fourths is regularly ovate, followed by a slight constriction, and then a somewhat narrowed upper one-fourth just below the short apertural neck; wall calcareous, hyaline, finely perforate, surface ornamented with numerous fine longitudinal costae, about 16 to 20, of which every second one is shorter, stopping at the constriction in the upper portion of the test, the remaining half continuing across the narrower upper portion to stop at the base of the smooth neck; aperture simple, terminal, rounded, on a smooth short neck.

Length of figured hypotype 0.44 mm., breadth 0.16 mm. Other hypotypes range from 0.29 to 0.49 mm. in length.

*Remarks.*—Parker and Jones referred this species to *L. caudata* (d'Orbigny), but the latter is more flask-shaped in outline, has an apical spine and a more elongate and slender neck. Wiesner defined the variety as differing from the species *L. gracilis* in the alternation of long and shorter ribs. As *L. gracilis* is fusiform in outline, with an apiculate base and very elongate neck, the "variety" is here raised to specific rank.

*Types and occurrence.*—Figured hypotype (U.S.N.M. No. P2080) from station 20; unfigured hypotypes are recorded from stations 20, 21, 22, 29, 30, 31, 32, 39, 42, and 45.

### LAGENA MOLLIS Cushman

Plate II, figures 25-27

*Lagena gracillima* (Seguenza) var. *mollis* CUSHMAN, 1944, Cushman Lab. Foram. Res. Spec. Publ. 12, p. 21, pl. 3, fig. 3.

Test free, unilocular, elongate-fusiform in outline, with a basal spine and an extremely long and slender neck at the opposite end, sides nearly parallel over the central portion of the test; wall calcareous, hyaline, finely perforate, ornamented with numerous very fine longitudinal ribs which die out at the beginning of the neck; aperture terminal, surrounded by a flared lip, at the end of a long, slender and smooth neck.

Length of hypotype of figure 25, 0.55 mm., greatest breadth 0.13 mm. Length of hypotype of figure 26, 0.60 mm., greatest breadth 0.08 mm. Length of hypotype of figure 27, 0.50 mm., greatest breadth 0.10 mm. Other hypotypes range from 0.39 to 0.73 mm. in length.

*Remarks.*—Cushman's complete description of this form stated, "Variety differing from the typical in the very fine, longitudinal costae on the surface." Cushman's illustrations do not show very clearly the fine striae characteristic of this species.

The writers have separated the present form as a distinct species, however, as it has a Recent Arctic and sub-Arctic range, and *L. gracillima* was from the Miocene of Sicily. It seems much more probable that the similar outline is accidental rather than the identical species being smooth in one environment and geologic period and ribbed at another time and region.

*Lagena distoma* Parker and Jones, 1864, may be the same as this species, and if so it would take priority. It is of similar size, shape, and ornamentation, but was described as having an aperture at each end. This assumption was undoubtedly due to the fact that the basal

spine and the elongate neck were broken, and a complete specimen might well be identical with *L. mollis*.

*Lagena mollis* Cushman differs from *L. gracilis* Williamson, 1848, in possessing many more fine ribs and in being less fusiform. *Lagena vulgaris* var. *gracilis* Williamson, 1858, possesses only a few distinct ribs, instead of the many fine ones of *L. mollis*. *Lagena laevis* (Montagu) var. *amphora* Williamson, and *L. elongata* Ehrenberg are similar to *L. mollis* in shape, but they are smooth forms.

*Types and occurrence*.—Figured hypotypes (U.S.N.M. Nos. P2041 a-c) from station 20; unfigured hypotypes are recorded from stations 13, 15, 16, 18, 20, 21, 22, 23, 26, 32, and 39.

#### LAGENA PARRI Loeblich and Tappan, new species

Plate 11, figures 11-13

*Lagena laevis* (Montagu) var. *baggi* Cushman and Gray, CUSHMAN and McCULLOCH, 1950 (not Cushman and Gray, 1946), Allan Hancock Pacific Exped., vol. 6, No. 6, p. 342, pl. 45, fig. 17.

Test free, unilocular, flask-shaped to ovate, widest in the lower half of the test, with a single distinct basal spine, and a long, very slender neck; wall calcareous, hyaline, finely perforate, surface smooth; aperture terminal on the long, delicate neck.

Length of holotype 0.68 mm., breadth 0.26 mm. Length of paratype of figure 12, 0.65 mm., breadth 0.29 mm. Length of paratype of figure 13, 0.68 mm. Other specimens range from 0.65 to 0.75 mm. in length.

*Remarks*.—Cushman and McCulloch (1950, pl. 45, fig. 17) figured a slender-necked apiculate specimen and referred it to *L. laevis* var. *baggi* Cushman and Gray. The type of the variety has an inconspicuous spine, almost obsolete, and has a short and thicker neck with a definite lip.

*Lagena parri*, new species, resembles *Oolina clavata* d'Orbigny in possessing the smooth test, elongate neck, and basal spine, but d'Orbigny's species is fusiform in outline rather than globose.

*Lagena* ? *sphaerula* Silvestri is similar, but has a more globular test and a more elongate basal spine.

The species is named in honor of the late Walter J. Parr, in recognition of his work on the lagenoid Foraminifera.

*Types and occurrence*.—Holotype (U.S.N.M. No. P2054) from station 32; figured paratype (U.S.N.M. No. P2055) from station 20; figured paratype (U.S.N.M. No. P2056) from station 21; unfigured paratypes are recorded from stations 20 and 21.

## LAGENA SEMILINEATA Wright

Plate II, figures 14-22

*Lagena semilineata* WRIGHT, 1886, Proc. Belfast Nat. Field Club, n. s., vol. 1, app. 9, p. 320, pl. 26, fig. 7.—CUSHMAN and McCULLOCH, 1950, Allan Hancock Pacific Exped., vol. 6, No. 6, p. 345, pl. 46, fig. 11.

*Lagena sulcata* Walker and Jacob var. *semistriata* Williamson, PARKER and JONES, 1865 (not *L. striata* (Montagu) var.  $\beta$  *semistriata* Williamson, 1848), Philos. Trans. Roy. Soc. London, vol. 155, p. 350, pl. 13, fig. 23.

*Lagena caudata* (d'Orbigny) CUSHMAN, 1948 (not d'Orbigny, 1839), Cushman Lab. Foram. Res. Spec. Publ. 23, p. 46, pl. 5, figs. 8, 9.

Test free, unilocular, flask-shaped, widest near the apiculate base, somewhat tapered at the upper portion and grading into a very long, slender and delicate neck; wall calcareous, hyaline, finely perforate, the upper one-half to two-thirds of the test is smooth, the lower portion ornamented with fine costae, which double in number by intercalation a short distance from the base, but in occasional specimens the intercalary costae apparently did not develop, so that fewer costae are present (fig. 19), a delicate basal spine of about one-half the diameter of the neck is present on well-preserved specimens, but more usually broken off; aperture terminal, surrounded by a slight lip, and at the end of a long, slender neck of a length about two-thirds that of the chamber itself.

Length of hypotype of figure 17, 0.60 mm., breadth 0.23 mm. Length of hypotype of figure 16, 0.62 mm., breadth 0.23 mm. Length of hypotype of figure 14, 0.62 mm., breadth 0.23 mm. Length of hypotype of figure 19, 0.65 mm., breadth 0.24 mm. Length of hypotype of figure 15, 0.68 mm., breadth 0.21 mm. Other hypotypes range from 0.47 to 0.83 mm. in length.

*Remarks.*—This species was described from the coast of Ireland, and also reported from the coast of Scotland. Cushman recorded this species as *L. caudata* (d'Orbigny) from off Greenland, but d'Orbigny's species from off the Falkland Islands is a much smaller form, about one-sixth the size of the present species.

Parker and Jones (1865, p. 350, pl. 13, fig. 23) figured a very similar specimen, referring it to *L. sulcata* var. *semistriata* Williamson. Williamson defined *L. striata* (Montagu) var.  $\beta$  *semistriata*, but this is a more globose form, and lacks a basal spine. Parker and Jones's figure shows a suggestion of a broken basal spine, but an examination of the actual specimen will be necessary to determine whether it has a spine.

*Types and occurrence.*—Figured hypotypes (U.S.N.M. Nos. P2083 a,b) from station 20; figured hypotypes (U.S.N.M. Nos. P2084a-d)

from station 21; figured hypotypes (U.S.N.M. Nos. P2085a,b) from station 22; figured hypotype (U.S.N.M. No. P2086) from station 23; unfigured hypotypes are recorded from stations 1, 13, 17, 18, 20, 21, 22, 23, 26, 27, 29, 30, 31, 32, 39, and 42.

### LAGENA SETIGERA Millett

Plate II, figures 23, 24

*Lagena clavata* (d'Orbigny) var. *setigera* MILLETT, 1901, Journ. Roy. Micr. Soc. London, pt. 11, p. 491, pl. 8, fig. 9.

*Lagena perlucida* (Montagu) var. CUSHMAN and McCULLOCH, 1950 (not *Vermiculum perlucidum* Montagu, 1803), Allan Hancock Pacific Exped., vol. 6, No. 6, p. 343, pl. 46, figs. 3, 4.

Test free, unilocular, circular in section, globose to flask-shaped in outline; wall calcareous, hyaline, surface smooth, with a flattened base surrounded by a cirlet of very tiny spines, which may easily be overlooked and in some specimens the spines are rudimentary or broken, so that only a ringlike scar marks their position; aperture terminal, surrounded by a thickened lip, at the end of a very elongate, slender and smooth neck.

Length of hypotype of figure 24, 0.52 mm., breadth 0.29 mm. Length of hypotype of figure 23, 0.55 mm., breadth 0.26 mm.

*Remarks.*—In describing this form as a variety, Millett stated, "Differs from the type in having at the aboral end a cup-shaped indentation surrounded by a circle of setae.

"In *Oolina striaticollis* d'Orbigny, and some of the figures of *Lagena tenuis* Bornemann, as interpreted by Reuss, the free ends of the ribs extend beyond the base of the shell and have a similar appearance; but in the variety under consideration the ribs are entirely wanting." *Oolina striaticollis* also differs from the present species in having a shorter neck, and in the neck being ornamented with spiraling striae.

*Lagena tenuis* (Bornemann) var. *ornata* Reuss, 1863, has a long smooth neck, but has a more slender and elongate chamber and the basal spines grade into costae on the basal portion of the chamber.

Millett's variety is here raised to specific rank, as d'Orbigny's type of *Oolina clavata* from the Tertiary of the Vienna Basin has a single central basal spine, rather than a depressed or flattened base surrounded by spines.

The specimens referred to *Lagena perlucida* (Montagu) var. by Cushman and McCulloch belong with this species. *Vermiculum perlucidum* Montagu has vertical costae covering the complete test.



*Types and occurrence.*—Figured hypotype (U.S.N.M. No. P2075) from station 18; figured hypotype (U.S.N.M. No. P2076) from station 29; unfigured hypotypes are recorded from stations 20, 21, 29, 30, 31, 32, 35, 39, and 42.

Genus OOLINA d'Orbigny, 1839

OOLINA CAUDIGERA (Wiesner)

Plate 13, figures 1-3

*Lagena (Entosolenia) globosa* (Montagu) var. *caudigera* WIESNER, 1931, Deutsche Südpolar-Exped., 1901-1903, vol. 20 (Zoology, vol. 12), p. 119, pl. 18, fig. 214.

*Lagena (Entosolenia) ovata* (Terquem) var. *caudigera* WIESNER, 1931, *ibid.*, p. 119, pl. 18, fig. 215.

*Entosolenia lineata* Williamson, CUSHMAN, 1948 (not Williamson, 1848), Cushman Lab. Foram. Res. Spec. Publ. 23, p. 64, pl. 7, fig. 5.

Test free, unilocular, globular to ovate, with a long, narrow basal spine; wall calcareous, hyaline, finely perforate, surface smooth; aperture terminal, rounded, with radial grooves extending a short distance down the side from the aperture, and with a very long entosolenian tube extending almost through the entire chamber cavity and slightly expanded at its lower extremity.

Length of hypotype of figure 3, 0.36 mm., breadth 0.23 mm. Length of hypotype of figure 1, 0.36 mm., breadth 0.29 mm. Length of hypotype of figure 2, 0.55 mm., breadth 0.39 mm. Other specimens range from 0.23 to 0.55 mm. in length.

*Remarks.*—Wiesner described a globular form (like that of fig. 1) as *Lagena globosa* var. *caudigera*, and an ovate specimen (like that of fig. 2) as *L. ovata* var. *caudigera*, thus making a homonym of the latter. We believe both to be merely individual variations, and are also raising the variety to specific rank.

Smooth, extremely hyaline specimens of this species were referred to *Entosolenia lineata* Williamson by Cushman (1948b, p. 64), but the latter species as described by Williamson is covered with exceedingly fine parallel longitudinal striae. Cushman's figure shows a smooth test, and this is borne out by his type specimen. *Entosolenia lineata* of Williamson has a straight internal tube that nearly reaches the base of the shell and is described as being slightly patulous at the base of the tube. In the specimen figured by Cushman (1948b, pl. 7, fig. 5) the internal tube is very short, but as the test agrees in form with several other specimens identified as this species by Cushman it is probable that an abnormal or damaged specimen was figured. The

other specimens in Cushman's collection do have long internal tubes running nearly to the base of the test and expanded at the lower extremity.

*Types and occurrence.*—Figured hypotype (U.S.N.M. No. P1093) from station 12; figured hypotype (U.S.N.M. No. P1094) from station 18; figured hypotype (U.S.N.M. P1095) from station 22; unfigured hypotypes are recorded from stations 1, 3, 4, 5, 6, 8, 9, 10, 12, 13, 18, 19, 20, 21, 22, 23, 26, 28, 29, 30, 32, 35, 38, 39, 42, and 50.

### OOLINA COSTATA (Williamson)

Plate 13, figures 4-6

*Entosolenia costata* WILLIAMSON, 1858, Recent Foraminifera of Great Britain, p. 9, pl. 1, fig. 18.

*Lagena costata* (Williamson) CUSHMAN, 1923, U. S. Nat. Mus. Bull. 104, pt. 4, p. 12, pl. 1, fig. 16, pl. 2, figs. 1, 2 (not pl. 3, fig. 8); 1944, Cushman Lab. Foram. Res. Spec. Publ. 12, p. 21, pl. 3, fig. 4.—CUSHMAN and McCULLOCH, 1950, Allan Hancock Pacific Exped., vol. 6, No. 6, p. 335, pl. 44, fig. 7.

*Oolina costata* (Williamson) F. PARKER, 1952, Bull. Mus. Comp. Zool., vol. 106, No. 9, p. 409, pl. 4, figs. 20, 21.

Test free, ovate in outline, somewhat broader at the base; wall calcareous, finely perforate, surface ornamented with about 12 to 17 well-separated, narrow longitudinal ribs which begin near a circular projecting area at the base, and extend up the sides, grading into a smooth area surrounding the aperture; aperture terminal, slightly produced, radiate, with an internal tube.

Length of hypotype of figure 4, 0.88 mm., breadth 0.60 mm. Length of hypotype of figure 6, 0.75 mm., breadth 0.52 mm. Length of bilocular freak 1.12 mm., breadth 0.47 mm. Other hypotypes range from 0.39 to 0.78 mm. in length.

*Remarks.*—Although originally defined as *Entosolenia costata* this species has been widely recorded as *Lagena*. The presence of an internal tube makes that designation erroneous. The aberrant bilocular form shown in figure 5 is rare, but a similar specimen of this species was figured by Balkwill and Wright (1882), and refigured by Cushman (1923). Occasional bilocular forms are also found in other unilocular species.

*Types and occurrence.*—Figured hypotypes (U.S.N.M. Nos. P2042a,b) from station 26; figured hypotype (U.S.N.M. No. P2043) from station 7; unfigured hypotypes are recorded from stations 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 18, 19, 21, 22, 23, 26, 27, 28, 29, 30, 31, 32, 39, 42, and 50

## OOLINA HEXAGONA (Williamson)

Plate 14, figures 1, 2

*Entosolenia squamosa* (Montagu) var.  $\gamma$  *hexagona* WILLIAMSON, 1848, Ann. Mag. Nat. Hist., ser. 2, vol. 1, p. 20, pl. 2, fig. 23; 1858, Recent Foraminifera of Great Britain, p. 13, pl. 1, fig. 32.

*Lagena hexagona* (Williamson) BRADY, 1884, Rep. Voy. Challenger, vol. 9 (Zoology), p. 472, pl. 58, figs. 32, 33.—CUSHMAN, 1913, U. S. Nat. Mus. Bull. 71, pt. 3, p. 17, pl. 6, figs. 2, 3; 1923, U. S. Nat. Mus. Bull. 104, pt. 4, p. 24, pl. 4, fig. 6.

*Lagena favosa* REUSS, 1863, Sitzb. Akad. Wiss. Wien, math.-nat. Kl., vol. 46, Abt. 1 (1862), p. 334, pl. 5, figs. 72, 73.

Test free, unilocular, ovate in outline, with a somewhat produced neck; wall calcareous, hyaline, surface ornamented with many tiny hexagonal reticulations which give a honeycombed appearance; aperture terminal, rounded, small, at the end of a short, smooth, cylindrical neck, and with an internal entosolenian tube.

Length of hypotype of figure 1, 0.37 mm., breadth 0.23 mm. Length of hypotype of figure 2, 0.42 mm., breadth 0.26 mm. Other hypotypes range from 0.29 to 0.44 mm. in length.

*Remarks.*—*Oolina hexagona* (Williamson) is similar to *Lagena cellularis* Silvestri, but differs in having the depressions more hexagonal in outline rather than diamond-shaped. The species *Lagena favosa* Reuss was based on specimens from the Shetland Islands, but Reuss's figures of the species were copied from Williamson and thus Reuss's species is here considered a junior synonym of *O. hexagona* (Williamson).

Williamson described this species as a variety of *Entosolenia squamosa* (Montagu) and characterized it as having hexagonal areas "not arranged in well-marked perpendicular rows." It is interesting to note that Cushman (1948b, p. 64, pl. 7, fig. 6) elevates *hexagona* to species rank, but makes the variety named by Williamson (1848, p. 20) as *Entosolenia squamosa* var. *scalariformis* a variety of *Entosolenia hexagona*. The "variety" *scalariformis* of Williamson, with its regularly arranged rows of reticulations, is certainly not closely related to *Oolina hexagona* and should not be associated as a variety of *hexagona*.

*Types and occurrence.*—Figured hypotypes (U.S.N.M. Nos. P2093a,b) from station 18; unfigured hypotypes are recorded from stations 1, 13, 18, 21, 22, 29, 30, and 32.

## OOLINA LINEATA (Williamson)

Plate 13, figures 11-13

*Entosolenia lineata* WILLIAMSON, 1848, Ann. Mag. Nat. Hist., ser. 2, vol. 1, p. 18, pl. 2, fig. 18.

*Entosolenia globosa* (Montagu) var. *lineata* Williamson, WILLIAMSON, 1858, Recent Foraminifera of Great Britain, p. 9, pl. 1, fig. 17.

*Lagena lineata* (Williamson) BRADY, 1884, Rep. Voy. *Challenger*, vol. 9 (Zoology), p. 461, pl. 57, fig. 13.—CUSHMAN, 1923, U. S. Nat. Mus. Bull. 104, pt. 4, p. 31, pl. 5, fig. 10, pl. 6, figs. 5-8.

not *Entosolenia lineata* Williamson, CUSHMAN, 1948, Cushman Lab. Forum. Res. Spec. Publ. 23, p. 64, pl. 7, fig. 5.

Test free, unilocular, globose to ovate, with a small basal spine; wall calcareous, hyaline, finely perforate, surface covered with numerous very fine and very closely spaced longitudinal striae; aperture terminal, rounded, surrounded by the more prominent ends of the longitudinal striae, and with an internal entosolenian tube.

Length of hypotype of figure 13, 0.47 mm., breadth 0.37 mm. Length of hypotype of figure 11, 0.29 mm., breadth 0.21 mm. Other specimens range from 0.23 to 0.55 mm. in length.

*Remarks.*—The specimen referred to this species by Cushman in 1948 is smooth and unornamented, and we consider it to belong to *O. caudigera* (Wiesner). Williamson's type is very finely striate, as are the present figured specimens.

*Types and occurrence.*—Hypotype of figure 12 (U.S.N.M. No. P2087) from station 7; hypotype of figure 13 (U.S.N.M. No. P2088a) from station 29; hypotype of figure 11 (U.S.N.M. No. P2088b) from station 29; unfigured hypotypes are recorded from stations 29, 30, 31, 39, and 42.

## OOLINA LINEATO-PUNCTATA (Heron-Allen and Earland)

Plate 13, figure 8

*Lagena globosa* (Montagu) var. *lineato-punctata* HERON-ALLEN and EARLAND, 1922, British Antarctic Exped., 1910, Nat. Hist. Rep., Zool., vol. 6, No. 2, p. 142, pl. 5, figs. 12-14.

Test free, unilocular, globose to ovate, with broadly rounded base and somewhat protruding neck; wall calcareous, hyaline, with many fine pits in the surface, closely arranged in vertical rows; aperture terminal, rounded, on a slight neck, with an entosolenian tube in the interior of the test.

Length of figured hypotype 0.42 mm., breadth 0.31 mm. Length of unfigured hypotypes range from 0.36 to 0.39 mm., and breadth from 0.31 to 0.34 mm.

*Remarks.*—Heron-Allen and Earland's type is from off the coast of New Zealand, but the present specimens appear the same in all respects.

*Types and occurrence.*—Figured hypotype (U.S.N.M. No. P2068) from station 1; unfigured hypotypes are recorded from stations 1 and 39.

### OOLINA MELO d'Orbigny

Plate 12, figures 8-15

*Oolina melo* D'ORBIGNY, 1839, Voyage dans l'Amérique méridionale, Foraminifères, vol. 5, pt. 5, p. 20, pl. 5, fig. 9.

*Entosolenia squamosa* (Montagu) var. *catenulata* WILLIAMSON, 1848, Ann. Mag. Nat. Hist., ser. 2, vol. 1, p. 19, pl. 2, fig. 20; 1858, Recent Foraminifera of Great Britain, p. 13, pl. 1, fig. 31.

*Entosolenia squamosa* (Montagu) var. *scalariformis* WILLIAMSON, 1848, Ann. Mag. Nat. Hist., ser. 2, vol. 1, p. 20, figs. 21, 22.

*Lagena squamosa* (Montagu) BRADY, 1884, Rep. Voy. Challenger, vol. 9 (Zoology), p. 471, pl. 58, figs. 28-31.

*Lagena catenulata* (Williamson) CUSHMAN, 1923, U. S. Nat. Mus. Bull. 104, pt. 4, p. 9, pl. 1, fig. 11.

*Entosolenia hexagona* Williamson var. *scalariformis* Williamson, CUSHMAN, 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 64, pl. 7, fig. 6.

Test free, unilocular, although occasional twinned specimens occur in this as in many similar species, ovate in outline, with a rounded base and slightly produced apertural end; wall calcareous, hyaline, finely perforate, surface ornamented with vertical and horizontal ridges, forming a surface network, the vertical rows of cancellations ranging from 8 to 19 in number, sometimes dividing or combining half-way up the test, and the horizontal divisions range from 4 to 11 in number and usually alternating rather than continuous around the test, so that at times the pits appear hexagonal, although the vertical costae are usually straight and more prominent; aperture terminal, rounded, slightly produced on a short tubular neck, and with an internal entosolenian tube.

Length of hypotype of figure 12, 0.39 mm., breadth 0.29 mm. Length of hypotype of figure 10, 0.36 mm., breadth 0.29 mm. Length of hypotype of figure 13, 0.39 mm., breadth 0.29 mm. Length of hypotype of figure 8, 0.36 mm., breadth 0.29 mm. Length of hypotype of figure 14, 0.44 mm., breadth 0.39 mm. Length of hypotype of figure 9, 0.39 mm., breadth 0.31 mm. Other hypotypes range in length from 0.21 to 0.55 mm.

*Remarks.*—This species has been much subdivided and variously known, *Lagena squamosa* (Montagu) being used for the forms with

many cancelli, the var. *scalariformis* Williamson for those with large cancelli in a small number of vertical rows, and *Entosolenia catenulata* Williamson [or *Lagena catenulata*] used for those with many vertical rows of small cancelli.

Brady in 1884 (p. 471) noted that the form referred to the species *catenulata* was identical with *Lagena melo* (d'Orbigny), and Heron-Allen and Earland (1922, p. 152) also considered it synonymous. They separated as a distinct species the form referred to *catenulata* of Williamson by Reuss, 1863, and credited the species to *Lagena catenulata* Reuss. This is an erroneous use of the name as Reuss did not use *catenulata* as a new specific name, and it can be used only for the species containing Williamson's type. Chapman and Parr (1937, p. 65) therefore renamed Reuss's species *Lagena pseudocatenulata*.

Brady considered *squamosa* as synonymous with its varieties *catenulata* and *scalariformis*, but he separated the variety *hexagona* as a distinct species. The present writers believe the forms described by Williamson as varieties *catenulata* and *scalariformis* to be merely end members of a gradational series. We have seen specimens with 8, 9, 10, 12, 13, 14, 16, 17, and 19 vertical rows of cancellations, and in some specimens two of the rows may combine into a single row halfway up the test. This evidence of gradation leads us to combine all these forms under the name *Oolina melo* d'Orbigny.

*Types and occurrence*.—Figured hypotypes (U.S.N.M. Nos. P2127a,b) from station 1; figured hypotypes (U.S.N.M. Nos. P2128a-c) from station 6; figured hypotype (U.S.N.M. No. P2129) from station 10; figured hypotype (U.S.N.M. No. P2130) from station 29; figured hypotype (U.S.N.M. No. P2131) from station 31; unfigured hypotypes are recorded from stations 1, 4, 5, 6, 7, 9, 10, 12, 16, 18, 19, 20, 21, 22, 23, 24, 26, 28, 30, 31, 39, 42, 45, and 50.

#### OOLINA SCALARIFORME-SULCATA (Wiesner)

Plate 13, figure 7

*Lagena (Entosolenia) scalariforme-sulcata* WIESNER, 1931, Deutsche Südpolar-Exped., 1901-1903, vol. 20 (Zoology, vol. 12), p. 120, pl. 18, fig. 219.

Test free, small, unilocular, ovate in outline or rounded at the base, with somewhat truncated sides sloping to the aperture; wall calcareous, hyaline, surface of the lower half of the test ornamented with 8 to 13 longitudinal costae, grading into hexagonal or polygonal reticulations in the upper portion of the test, with larger and more regular polygons near the midline passing into smaller and less regularly arranged reticulations near the aperture; aperture terminal,

rounded, surrounded by a smooth lip, without a distinct neck, but with an internal entosolenian tube.

Length of hypotype 0.36 mm., breadth 0.26 mm.

*Remarks.*—This species differs from *O. squamoso-sulcata* (Heron-Allen and Earland), in averaging fewer ribs in the lower portion, more truncated sides in the upper portion, and more irregular and smaller reticulations.

*Type and occurrence.*—Figured hypotype (U.S.N.M. No. P2069) from station 30.

### OOLINA SQUAMOSA (Montagu)

Plate 13, figures 9, 10

*Vermiculum squamosum* MONTAGU, 1893, Testacea Britannica, p. 526, pl. 14, fig. 2.

*Entosolenia squamosa* (Montagu) WILLIAMSON, 1848, Ann. Mag. Nat. Hist., ser. 2, vol. 1, p. 18, pl. 2, fig. 19.—CUSHMAN, 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 64.

*Lagena squamosa* (Montagu) CUSHMAN, 1923, U. S. Nat. Mus. Bull. 104, pt. 4, p. 51, pl. 10, fig. 3 (not fig. 4 = *Oolina hexagona*).

not *Lagena squamosa* (Montagu) CUSHMAN, 1913, U. S. Nat. Mus. Bull. 71, pt. 3, p. 16, pl. 6, fig. 1 [= *Oolina hexagona*?].

not *Entosolenia squamosa* (Montagu) CUSHMAN, 1941, Contr. Cushman Lab. Foram. Res., vol. 17, pt. 2, p. 36, pl. 9, fig. 13.—CUSHMAN and GRAY, 1946, Cushman Lab. Foram. Res. Spec. Publ. 19, p. 31, pl. 5, figs. 37-39 [all = *Oolina melo*].

not *Entosolenia squamosa* (Montagu) CUSHMAN and TODD, 1947, Contr. Cushman Lab. Foram. Res., vol. 23, pt. 3, p. 66, pl. 15, fig. 27 [= *Oolina hexagona*].

Test free, unilocular, ovate, with rounded base and slightly produced apertural end; wall calcareous, hyaline, ornamented with numerous fine cancelli, only slightly depressed, and with the pits rounded; aperture terminal, rounded, only slightly produced, with an internal entosolenian tube.

Length of hypotype of figure 10, 0.29 mm., breadth 0.23 mm. Length of hypotype of figure 9, 0.36 mm., breadth 0.31 mm. Other hypotypes range in length from 0.26 to 0.42 mm.

*Remarks.*—This species has often been confused with *Oolina melo* and *Oolina hexagona*, but differs in having less regularly arranged cancelli, and in having rounded pits rather than rectangular or hexagonal ones, and the pits are usually of much smaller size in the present species.

*Types and occurrence.*—Figured hypotype (U.S.N.M. No. P2132) from station 18; figured hypotype (U.S.N.M. No. P2133) from

station 20; unfigured hypotypes are recorded from stations 1, 12, 18, 20, 21, 29, 30, 32, 35, 39, and 42.

**OOLINA SQUAMOSO-SULCATA (Heron-Allen and Earland)**

Plate 12, figures 6, 7

*Lagena melo* (d'Orbigny) (intermediate var.) Brady, PARKER and JONES, 1888, Trans. Zool. Soc. London, vol. 12, p. 237, pl. 44, fig. 25.

*Lagena squamoso-sulcata* HERON-ALLEN and EARLAND, 1922, British Antarctic Exped., 1910, Nat. Hist. Rep., Zool., vol. 6, No. 2, p. 151, pl. 5, figs. 15, 19.

Test free, unilocular, inflated, ovate in outline, widest at the base and tapering somewhat toward the aperture, circular in section; wall calcareous, hyaline, finely perforate, the lower one-half ornamented by about 12 to 20 longitudinal ribs, which are connected in the upper half of the test by many slightly arched transverse costae, so that the upper portion of the test is reticulate in appearance; aperture terminal, rounded, surrounded by a slight lip, and a short, smooth collar, but without a distinct neck, an entosolenian tube occurs in the center of the chamber cavity and can be seen through the wall of some of the translucent specimens.

Length of hypotype of figure 7, 0.44 mm., breadth 0.34 mm. Length of hypotype of figure 6, 0.44 mm., breadth 0.34 mm.

*Remarks.*—*Lagena (Entosolenia) scalariforme-sulcata* Wiesner, 1931, is a similar form, with costae in the lower half and reticulations in the upper half. It differs in being more acuminate at the oral end, and in having hexagonal reticulations, whereas in the present species there are continuous vertical ribs, which are joined by arched transverse ribs in the upper portion.

The present species is here placed in *Oolina*, as a distinct entosolenian tube can be seen on some of the more translucent specimens.

One of the specimens has 12 vertical ribs, another 13. Heron-Allen and Earland's type also had 13. The specimen here shown in figure 7 has 20 ribs which is considerably more, but as the number of ribs is variable, this specimen is considered to belong to the same species.

*Types and occurrence.*—Figured hypotype (U.S.N.M. No. P2070) from station 29; figured hypotype (U.S.N.M. P2071) from station 45; unfigured hypotype from station 42.

**OOLINA STRIATOPUNCTATA (Parker and Jones)**

Plate 12, figures 2-5

*Lagena sulcata* (Walker and Jacob) var. *striatopunctata* PARKER and JONES, 1865, Philos. Trans. Roy. Soc. London, vol. 155, p. 350, pl. 13, figs. 25-27.



*Entosolenia striatopunctata* (Parker and Jones) DAWSON, 1870, Can. Nat., n.s., vol. 5, p. 178, fig. 11.

*Lagena striatopunctata* Parker and Jones, BRADY, 1878, Ann. Mag. Nat. Hist., ser. 5, vol. 1, p. 434, pl. 20, fig. 3; 1884, Rep. Voy. *Challenger*, vol. 9 (Zoology), p. 468, pl. 58, figs. 37, 40.—CUSHMAN, 1913, U. S. Nat. Mus. Bull. 71, pt. 3, p. 30, pl. 14, fig. 10; 1923, U. S. Nat. Mus. Bull. 104, pt. 4, p. 55, pl. 10, fig. 10; 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 47, pl. 5, fig. 10.

Test free, unilocular, flask-shaped, somewhat elongate, rounded in section, occasionally with a thick, blunt, spinelike projection at the base (fig. 4), the opposite end produced into a long and delicate neck; wall calcareous, perforate, surface ornamented with 12 to 14 narrow longitudinal ribs, of which only one-half begin at the base of the test, the remainder being intercalated a short distance above the base where the chamber is wider, ribs ornamented by a row of pores on each side which extend into the central cavity of the test, the ribs dying out at the upper end of the test, and the test becoming smooth for a short distance, passing into the somewhat elongate neck; aperture terminal, radial, surrounded by a slight lip which is petaloid in appearance because of the radial grooves, and with a long and delicate entosolenian tube in the interior of the chamber (fig. 5).

Length of hypotype of figure 2, 0.55 mm., breadth 0.26 mm. Length of hypotype of figure 3, 0.60 mm., breadth 0.23 mm. Length of hypotype of figure 4, 0.47 mm., breadth 0.26 mm. Other hypotypes range from 0.39 to 0.65 mm. in length.

*Remarks.*—This species was originally defined as a variety of *Lagena sulcata*, but was placed in *Entosolenia* by Dawson (1870). All other authors have apparently referred it to *Lagena*. As it has a distinct internal tube (fig. 5), it is here placed in *Oolina*.

Cushman and McCulloch (1950, p. 352) described *L. striatopunctata* var. *excentricitas*, stating that it differed from the typical form in the axis of the test being bent at the apertural end and the costae fewer and more prominent. In our material a large proportion of the specimens are more or less irregular, and it seems probable that this irregularity is due to the form of the material upon which the specimen grew, rather than an inherited characteristic.

*Types and occurrence.*—Figured hypotype (U.S.N.M. No. P2044) from station 1; figured hypotype (U.S.N.M. No. P2045) from station 3; figured hypotype (U.S.N.M. No. P2046) from station 29; figured hypotype (U.S.N.M. P2047) from station 30; unfigured hypotypes are recorded from stations 1, 3, 4, 5, 18, 21, 22, 23, 24, 26, 29, 30, 31, 32, 36, 39, 42, and 45.

Genus **FISSURINA** Reuss, 1850**FISSURINA CUCURBITASEMA** Loeblich and Tappan, new species

Plate 14, figures 10, 11

Test free, ovate, flattened with an outline like that of a melon seed, occasionally very slightly produced at the base; wall calcareous, translucent, finely perforate, with a thin marginal keel, surface smooth; aperture terminal, ovate, with a slight lip, and with an entosolenian tube extending about one-half the length of the test.

Length of holotype 0.26 mm., breadth 0.16 mm., thickness 0.10 mm. Length of paratype of figure 10, 0.23 mm., breadth 0.13 mm., thickness 0.13 mm. Other paratypes range from 0.18 to 0.42 mm. in length.

*Remarks.*—This species differs from *F. marginata* (Montagu) in the more elongate test, less-produced aperture and mucronate base.

*Types and occurrence.*—Holotype (U.S.N.M. No. P2119) from station 29; figured paratype (U.S.N.M. No. P2120) from station 25; unfigured paratypes are recorded from stations 3, 20, 21, 26, 29, 30, 32, 42, and 51.

**FISSURINA LUCIDA** (Williamson)

Plate 14, figure 4

*Entosolenia marginata* (Montagu) var. *lucida* WILLIAMSON, 1848, Ann. Mag. Nat. Hist., ser. 2, vol. 1, p. 17, pl. 2, fig. 17.

*Entosolenia lucida* (Williamson) CUSHMAN and GRAY, 1946, Cushman Lab. Foram. Res. Spec. Publ. 19, p. 30, pl. 5, figs. 16-18.—CUSHMAN and TODD, 1947, Cushman Lab. Foram. Res. Spec. Publ. 21, p. 20, pl. 3, fig. 11; 1947, Contr. Cushman Lab. Foram. Res., vol. 23, pt. 3, p. 65, pl. 15, fig. 22.

not *Entosolenia lucida* (Williamson) CUSHMAN, 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 63, pl. 7, fig. 2.

Test free, unilocular, somewhat compressed, ovate in outline, base smooth and rounded; wall calcareous, hyaline, with a horseshoe-shaped opaque border on the lower margin and up the sides, around the clear central area of the test; aperture terminal, ovate, with a short entosolenian tube.

Length of figured hypotype 0.27 mm., breadth 0.22 mm., thickness 0.16 mm. Length of unfigured hypotype 0.24 mm.

*Remarks.*—This species is characterized by the horseshoe-shaped opaque area near the outer margin, and the clear central portion of the shell. This specimen figured from Greenland by Cushman (1948b, pl. 7, fig. 2) does not have this surface character.

*Types and occurrence.*—Figured hypotype (U.S.N.M. No. P2118) and unfigured hypotype from station 3.

### FISSURINA MARGINATA (Montagu)

Plate 14, figures 6-9

*Vermiculum marginatum* MONTAGU, 1803, Testacea Britannica, p. 524.

*Lagena sulcata* Walker and Jacob var. (*Entosolenia marginata* (Montagu) PARKER and JONES, 1865 (part), Philos. Trans. Roy. Soc. London, vol. 155, p. 355, pl. 13, figs. 42, 43 (not fig. 44 and not pl. 16, fig. 12).

*Lagena marginata* (Walker and Boys) BRADY, 1884 (part), Rep. Voy. *Challenger*, vol. 9 (Zoology), p. 476, pl. 59, fig. 22 (not figs. 21, 23).—CUSHMAN, 1913, U. S. Nat. Mus. Bull. 71, pt. 3, p. 37, pl. 22, figs. 1-7.

*Entosolenia marginata* (Montagu) var. CUSHMAN and GRAY, 1946 (part), Cushman Lab. Foram. Res. Spec. Publ. 19, p. 30, pl. 5, figs. 19-21 (not figs. 22-24).—CUSHMAN and TODD, 1947, Contr. Cushman Lab. Foram. Res., vol. 23, pt. 3, p. 65, pl. 15, figs. 23, 24.

*Entosolenia marginata* (Montagu)? CUSHMAN, 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 65, pl. 7, fig. 7.

Test free, unilocular, somewhat compressed, rounded to ovate in outline, with a slightly produced apertural end; wall calcareous, finely perforate, translucent, with a narrow marginal keel, surface otherwise smooth; aperture terminal, varying from an elongate slit to ovate, with a clear collarlike portion surrounding it and with a short to elongate entosolenian tube which is free for one-third to one-half the length of the test and is then attached to the wall at its lower end, where it is somewhat flared.

Length of hypotype of figure 6, 0.31 mm., breadth 0.26 mm., thickness 0.18 mm. Other hypotypes range from 0.16 to 0.42 mm. in length.

*Remarks.*—This species is one of the commonest in the Arctic and is quite variable, particularly in the character of the internal tube. Some have a straight tube, in others the tube bends to one side. The tube may be attached to one wall at the lower end, but in many specimens the attached tube extends to the base and up the opposite wall. We also have two "freak" specimens with double apertures. In these two specimens both apertures are ovate in the plane of the peripheral keel, and only one aperture of each has an internal tube.

*Types and occurrence.*—Figured hypotype (U.S.N.M. No. P2136) from station 3; figured hypotype (U.S.N.M. No. P2137) from station 18; figured hypotypes (U.S.N.M. Nos. P2138a-b) from station 36; unfigured hypotypes are recorded from stations 1, 2, 3, 4, 5, 6, 7, 9, 10, 12, 18, 19, 20, 21, 22, 24, 28, 29, 30, 31, 35, 36, 39, 42, 45, and 50.

**FISSURINA SEMIMARGINATA (Reuss)**

Plate 14, figure 3

*Lagena* sp. (Nos. 64-65) VON SCHLICT, 1870, Die Foraminiferen Septarienthones Pielzpuhl, p. 11, pl. 4, figs. 4-6, 10-12.

*Lagena marginata* Williamson var. *semimarginata* REUSS, 1870, Sitzb. Akad. Wiss. Wien, vol. 62, pt. 1, p. 468.—BRADY, 1884, Rep. Voy. *Challenger*, vol. 9 (Zoology), p. 446, pl. 59, figs. 17, 19.

*Lagena (Entosolenia) marginata* var. *semimarginata* REUSS, WIESNER, 1931, Deutsche Südpolar-Exped., 1901-1903, vol. 20 (Zoology, vol. 12), p. 120, pl. 19, fig. 224.

Test free, unilocular, compressed, ovate in outline, with rounded base; wall calcareous, finely and distinctly perforate, translucent to opaque, surface smooth, but with a slight marginal keel in the upper part; aperture elongate, produced on a clear necklike extension of the chamber, and with a long entosolenian tube attached to the wall.

Length of figured hypotype 0.34 mm., breadth 0.21 mm., thickness 0.13 mm. Length of unfigured hypotype 0.23 mm.

*Types and occurrence*.—Figured hypotype (U.S.N.M. No. P2090) from station 30; unfigured hypotype from station 19.

**FISSURINA SERRATA (Schlumberger)**

Plate 14, figure 5

*Lagena serrata* SCHLUMBERGER, 1894, Mém. Soc. Zool. France, vol. 7, p. 258, pl. 3, fig. 7.

*Entosolenia serrata* (Schlumberger) CUSHMAN, 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 63, pl. 7, fig. 3.

Test free, unilocular, compressed, of a shape like a melon seed, ovate in outline, bluntly rounded at the base, widening rapidly and then narrowing to the short, thick neck; wall calcareous, hyaline, finely perforate, surface smooth, except for a marginal keel, which has radial tubules passing through it and presenting a serrated or almost fimbriate appearance; aperture terminal, radial, at the end of the blunt neck, and with an internal entosolenian tube.

Length of figured hypotype 0.34 mm., breadth 0.18 mm., thickness 0.10 mm. Other hypotypes range from 0.29 to 0.44 mm. in length.

*Remarks*.—This species was originally described from the Arctic Ocean off Russia and was recorded by Cushman from northeastern Greenland. It is similar to *Entosolenia marginata* var. *lagenoides* Williamson, but differs in having a much less elongate neck. This is the second species of the genus having a radiate aperture.

*Types and occurrence*.—Figured hypotype (U.S.N.M. No. P2108) from station 3; unfigured hypotypes are recorded from stations 3, 13, 18, 20, 21, 22, 23, 32, 39, 45, and 51.

**FISSURINA VENTRICOSA (Wiesner)**

Plate 14, figure 15

*Lagena (Entosolenia) marginata* var. *ventricosa* WIESNER, 1931, Deutsche Südpolar-Exped., 1901-1903, vol. 20 (Zoology, vol. 12), p. 120, pl. 19, fig. 222.

Test free, unilocular, small, ovate in outline, inflated and nearly circular in section; wall calcareous, hyaline, surface smooth; aperture ovate, terminal, with an internal tube extending about one-half to two-thirds the length of the test, free in the upper portion, then curving downward to become attached to one wall for a short distance and flaring slightly at its extremity.

Length of figured hypotype 0.29 mm., breadth 0.23 mm., thickness 0.21 mm. Other hypotypes range from 0.18 to 0.23 mm. in length.

*Remarks.*—This species is one of the most nearly globular in the genus, and lacks the marginal keel of *Fissurina marginata* (Montagu).

*Types and occurrence.*—Figured hypotype (U.S.N.M. No. P2089) from station 43; unfigured hypotypes are recorded from stations 3, 12, and 13.

**Genus PARAFISSURINA Parr, 1947****PARAFISSURINA FOLLICULA Loeblich and Tappan, new species**

Plate 14, figure 16

Test free, unilocular, ovate in outline, inflated, widest near the base; hyaline, surface smooth, with occasional large perforations giving a spotted appearance to the surface; aperture an arched slit covered over by a flap from the aboral side, with an entosolenian tube on the inside against the aboral wall.

Length of holotype 0.29 mm., breadth 0.16 mm.

*Remarks.*—This species resembles *P. tectulostoma*, new species, in the small size and occasional large perforations, but the present species differs in being more robust, in having a broader and lower aperture, and a rounded rather than apiculate base.

*Type and occurrence.*—Holotype (U.S.N.M. No. P2066) from station 20.

**PARAFISSURINA FUSULIFORMIS Loeblich and Tappan, new species**

Plate 14, figures 18, 19

Test free, narrow, elongate, slightly curved, acute to subrounded at the base, tapering to an acutely angled upper extremity; wall calcareous, hyaline, finely perforate, surface smooth; aperture eccentric, a small rounded opening, partially covered by a flap from the

aboral side and connected to an entosolenian tube which is attached to the interior of the aboral side, extending about two-fifths the length of the test and visible through the translucent wall.

Length of holotype 0.29 mm., breadth 0.10 mm. Length of paratype 0.31 mm., breadth 0.08 mm. Other specimens range from 0.26 to 0.36 mm. in length.

*Remarks.*—This species differs from *Parafissurina tectulostoma*, new species, in being smaller and narrower and slightly curved, with a less apiculate base. The aperture is smaller, and rounded, rather than arched, and the entosolenian tube is not as long as in *P. tectulostoma*.

*Types and occurrence.*—Holotype (U.S.N.M. No. P2048) and figured paratype (U.S.N.M. No. P2049) from station 20; unfigured paratypes are recorded from stations 20, 32, and 39.

#### PARAFISSURINA HIMATIOSTOMA Loeblich and Tappan, new species

Plate 14, figures 12-14

Test free, unilocular, ovate in outline, with a wide but pointed base and narrowing somewhat toward the oral extremity; wall calcareous, hyaline, finely perforate, with scattered large pores that give a rather speckled appearance to the otherwise smooth surface; aperture ovate, eccentric, partially covered by an extension of the aboral side of the test, which forms a semicircular hood, and with an internal entosolenian tube adjacent to the aboral side.

Length of holotype 0.31 mm., breadth 0.16 mm. Length of paratype of figure 13, 0.29 mm., breadth 0.13 mm. Length of paratype of figure 12, 0.31 mm., breadth 0.16 mm. Other unfigured paratypes range from 0.26 to 0.39 mm. in length.

*Remarks.*—This species differs from *P. fusuliformis*, new species, in being more robust, and in having a pointed rather than rounded base, and a rounded rather than narrow and pointed oral extremity. The characteristic spotty appearance of the present species due to the perforations is also distinct.

From *P. tectulostoma*, new species, the present form may be distinguished by its shorter and broader form, and the rounded aperture, instead of the arched slit of *P. tectulostoma*, and a much shorter entosolenian tube in the interior of the chamber.

*Types and occurrence.*—Holotype (U.S.N.M. No. P2072) and figured paratype (U.S.N.M. No. P2073) from station 20; figured paratype (U.S.N.M. No. P2074) from station 18; unfigured paratypes are recorded from stations 3, 18, 20, 21, 29, 30, 32, 39, and 50.

## PARAFISSURINA TECTULOSTOMA Loeblich and Tappan, new species

Plate 14, figure 17

Test free, unilocular, elongate-ovate, with a pointed base, widest across the lower portion, narrowing somewhat to the aperture; wall calcareous, hyaline, finely perforate, surface smooth; aperture eccentric, appearing as a crescent and covered by a hood, with a long, narrow entosolenian tube extending from the orifice down the side opposite the opening, attached to this aboral wall, and of a length slightly greater than one-half the length of the test.

Length of holotype 0.42 mm., greatest breadth 0.18 mm., greatest thickness 0.16 mm. Length of unfigured paratype 0.31 mm., breadth 0.16 mm.

*Remarks.*—This species resembles some of the forms referred to *Lagena felsinea* Fornasini by Cushman (1923, p. 17). However, under this name Cushman mixed species belonging to two genera, one (U.S.N.M. No. 19136) being closer to *Oolina* than to *Parafissurina* in that it has a collar at the apertural end, and a stellate aperture, and lacks the hooded aperture. The second form includes the remainder of Cushman's Atlantic specimens referred to Fornasini's species, but belong to the genus *Parafissurina*, showing a well-developed hooded aperture. However, neither of these species appears to be that illustrated and described by Fornasini from the Pliocene of Italy, as the latter species had neither a hooded nor radiate aperture, but had a simple eccentric aperture, and an entosolenian tube attached to the aboral wall on the side opposite the apertural opening. Furthermore, Fornasini's species is rounded at the base rather than apiculate.

The present form has a broader aperture than Cushman's specimens or Fornasini's species, and has a long tube attached to the aboral wall and a pointed base.

*Types and occurrence.*—Holotype (U.S.N.M. No. P2050) and unfigured paratype (U.S.N.M. No. P2051) from station 20.

## Family POLYMORPHINIDAE

Genus GLANDULINA d'Orbigny, 1826

GLANDULINA LAEVIGATA d'Orbigny

Plate 16, figures 2-5

*Nodosaria (Glandulina) laevigata* D'ORBIGNY, 1826, Ann. Sci. Nat., vol. 7, p. 252, pl. 10, figs. 1-3.

*Glandulina laevigata* d'ORBIGNY, 1846, Foraminifères fossiles du bassin tertiaire Vienne . . . , p. 29, pl. 1, figs. 4, 5.—CUSHMAN and OZAWA, 1930, Proc. U. S. Nat. Mus., vol. 77, art. 6, p. 143, pl. 40, figs. 1a,b.—CUSHMAN, 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 52, pl. 5, figs. 20, 21, pl. 6, fig. 1.—VAN VOORTHUYSEN, 1950, Meded. Geol. Sticht., n. s., No. 4, p. 37, text fig. 4 (1-5b).

*Pseudoglandulina laevigata* (d'Orbigny) CUSHMAN and McCULLOCH, 1950, Allan Hancock Pacific Exped., vol. 6, No. 6, p. 325, pl. 42, fig. 4.

Test free, ovate to fusiform in outline, circular in section, pointed at the base, early portion biserial, later becoming uniserial; as many as 3 pairs of biserially arranged chambers, and usually one or two uniserial ones, chambers increasing rapidly in size as added, final chamber occupying from one-half to two-thirds the length of the test; sutures distinct, not depressed; wall calcareous, thin and sometimes translucent, especially near the aperture, surface smooth; aperture terminal, central, radiate, with an internal tube.

Length of hypotype of figure 3, 1.17 mm., breadth 0.52 mm. Length of hypotype of figure 4, 0.94 mm., breadth 0.52 mm. Length of hypotype of figure 5, 0.73 mm., breadth 0.39 mm.

*Remarks.*—Cushman and McCulloch (1950, p. 325) placed *Glandulina laevigata* d'Orbigny under the generic designation of *Pseudoglandulina* Cushman, 1929. If it were congeneric with *Glandulina*, d'Orbigny's name has more than a hundred years' priority over *Pseudoglandulina* Cushman. The latter was defined as differing from *Glandulina* in being uniserial throughout, rather than biserial in the early portion. An internal tube has also been noted by Selli (1947) in *Glandulina glans* and *G. silvestrii*. It was recorded in *Glandulina laevigata* by Van Voorthuysen (1950a). Furthermore, the internal tube is apparent in figures (and specimens) from the Arctic (Cushman, 1948b, pl. 5, fig. 21), but as this character was never mentioned by Cushman in descriptions of specimens from this area it must be assumed it was interpreted as a highlight on the drawings. Gallo-way (1933, p. 244) implied the presence of a tube in stating, "aperture terminal, central, round, protruding, sometimes with entosolenian collar."

*Types and occurrence.*—Figured hypotypes (U.S.N.M. Nos. P1070a-c) from station 26; figured hypotype (U.S.N.M. No. P1071) from station 22; unfigured hypotypes are recorded from stations 1, 20, 22, 26, 29, 30, 39, and 40.



**LARYNGOSIGMA**<sup>4</sup> Loeblich and Tappan, new genus

Synonyms: *Sigmomorphina* of authors (not Cushman and Ozawa, 1928).

*Polymorphina* of authors (not d'Orbigny, 1826).

Genotype (type species): *Laryngosigma hyalascidia* Loeblich and Tappan, new species.

Test free, somewhat compressed, chambers added in planes slightly less than 180°, forming a sigmoid series, each succeeding chamber farther removed from the base; wall calcareous, finely perforate; aperture terminal, radiate, with an internal tube.

*Remarks.*—*Laryngosigma* differs from *Sigmomorphina* Cushman and Ozawa in possessing an "entosolenian" tube within the aperture, and from *Esosyrinx*, new genus, in having a sigmoid chamber arrangement rather than a biserial arrangement in a single plane. It differs from *Siphoglobulina* Parr in having a sigmoid rather than triloculine chamber arrangement, and in the entosolenian tube being free rather than attached to the wall interior.

Other species that belong here include *Sigmomorphina subulata* Chapman and Parr and *Polymorphina williamsoni* Terquem. In addition *Sigmomorphina pearceyi* Cushman and Ozawa was described as having an internal tube, but this was apparently done on the basis of the tube shown by Pearcey in his species *Polymorphina inflata* (not *P. inflata* Zittel) which Cushman and Ozawa placed in the synonymy of their species. However, the holotype selected by Cushman and Ozawa from Dry Tortugas, Fla., does not show such an internal tube, and Chapman and Parr (1937, p. 77) stated that Cushman and Ozawa's species was distinct from that of Pearcey. Chapman and Parr therefore proposed the new name *Sigmomorphina subulata* for the species with the internal tube described by Pearcey from the south Atlantic, and *Sigmomorphina pearceyi* remains in that genus, the specific description being here emended to delete mention of an "entosolenian" tube.

**LARYNGOSIGMA HYALASCIDIA** Loeblich and Tappan, new species

Plate 15, figures 6-8

Test free, ovate to elongate-ovate in outline, slightly compressed; chambers numerous, biserially arranged but not in a plane, a line through the center of the chambers forming a sigmoid curve, each chamber farther removed from the base, but extending far back on the sides; sutures distinct, strongly oblique, slightly depressed; wall

<sup>4</sup> From Gr. *laryngos*, gullet; *sigma*, s (shape).

calcareous, finely perforate, translucent, surface smooth; aperture terminal, radiate, with a short and narrow, tubular, slightly curved "entosolenian" tube.

Length of holotype 0.68 mm., breadth 0.31 mm., thickness 0.21 mm. Length of paratype of figure 6, 0.53 mm., breadth 0.36 mm. Length of paratype of figure 8, 0.44 mm. Other paratypes range from 0.31 to 0.65 mm. in length.

*Remarks.*—This species is closest in appearance to *Sigmomorphina lamarcki* Cushman and Ozawa, but is more rounded in outline and less compressed, lacks the surface striae and has an "entosolenian" tube. It differs from *Sigmomorphina pearceyi* Cushman and Ozawa and *Sigmomorphina subulata* Chapman and Parr in being widest near the base rather than tapered at the base. *Polymorphina williamsoni* Terquem differs in having parallel sides and nearly vertical sutures.

*Types and occurrence.*—Holotype (U.S.N.M. No. P2139) from station 1; figured paratypes (U.S.N.M. Nos. P2140a,b) from station 35; unfigured paratypes are recorded from stations 3, 5, 7, 9, 20, 26, 29, 30, 31, and 51.

#### LARYNGOSIGMA WILLIAMSONI (Terquem)

Plate 16, figure 1

*Polymorphina lactea* (Walker and Jacob) var. *oblonga* WILLIAMSON, 1858 (not *Polymorphina (Globulinen) oblonga* Roemer, 1838, and not *Polymorphina oblonga* d'Orbigny, 1846), Recent Foraminifera of Great Britain, p. 71, pl. 6, figs. 149, 149a.—CUSHMAN, 1923, U. S. Nat. Mus. Bull. 104, pt. 4, p. 147, pl. 40, figs. 7, 8.

*Polymorphina williamsoni* TERQUEM, 1878, Mém. Soc. Géol. France, ser. 3, vol. 1, p. 37.—HERON-ALLEN and EARLAND, 1932, *Discovery* Rep., vol. 4, p. 393, pl. 12, figs. 26-28.

*Sigmomorphina williamsoni* (Terquem) CUSHMAN and OZAWA, 1930, Proc. U. S. Nat. Mus., vol. 77, art. 6, p. 138, pl. 38, figs. 3, 4.—CUSHMAN, 1944, Cushman Lab. Foram. Res. Spec. Publ. 12, p. 23, pl. 3, fig. 21.

Test free, subquadrate in outline, with somewhat rounded extremities, compressed; chambers biserially sigmoid in arrangement, increasing gradually in size as added successively farther from the base, but very much overlapping at the sides; sutures distinct, depressed, and so strongly oblique as to be nearly vertical; wall calcareous, finely perforate, hyaline and translucent, surface smooth; aperture terminal, radiate, with a short tubular "entosolenian" neck.

Length of hypotype of figure 1, 0.47 mm., greatest breadth 0.21 mm., thickness 0.18 mm.

*Remarks.*—This species differs from *L. hyalascidia*, new species, in

being subquadrate rather than ovate in outline, with parallel margins, and very strongly oblique to nearly vertical sutures.

*Types and occurrence.*—Figured hypotype (U.S.N.M. No. P2141) from station 15; unfigured hypotypes are recorded from stations 7, 18, 20, 21, 30, and 35.

#### ESOSYRINX<sup>5</sup> Loeblich and Tappan, new genus

Synonym: *Pseudopolymorphina* Cushman and Ozawa, 1930 (not 1928).

Genotype (type species): *Pseudopolymorphina curta* Cushman and Ozawa, 1930.

Test free, chambers biserially arranged throughout; wall calcareous, perforate; aperture terminal, radiate, with a distinct internal tube.

*Remarks.*—This genus differs from *Pseudopolymorphina* Cushman and Ozawa in being biserial throughout and in having an “entosolenian” tube. It differs from *Polymorphina* d’Orbigny, 1826, and *Polymorphinoides* Marie, 1941, in the possession of the internal tube.

#### ESOSYRINX CURTA (Cushman and Ozawa)

Plate 15, figures 1-5

*Pseudopolymorphina curta* CUSHMAN and OZAWA, 1930, Proc. U. S. Nat. Mus., vol. 77, art. 6, p. 105, pl. 27, figs. 3a,b.—CUSHMAN, 1944, Cushman Lab. Foram. Res. Spec. Publ. 12, p. 23, pl. 3, fig. 16; 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 52, pl. 5, fig. 18 (not figs. 17, 19).

not *Pseudopolymorphina* sp. CUSHMAN and OZAWA, 1929, Japanese Journ. Geol. and Geogr., vol. 6, Nos. 3-4, p. 71, pl. 15, fig. 7.

not *Pseudopolymorphina curta* Cushman and Ozawa, CUSHMAN and TODD, 1947, Contr. Cushman Lab. Foram. Res., vol. 23, pt. 3, p. 63, pl. 15, fig. 14.

Test free, ovate in outline, slightly compressed, robust with rounded margins; chambers few in number, biserially arranged, but overlapping previous chambers; sutures oblique, very slightly depressed, sometimes obscure; wall calcareous, thin and translucent, surface smooth; aperture terminal, radiate, with a prominent internal tube.

Length of holotype 0.56 mm., breadth 0.42 mm., thickness 0.29 mm. Length of hypotype of figure 5, 0.55 mm., breadth 0.39 mm. Length of hypotype of figure 3, 0.81 mm., breadth 0.44 mm. Length of hypotype of figure 1, 0.94 mm., breadth 0.62 mm. Length of hypotype of figure 2, 0.86 mm., breadth 0.57 mm. Other hypotypes range from 0.31 to 0.83 mm. in length.

*Remarks.*—The genus *Pseudopolymorphina* Cushman and Ozawa was described (1928, p. 15) as having the chambers “in a closed

<sup>5</sup> From Gr. *esō*, within; *syrinx*, tube.

sigmoid series in the earlier stages, becoming biserial in the adult." The figures of the type species of *Pseudopolymorphina* show the early plan to be quinqueloculine, however, and the genus is so described by Cushman (1948a, p. 229). No "entosolenian" or internal tube was described in the genotype species, or for that matter in any species of *Pseudopolymorphina*. All specimens of this species encountered in Arctic or sub-Arctic waters show a test with relatively thin walls, biserial chambers with no trace of an early "closed sigmoid series" or quinqueloculine stage, and all possessing prominent internal tubes. The original drawings of the holotype of this species (Cushman and Ozawa, 1930, pl. 27, figs. 3a,b) are inaccurate. The type shows a test of only four biserial chambers (fig. 4), not five as originally drawn, and shows a radiate aperture with a prominent internal tube visible when the test is dampened.

Two of the specimens figured by Cushman in 1948 (pl. 5, figs. 17 and 19) do not agree with the types of this species. These specimens have more chambers, a test of a different outline, and lack the internal tube. However, the specimen of figure 18 (1948b, pl. 5) is a true *Esosyrinx curta* and shows the internal tube. On the drawing this is shown as a light area running downward to the right from the aperture. As no mention was made of the tube in any description it must be assumed that these were interpreted as "highlights" on the drawing of the specimen. The specimen figured from New England (Cushman, 1944, pl. 3, fig. 16) shows the internal tube characteristic of this species. The specimen figured by Cushman and Todd (1947a, pl. 15, fig. 14) from the Pliocene? of Amchitka Island has a large, thick-walled, robust test with numerous chambers bearing little resemblance to *E. curta* (Cushman and Ozawa).

*Types and occurrence.*—Holotype (Cushman Coll. No. 2254) from Recent deposits at 32 fathoms, 0.5 mile northwest of Eagle Island, Casco Bay, Maine; figured hypotype (U.S.N.M. No. P2000) from station 29; figured hypotypes (U.S.N.M. Nos. P2001a-c) from station 30; unfigured hypotypes are recorded from stations 20, 23, 28, 29, 30, and 61.

### Family NONIONIDAE

Genus NONION Montfort, 1808

#### NONION LABRADORICUM (Dawson)

Plate 17, figures 1, 2

*Nonionina labradorica* DAWSON, 1860, Can. Nat., vol. 5, p. 191, fig. 4.

*Nonionina scapha* (Fichtel and Moll) var. *labradorica* DAWSON, 1870, Can. Nat., n. s., vol. 5, p. 177, fig. 5.

*Nonion labradorica* (Dawson) CUSHMAN, 1927, Bull. Scripps Inst. Oceanography, techn. ser., vol. 1, p. 148, pl. 2, figs. 7, 8; 1930, U. S. Nat. Mus. Bull. 104, pt. 7, p. 11, pl. 4, figs 6-12.

*Nonion labradoricum* (Dawson) CUSHMAN, 1939, U. S. Geol. Surv. Prof. Pap. 191, p. 23, pl. 6, figs. 13-16.—PHLEGER, 1939, Bull. Geol. Soc. Amer., vol. 50, p. 1403, pl. 2, figs. 13, 14.—CUSHMAN, 1944, Cushman Lab. Foram. Res. Spec. Publ. 12, p. 24, pl. 3, fig. 23; 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 52, pl. 6, fig. 2.—F. PARKER, 1952, Bull. Mus. Comp. Zool., vol. 106, No. 9, p. 413, pl. 5, fig. 12.

Test free, medium in size, ovate to auriculate in outline, planispiral, completely involute and bilaterally symmetrical, biconvex, and bi-umbilicate, periphery subacute, margin slightly lobulate, apertural face broad and subtriangular; chambers numerous, 8 to 10 in the final whorl, increasing gradually in size as added, but the final chamber is nearly twice as high as the preceding; sutures distinct, gently curved, very slightly depressed except near the umbilicus, where they are distinctly incised; wall calcareous, hyaline, finely perforate, thin and translucent, so that the outline of the preceding chamber may be discerned within the final chamber; aperture a low, arched slit at the base of the apertural face.

Greatest diameter of hypotype of figure 1, 0.81 mm., least diameter 0.60 mm., greatest breadth of apertural face 0.47 mm. Other specimens range from 0.23 to 0.86 mm. in greatest diameter.

*Types and occurrence.*—Figured hypotypes (U.S.N.M. Nos. P1063a,b) from station 18; unfigured hypotypes are recorded from stations 1, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 15, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 29, 30, 31, 32, 33, 34, 35, 38, 39, 40, 42, 45, 46, 50, and 51.

#### NONION ZAANDAMAE (van Voorthuysen)

Plate 16, figures 11, 12

*Nonion pompilioides* (Fichtel and Moll) CUSHMAN, 1930 (not *Nautilus pompilioides* Fichtel and Moll, 1798), U. S. Nat. Mus. Bull. 104, pt. 7, p. 4, pl. 2, figs. 1, 2 (not pl. 1, figs. 7-11).

*Nonion barleeanum* (Williamson) CUSHMAN and HENBEST, 1940 (not *Nonionina barleeanum* Williamson, 1858), U. S. Geol. Surv. Prof. Pap. 196-A, pl. 9, fig. 13.—CUSHMAN, 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 54, pl. 6, fig. 4.

not *Nonion barleeanum* (Williamson) CUSHMAN, 1930, U. S. Nat. Mus. Bull. 104, pt. 7, p. 11, pl. 4, fig. 5; 1939, U. S. Geol. Surv. Prof. Pap. 191, p. 23, pl. 6, fig. 11.

*Nonion barleeanum* (Williamson) var. *inflatum* VAN VOORTHUYSEN, 1950 (not *Nonionina inflata* Alth, 1850), Meded. Geol. Sticht., n. s., No. 4, p. 41, text fig. 7, pl. 3, figs. 6a,b.

- not *Anomalinoides barlecanum* (Williamson) var. *inflatum* (van Voorthuysen)  
VAN VOORTHUYSEN, 1950, *ibid.*, p. 66, pl. 4, figs. 3a,b.
- Anomalinoides barlecanum* (Williamson) var. *saandamae* (van Voorthuysen)  
VAN VOORTHUYSEN, 1952, *Journ. Paleontol.*, vol. 26, No. 4, p. 681.

Test free, of medium size, planispiral and involute, biumbilicate, periphery broadly rounded; chambers increasing gradually in size as added, 9 to 11 in the final whorl surrounding the open umbilicus; sutures distinct, much thickened, gently curved; wall calcareous, hyaline, coarsely perforate, but otherwise smooth; aperture an elongate curved slit, at the base of the apertural face of the final chamber, extending nearly to the umbilicus on each side, and bordered above by a slight lip.

Greatest diameter of hypotype of fig. 11, 0.49 mm., least diameter 0.44 mm., greatest thickness 0.23 mm. Greatest diameter of hypotype of fig. 12, 0.43 mm., thickness 0.18 mm. Other hypotypes range from 0.26 to 0.70 mm. in greatest diameter.

*Remarks.*—Some of the specimens figured by Cushman (1930, pl. 2, figs. 1-2) as *N. pompilioides* belong to the present species, but they are much more compressed than the species of Fichtel and Moll, and like the present form are characterized by limbate sutures and a coarsely perforate wall.

In 1930, Cushman described *Nonion barlecanum* (Williamson), but listed no types or occurrences. His figures were copied from Williamson and the description was apparently modified after Williamson. In the monograph on the Nonionidae (Cushman, 1939), the same description and figures were given. However, in 1940, Cushman and Henbest figured as *N. barlecanum* a specimen from a deep-sea core from the north Atlantic. This specimen has only 9 chambers visible, and has somewhat limbate sutures, thus differing from the types of Williamson's species which had 12 chambers in the final whorl and depressed sutures. No specific description was given in this article.

In 1948, in his publication on the Arctic Foraminifera, Cushman again gave the identical specific description of *Nonion barlecanum* as was given in his 1930 and 1939 papers. However, the specimen then figured was of the type shown by Cushman and Henbest (1940), and here referred to as a distinct species. Thus the description stated in part (Cushman, 1948b, p. 54), "chambers numerous, 12 or more in the last formed coil." Examination of all specimens in the Cushman collection shows no specimens having more than 10 chambers, and that figured by Cushman (1948b, pl. 6, fig. 4) had only 9. Williamson's type of *N. barlecana* shows about 13 chambers as well as a higher aperture, at the periphery. In addition, his species had more

strongly curved sutures and they do not appear limbate as in the present species.

Numerous specimens of the present species observed by the writers show that by far the greatest number have 10 chambers in the final whorl, a few have only 9, and a single specimen was found with 11 chambers.

Van Voorthuysen (1950a) described *Nonion barlecanum* (Williamson) var. *inflatum* van Voorthuysen, stating that it differed from the typical form of the species in that "specimens are less compressed and of smaller proportions than the recent species of the British Isles. The number of chambers in the youngest whorl is not 12 or more, but 10-12, mostly 11. A transverse section shows the thickened extremities of the septa, corresponding with the thickened apertural edge. The test is typically coarsely perforate."

Later (1950b) he placed the species and variety in the genus *Anomalinoidea* Brotzen, 1942, stating that "the aperture is composed of a peripheric one extending onto the umbilical side with a distinct lip, visible on the three or four youngest chambers. This fact has convinced us that this form is not a *Nonion*, but belongs to the genus *Anomalinoidea* Brotzen, 1942."

In this latter paper, however, he figured a form which he described as differing from those of his previous paper, in being "nearly twice as large with about 15 chambers. . . . The main characters are the same however, so we consider these larger ones only as having lived in exceptionally favorable conditions."

As the smaller size and fewer chambers were the original basis for separating van Voorthuysen's form from that of Williamson, it would seem that placing both forms together would remove the distinction from Williamson's species and therefore invalidate the variety of van Voorthuysen. In any case, van Voorthuysen's varietal name was a homonym, being preoccupied by *Nonionina inflata* Alth, 1850, and he renamed it var. *saandamae* in 1952.

The large specimen figured by van Voorthuysen (1950b) is more compressed, has much more numerous chambers, and does not seem to have the thickened sutures characteristic of the present species. Furthermore, the aperture shown for his type of *N. barlecanum* var. *inflatum* is like that here shown (fig. 11) and does not have the high arch on the periphery shown in Williamson's figures. We therefore believe van Voorthuysen's original type of *N. barlecanum* var. *inflatum* to be identical with the present species, but distinct from that of Williamson and also distinct from the larger specimens referred to the variety in his later paper (1950b).

The present species we believe should remain in the genus *Nonion*, and not in *Anomalinoides* where it was placed by van Voorthuysen (1950b, p. 66). A study of topotype specimens of *Anomalinoides plummerae* Brotzen shows a distinctly trochoid coil, and the much more coarsely perforate test typical of the Anomalinidae. Furthermore, the aperture extends over onto the dorsal side in *Anomalinoides* and in the present species the aperture extends equally onto the two sides, much as in the genotype species of *Nonion*. Incidentally, an examination of the wall structure of the type species of *Anomalinoides* shows it to be perforate granular, as were *Anomalinella* and *Cibicides* (Wood, 1949, p. 252), although the majority of the genera of this family have perforate radiate walls. The present species also has perforate granular walls, as do all species of true *Nonion* examined by Wood.

*Types and occurrence*.—Figured hypotype (U.S.N.M. No. P2027) from station 36; figured hypotype (U.S.N.M. No. P2028) from station 52; unfigured hypotypes are recorded from stations 26, 43, 51, and 52.

Genus **ASTRONONION** Cushman and Edwards, 1937

**ASTRONONION GALLOWAYI** Loeblich and Tappan, new name

Plate 17, figures 4-7

*Astrononion stellatum* CUSHMAN and EDWARDS, 1937 (not *Nonionina stellata* Terquem, 1882), Contr. Cushman Lab. Foram. Res., vol. 13, p. 32, pl. 3, figs. 9-11.—CUSHMAN, 1939, U. S. Geol. Surv. Prof. Pap. 191, p. 36, pl. 10, figs. 3-5.—CUSHMAN and McCULLOCH, 1940, Allan Hancock Pacific Exped., vol. 6, No. 3, p. 168, pl. 18, fig. 11.—CUSHMAN and TODD, 1947, Cushman Lab. Foram. Res. Spec. Publ. 21, p. 13, pl. 2, fig. 15.—CUSHMAN, 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 56.—F. PARKER, 1952, Bull. Mus. Comp. Zool., vol. 106, No. 9, p. 410, pl. 5, figs. 2, 3.

*Astrononion stelligerum* (d'Orbigny) CUSHMAN, 1948 (not *Nonionina stelligera* d'Orbigny, 1839), Cushman Lab. Foram. Res. Spec. Publ. 23, p. 55, pl. 6, fig. 6.

Test free, planispiral and involute, compressed, umbilical region somewhat concave, periphery rounded; chambers increasing in size as added, larger chambers 8 to 10 in number, strongly inflated, smaller wedge-shaped supplementary chambers surround the umbilicus on each side, tapering outward to the suture about one-half the distance to the periphery; sutures distinct, gently to strongly curved, depressed; wall calcareous, hyaline, larger chambers fairly coarsely perforate, the supplementary chambers less coarsely perforate; aperture a low arch at the base of the final chamber, extending on each



side toward the umbilicus, with a supplementary opening at the outer posterior margin of each of the supplementary chambers.

Greatest diameter of hypotype of figure 7, 0.49 mm., thickness 0.18 mm. Greatest diameter of hypotype of figure 5, 0.49 mm. Greatest diameter of hypotype of figure 6, 0.42 mm. Greatest diameter of hypotype of figure 4, 0.42 mm.

*Remarks.*—*Astrononion stellatum* Cushman and Edwards is preoccupied by *Nonionina stellata* Terquem, 1882, which is a distinct *Astrononion*, and the former is here renamed *A. gallowayi*, new name. In the monograph on the Nonionidae, Cushman (1939, p. 4) referred to Terquem's species as *Nonion? stellatum* (Terquem), stating, "No specimens were found in any of the collections from the Paris Basin which I studied. The exact generic position of this species must be left in some doubt until actual specimens can be studied."

However, the original figure of Terquem shows a distinct stellate arrangement in the center of the test, and the original description (1882, p. 43) stated in part, "sutures couvertes par une étoile à cinq rayons inégaux et creusés en sillon."

Furthermore, Terquem compared his species to two others, *N. stelligera* d'Orbigny (which Cushman and Edwards selected as the genotype for *Astrononion*) and *N. asterizans* Brady (which Cushman and Edwards described (1937, p. 35) as *Astrononion fijiense*, as it was distinct from *N. asterizans* Fichtel and Moll).

Terquem's species was from the Eocene of France, and in the original description of *Astrononion*, Cushman and Edwards (1937, p. 30) stated, "Stellate forms referred to '*Nonionina*' have been recorded as early as the Eocene of Europe. We have found specimens in our material from the Eocene of Biarritz, France, the locality from which Halkyard recorded the species (*N. stelligera*), which probably belong to this genus."

Although hesitating to refer Terquem's species to *Astrononion* without an examination of the specimens, Cushman and Edwards selected as genotype of their genus the Recent species of d'Orbigny from the Canary Isles, for which the type repository is unknown, and of which they stated, "There have been many records referred to this species. . . . A study of these figures seems to show that none of them are identical with the species figured and described by d'Orbigny. We have been unable to study any material from the type locality."

Therefore, although the genus was based on a species unknown to them, another species was considered questionable until the types were examined, and the identical specific name was proposed for a new species.

Parker (1952a, p. 410) considered *A. stelligerum* Cushman, 1948 (not d'Orbigny, 1839) as conspecific with this species. An examination of all types in the Cushman collection and U. S. National Museum collections shows that these are conspecific. However, all these types are from the Arctic or from cold waters and none were from the warm water of the type area of *A. stelligera*. The Arctic species is thicker, the periphery more lobulate, and the supplementary chambers broader and more wedge-shaped, while those of d'Orbigny's species were narrower and distinctly angled at a short distance from the umbilicus.

*Types and occurrence.*—Figured hypotypes (U.S.N.M. Nos. P2031a-d) from station 6; unfigured hypotypes are recorded from the following stations: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 18, 19, 20, 21, 22, 23, 24, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 37, 38, 39, 40, 42, 45, 46, 48, 50, 51, 52, 54, 66, 67, 74, 75, and 77.

Genus **NONIONELLA** Cushman, 1926

**NONIONELLA AURICULA** Heron-Allen and Earland

Plate 16, figures 6-10

*Nonionella auricula* HERON-ALLEN and EARLAND, 1930, Journ. Roy. Micr. Soc., vol. 50, p. 192, pl. 5, figs. 68-70.—CUSHMAN, 1939, U. S. Geol. Surv. Prof. Pap. 191, p. 33, pl. 9, figs. 7-9; 1944, Cushman Lab. Foram. Res. Spec. Publ. 12, p. 25, pl. 3, figs. 26, 27.—F. PARKER, 1952, Bull. Mus. Comp. Zool., vol. 106, No. 9, p. 413, pl. 5, figs. 13a-14b.

Test free, ovate in outline and compressed, coiled and slightly trochoid, periphery rounded; chambers slightly inflated, increasing rapidly in size as added, the 5 or 6 of the previous whorl visible dorsally where the test is partially evolute, only the 9 to 10 chambers of the final whorl visible ventrally, final chamber somewhat inflated and comparatively higher than the preceding chambers, extending farther over the ventral side when seen in edge view; sutures distinct, gently curved or even slightly sinuate, moderately depressed; wall calcareous, thin, hyaline, finely perforate and smooth; aperture at the base of the apertural face extending from the periphery a short distance on the ventral side.

Greatest diameter of hypotype of figure 10, 0.73 mm., least diameter 0.52 mm., greatest thickness 0.29 mm. Greatest diameter of hypotype of figure 7, 0.70 mm., least diameter 0.55 mm., thickness 0.23 mm. Greatest diameter of hypotype of figure 8, 0.65 mm., of figure 6, 0.49 mm., of figure 9, 0.75 mm.

*Remarks.*—This species was described from off Plymouth, England, and has been recorded off the coast of New England (Rhode Island, Massachusetts, and New Hampshire).

*Types and occurrence.*—Figured hypotypes (U.S.N.M. Nos. P1067 a-d) from station 18; figured hypotype (U.S.N.M. No. P1068) from station 30; unfigured hypotypes are recorded from the following stations: 1, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 15, 16, 18, 19, 20, 21, 22, 23, 27, 29, 30, 31, 32, 34, 39, 42, and 50.

Genus **CHILOSTOMELLINA** Cushman, 1926

**CHILOSTOMELLINA FIMBRIATA** Cushman

Plate 17, figure 3

*Chilostomellina fimbriata* CUSHMAN, 1926, Contr. Cushman Lab. Foram. Res., vol. 1, pt. 4, p. 78, pl. 11, figs. 22a-c.

Test free, robust, nearly globular, planispiral and involute; chambers few in number, increasing very rapidly in size as added, final chamber nearly completely enveloping the test, and overlapping far down over the umbilical region on each side, with a fimbriate margin at the sides and base of the apertural face, so that only the 6 preceding chambers are visible; sutures distinct, gently curved, not depressed; wall calcareous, thin and fragile, finely perforate, smooth; aperture low, crescentiform, on the periphery at the base of the final chamber, with additional supplementary apertures at the reentrants between the fingerlike projections of the final chamber.

Height of test of figured hypotype 0.60 mm., thickness 0.55 mm.

*Remarks.*—Cushman (1926, p. 78) described the genus *Chilostomellina* and placed it in the family Chilostomellidae, stating, "Test composed of a few inflated chambers, the last-formed one almost completely enveloping the preceding ones. . . . This is a peculiar genus in some characters related to *Chilostomella* especially in the apparent alternation of chambers and the embracing character of each newly added chamber." Cushman's diagnosis of the genus and species describes little except the gross form, but says nothing of the early chamber arrangement.

Galloway (1933, p. 268) correctly interpreted the structure of the genus as planispiral, but placed this genus, as well as *Allomorphinella*, which Cushman and Galloway both considered its ancestor, and the planispiral *Pullenia* all in the Nonionidae. These three genera Cushman (1940, p. 283; 1948a, p. 316) again placed in the Chilostomellidae and stated, "These genera have sometimes been placed with

the Nonionidae, but a study of their microspheric forms in the early stages will show that they do not belong there, but have been derived from *Chilostomella*."

Dissection of specimens of *Chilostomellina* by the writers show a planispiral development throughout, and not the early trochoid or biserial development characteristic of *Allomorphina* and *Chilostomella*. It is very similar to *Allomorphinella* however, which also is completely planispiral.

An interesting sidelight is the fact that Wood (1949), in examining the wall structure of various genera, found among the so-called Chilostomellidae that the genotype species of *Allomorphina*, *Chilostomella*, and *Pullenia* have a perforate granulate structure, and the types of *Seabrookia* and *Sphaeroidina* are perforate radiate. *Nonion* also is perforate and granulate and Wood suggested that it should be placed with the similar "Chilostomellidae" such as *Pullenia* rather than in a family with *Elphidium*, which is radiate in wall structure. He thus upholds Galloway's suggestion as to the relationship of *Nonion* to various members of the Chilostomellidae. Wood's original study of the wall structure did not cover the monotypic genus *Chilostomellina*. The present writers have examined the wall structure of this form, and find it to be granular in structure, so that although more closely related to *Allomorphinella* and *Pullenia* in its planispiral character, it nevertheless should probably be kept in the same family as *Chilostomella*. Galloway associated *Pullenia*, *Nonion*, and *Chilostomellina*, but placed them in the Nonionidae and separated *Chilostomella* and allied genera in the Chilostomellidae. As these are so similar in wall character as well as other features, it would seem better to place *Nonion* and its related genera with the entire family of the Chilostomellidae. In this event the family name Nonionidae Reuss, 1860, would take precedence over the Chilostomellidae of Brady, 1881. In any event, *Elphidium* and related radiate walled genera are here placed in a separate family, the Elphidiidae. They may possibly have arisen from a form such as *Globigerinella* which is similarly planispiral with radiate perforate walls, and an aperture at the base of the apertural face of the final chamber. It is interesting to note that some of the Globigerinidae (i.e., *Globigerinoides*, *Globigerinatella*, *Canorbulina*, and *Candeina*) also have sutural pores as do the Elphidiidae.

*Types and occurrence.*—Figured hypotype (U.S.N.M. No. P1075) from station 68; unfigured hypotypes are recorded from stations 18, 68, 69, 70, 71, 72, and 73.

## Family ELPHIDIIDAE

Tests free, planispiral, trochoid or uncoiling; wall calcareous, hyaline, perforate radial in structure, with a canal system ending in a single or double row of pores along the sutures, and with retral processes projecting across the sutures; aperture consisting of a single slit or row of pores at the base of the apertural face, or scattered pores on the face.

*Remarks.*—The following genera are included in the Elphidiidae: *Elphidium* Montfort, *Elphidioides* Cushman, *Elphidiella* Cushman, *Ozawaia* Cushman, *Polystomellina* Yabe and Hanzawa, *Notorotalia* Finlay, and *Faujasina* d'Orbigny.

This group of genera has previously been placed in the Nonionidae, and various authors have considered *Nonion* and *Elphidium* to intergrade. In his monograph on the Nonionidae, Cushman stated (1939, p. 2), "It is evident, however, that the simpler forms of *Elphidium* developed directly from *Nonion* by the addition of the pores along the sutures and the development of retral processes. Species are known in which the characteristics of *Elphidium* are not developed until the last two or three chambers of the adult, and the entire younger stages, if found alone, would unhesitatingly be described as *Nonion*."

Galloway (1933, p. 265) concurred in this derivation of *Elphidium*, stating "It is difficult to distinguish a simple *Elphidium* from *Nonion*," but he did separate the four genera known at that time which possess retral processes and the canal and pore systems into the subfamily Elphidiinae.

The first question raised as to the placement of these forms in the family Nonionidae was that of Wood (1949), based on the wall structure. Wood stated (p. 243), "The separation between *Nonion* and *Elphidium* on the character of the test-wall is remarkably sharp. Hitherto the two genera have been considered to be connected by intermediate species, an idea due to Carpenter (1862). Though the resemblance in form between *Nonion* and *Elphidium* may be close, I have never found a type with retral processes and a canal system which did not have radially built walls. . . . These facts suggest that *Nonion* may be more correctly placed in the Chilostomellidae, with *Pullenia*, whose structure so closely resembles it in other respects." <sup>6</sup>

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<sup>6</sup> *Nonion* could not be placed in the Chilostomellidae, for the family Nonionidae Reuss, 1860, clearly preoccupies the Chilostomellidae of Brady, 1881. If a close relationship exists, *Pullenia* should be placed in the Nonionidae, and this was in fact done by Galloway, 1933, p. 267. The placement of these additional genera is not within the scope of the present paper, however.

We have also found the wall characters to afford a sharp distinction, and to supply an easy method of separating the "simple" species of *Elphidium* and *Nonion*, so difficult to separate on external features alone. The few species that seemed to show transitional characters were found to be incorrectly placed (i.e., *Nonionina orbicularis* Brady = *Elphidium orbiculare*, discussed here in more detail on pp. 102-103). It is also probable that there was another ancestral genus than *Nonion*, for this present family, as Wood's work showed the wall structure to be of considerable importance in classification. All members of the present family have radial perforate walls, and *Nonion*, *Pullenia*, and other members of the Nonionidae are perforate granular in structure.

The family Elphidiidae is therefore considered to include those genera characterized by a radial perforate wall, and possessing sutural pores, retral processes, and an internal canal system.

Genus **ELPHIDIUM** Montfort, 1808

**ELPHIDIUM BARTLETTI** Cushman

Plate 18, figures 10-14

- Nonionina striatopunctata* (Fichtel and Moll) PARKER and JONES, 1865 (not *Nautilus striato-punctatus* Fichtel and Moll, 1798), Philos. Trans. Roy. Soc. London, vol. 155, p. 402, pl. 14, figs. 31-34, pl. 17, fig. 60.
- Elphidium bartletti* CUSHMAN, 1933, Smithsonian Misc. Coll., vol. 89, No. 9, p. 4, pl. 1, fig. 9; 1939, U. S. Geol. Surv. Prof. Pap. 191, p. 64, pl. 18, fig. 10; 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 59, pl. 6, fig. 13.
- Criboelphidium arcticum* TAPPAN, 1951, Contr. Cushman Found. Foram. Res., vol. 2, pt. 1, p. 6, pl. 1, figs. 27, 28; 1951, U. S. Geol. Surv., Oil and Gas Invest. Map OM-126, sheet 3, fig. 21 (1a,b).
- Elphidium articulatum* (d'Orbigny) F. PARKER, 1952 (not ?*Polystomella articulata* d'Orbigny, 1839), Bull. Mus. Comp. Zool., vol. 106, No. 9, p. 411, pl. 5, figs. 5-7.

Test free, of medium size, robust, planispiral and involute to very slightly evolute, sides almost flat, with slightly depressed umbilical regions, periphery broadly rounded, peripheral margin moderately lobulate; chambers numerous, from 7 to 12 in the final whorl, most commonly 9 or 10, slightly inflated; sutures distinct, depressed, gently curved, with 8 to 12 pores visible on each side along each suture, retral processes short and broad; wall calcareous, very finely perforate, surface smooth and glassy, umbilical area filled with granular material which may also have pores similar to those along the septa; aperture consists of a row of small pores at the base of the apertural

face and numerous scattered pores in the apertural face of the final chamber.

Greatest diameter of hypotype of figure 13, 0.73 mm., thickness 0.36 mm. Greatest diameter of hypotype of figure 10, 0.55 mm., thickness 0.29 mm. Greatest diameter of hypotype of figure 12, 1.09 mm., thickness 0.49 mm. Greatest diameter of hypotype of figure 11, 0.68 mm., thickness 0.36 mm. Other hypotypes range from 0.34 to 1.04 mm. in diameter.

*Remarks.*—The specimens referred to *Nonionina striatopunctata* by Parker and Jones are like the present species, but wholly unlike the species of Fichtel and Moll which has far more numerous chambers and very prominent retral processes which give the appearance of continuous revolving ribs.

*Criboelphidium arcticum* was described from the Alaskan Pleistocene and compared to *E. bartletti*, although it was stated (Tappan, 1951, p. 6) to be "of greater thickness, has fewer and more inflated chambers in the final whorl, and possesses the multiple aperture of the genus *Criboelphidium*." At the time this description of *Criboelphidium arcticum* was written, Cushman's types were not available and neither the original nor later descriptions, nor any figures showed the presence of the very prominent multiple aperture in *E. bartletti*, so that it was assumed that the two forms were not even congeneric. Since then, an examination of the holotype of *E. bartletti* shows that it also has a multiple aperture, and paratype specimens are identical with the somewhat thicker, fewer-chambered holotype of *Criboelphidium arcticum*. Furthermore, a few specimens of the more-compressed type were also found in the Alaskan Pleistocene. As both forms are found together and apparently intergrade, and all have a multiple aperture, they are here considered identical.

*Elphidium articulatum* d'Orbigny of Parker (1952a, p. 411) is the same as the present species, and she stated that "*E. articulatum* appears to be closely related to *E. bartletti* Cushman. The adult forms of the latter species have a maximum of 12 chambers instead of the 10 or less of the former. The young specimens of *E. bartletti*, however, appear to be identical with *E. articulatum*. It is possible that *E. bartletti* represents the Arctic development of *E. articulatum*, which is not reported from that area." She further stated that "A comparison with specimens from the Falkland Islands, one of the localities from which d'Orbigny described the species, shows the Portsmouth species to be almost identical although slightly less compressed." Cushman (1930, pl. 10, figs. 7-8) illustrated one of these specimens from the Falklands, which is very similar to the present

species. However, d'Orbigny's type figure shows a sharp, acutely angled periphery, rather than the broadly rounded periphery of all other specimens referred to his species, and present also in *E. bartletti*. Until d'Orbigny's types can be examined, it seems advisable to consider the present form as a distinct species, and if future study proves them to be conspecific, d'Orbigny's specific name would then take priority.

*Types and occurrence.*—Figured hypotypes (U.S.N.M. Nos. P2124a,b) from station 16; figured hypotype (U.S.N.M. No. P2125) from station 17; figured hypotypes (U.S.N.M. Nos. P2126a, b) from station 23; unfigured hypotypes are recorded from stations 1, 3, 4, 5, 7, 9, 12, 14, 15, 16, 17, 18, 19, 22, 23, 24, 25, 26, 27, 28, 30, 31, 33, 34, 35, 39, 40, 42, 45, 50, and 51.

### ELPHIDIUM CLAVATUM Cushman

Plate 19, figures 8-10

*Elphidium incertum* (Williamson) var. *clavatum* CUSHMAN, 1930, U. S. Nat. Mus. Bull. 104, pt. 7, p. 20, pl. 7, fig. 10.—CUSHMAN and COLE, 1930, Contr. Cushman Lab. Foram. Res., vol. 6, p. 96, pl. 13, figs. 8, 9.—CUSHMAN, 1939, U. S. Geol. Surv. Prof. Pap. 191, p. 57, pl. 16, figs. 1, 2; 1944, Cushman Lab. Foram. Res. Spec. Publ. 12, p. 25, pl. 3, figs. 32, 33; 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 57, pl. 6, fig. 8.—F. PARKER, 1952, Bull. Mus. Comp. Zool., vol. 106, No. 9, p. 412, pl. 5, figs. 10, 11.—PHLEGER, 1952, Contr. Cushman Found. Foram. Res., vol. 3, pt. 2, p. 83, pl. 14, fig. 7.

Test free, of medium size, planispiral, involute, biumbonate, periphery subacute; 9 to 13 chambers in the final whorl, increasing gradually in size as added; sutures distinct, gently curved, thickened, may be slightly depressed with a single row of sutural pores, and short, distinct retral processes; wall calcareous, very distinctly perforate, thin and translucent, umbilical region with a somewhat elevated boss; aperture a single row of small pores at the base of the apertural face of the final chamber.

Greatest diameter of hypotype of figure 9, 0.60 mm., thickness 0.26 mm. Greatest diameter of hypotype of figure 8, 0.55 mm., thickness 0.31 mm. Greatest diameter of hypotype of figure 10, 0.57 mm., thickness 0.31 mm. Other hypotypes range from 0.23 to 0.70 mm. in maximum diameter.

*Remarks.*—We have raised this form to specific rank, as a restudy based on the holotype of Cushman's variety shows it to differ from *E. incertum* (Williamson) in many more important features than "in the ornamentation of the test, the umbilical portions being oc-



cupied by several large irregular bosses, very distinct but not forming a distinct umbonate mass" which was the varietal description of Cushman (1930, p. 20).

An examination of all Arctic specimens in the Cushman collection and the U. S. National Museum collections which have been referred to *E. incertum* shows not a single specimen that is similar to Williamson's type (see discussion here under that species), but *E. clavatum* differs in being thickest through the umbonal region, with an elevated central boss, which may be subdivided into more than one irregular knob, and the test of *E. clavatum* is much more coarsely perforate. Furthermore, basing the size on the figures of Macfadyen, *E. incertum* is a considerably larger species. Williamson gave no measurements for *E. incertum* and no magnification was given for the illustration.

*Types and occurrence.*—Figured hypotypes (U.S.N.M. Nos. P2024a,b) from station 13; figured hypotype (U.S.N.M. No. P2025) from station 14; unfigured hypotypes are recorded from stations 1, 2, 3, 4, 5, 6, 8, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 32, 33, 36, 37, 38, 39, 40, 42, 44, 45, and 50.

#### ELPHIDIUM FRIGIDUM Cushman

Plate 18, figures 4-9

*Elphidium frigidum* CUSHMAN, 1933, Smithsonian Misc. Coll., vol. 89, No. 9, p. 5, pl. 1, fig. 8; 1939, U. S. Geol. Surv. Prof. Pap. 191, p. 64, pl. 18, fig. 8; 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 57, pl. 6, figs. 9-11.

Test free, planispiral and involute, discoidal, sides nearly flat, umbilical area slightly depressed, periphery broadly rounded; 8 to 9 slightly inflated chambers in the final whorl, the later chambers being more inflated, and the final chamber sometimes higher and extending away from the general outline of the test; sutures distinct, slightly depressed, curved, with a row of sutural pores from which about 10 grooves extend in both directions, parallel to the peripheral margin, extending over the lower portion of the next succeeding chamber and over the upper portion of the preceding chamber, these grooves usually dying out over the most-inflated central portion of each chamber; wall calcareous, rather coarsely perforate, ornamented by the sutural pores and above-mentioned spiraling striae; aperture consisting of a row of pores at the base of the apertural face and numerous scattered pores in the face of the final chamber.

Greatest diameter of hypotype of figure 8, 0.94 mm., thickness 0.34 mm. Greatest diameter of hypotype of figure 4, 0.44 mm., thickness 0.18 mm. Greatest diameter of hypotype of figure 6, 0.57 mm.,

thickness 0.18 mm. Greatest diameter of hypotype of figure 9, 0.62 mm., thickness 0.21 mm. Other hypotypes range from 0.31 to 1.01 mm. in diameter.

*Remarks.*—Although defined as an *Elphidium* and retained in that genus by Cushman (1948b) after the genus *Criboelphidium* was erected by Cushman and Bronnimann the previous month, this species has a distinct multiple aperture. We have found numerous other species, originally described as *Elphidium*, to have a similar cribrate aperture, although not always as distinct. These pores may be filled in the apertural face of some specimens, but visible in that of the penultimate chamber when the last chamber is broken away. However, the original figure of the genotype species of *Elphidium* (*Nautilus macellus* Fichtel and Moll, 1798) shows pores in the apertural face and these were noted in the description as “quinque foraminula per medium.” It therefore seems that *Criboelphidium* should be considered a synonym of *Elphidium*, and the present species is here retained in the genus *Elphidium*.

*Types and occurrence.*—Figured hypotype (U.S.N.M. No. P2059) from station 3; figured hypotypes (U.S.N.M. Nos. P2060a-c) from station 10; figured hypotypes (U.S.N.M. Nos. P2061a,b) from station 19; unfigured hypotypes are recorded from stations 1, 4, 5, 6, 7, 8, 9, 10, 12, 17, 18, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 37, 38, 39, 42, 45, 46, 49, 50, 51, and 52.

#### ELPHIDIUM INCERTUM (Williamson)

*Polystomella umbilicatula* var. *incerta* WILLIAMSON, 1858, Recent Foraminifera of Great Britain, p. 44, pl. 3, fig. 82a.

*Elphidium incertum* (Williamson) MACFADYEN, 1932, Geol. Mag., vol. 69, No. 821, pl. 35, figs. 6a,b.— ? PHLEGER, 1952, Contr. Cushman Found. Foram. Res., vol. 3, pt. 2, p. 83, pl. 14, fig. 7.

Williamson's complete original description stated, “This variety differs from the typical form in the smaller number of the transverse crenulations along the septal lines, in their less uniform aspect, and more unequal size. Sometimes they form long radiating grooves, especially near the umbilicus; at others they appear as small oval pits, the long axes of which are also parallel with the septal line; and not unfrequently they are so slight as to be scarcely visible. In such examples it is exceedingly difficult to distinguish this shell from *Nonionina umbilicatula*, except by preparing a transverse section of the specimen, and mounting it in Canada balsam, so as to bring the septal apertures into view. I have met with single specimens of this

variety in several localities, but I have only found it to be the prevalent form at Scarborough."

*Remarks.*—This species has apparently been misidentified with abandon throughout the American literature. An examination of all Arctic specimens in the Cushman and U. S. National Museum collections shows not a single specimen like that figured by Williamson. Probably no other species has been so thoroughly confused. On slides referred to *E. incertum* in the Cushman collection are a mixture of specimens of *E. bartletti* Cushman, *E. clavatum* Cushman, and *E. orbiculare* (Brady), showing the wide, inflated test and cribrate aperture like the holotype of *bartletti*, the coarsely perforate specimens with umbonal boss like the holotype of *clavatum*, and other inflated specimens with the very slight sutural pores of *orbiculare*.

To add to the confusion, in the monograph on Atlantic Foraminifera, Cushman figured Williamson's illustrations, but the side view figured by Williamson (1858, fig. 81) Cushman referred to *E. excavatum* (Terquem) (Cushman, 1930, pl. 8, fig. 7), whereas Williamson's edge view of this same specimen (1858, fig. 82) Cushman reillustrated and identified as *E. incertum* (Cushman, 1930, pl. 7, fig. 4b), and considered it the edge view of Williamson's figure 82a, the holotype of *E. incertum* (Williamson). Williamson's plate description and the text also show his true intent, and a comparison of the illustrations shows the obvious discrepancy, particularly as to the number and distribution of the sutural pores (the character on which Williamson separated these forms). This same mistake was copied again by Cushman in this monograph on the Nonionidae (1939), where Williamson's figures of "*Polystomella umbilicatula*" again are separated, the side view referred to *E. excavatum* (Cushman, 1939, pl. 16, fig. 10) and the edge view referred to *E. incertum* (Cushman, 1939, pl. 15, fig. 21b).

Cushman (1930, pl. 7, fig. 5) also refigured as *E. incertum* a drawing "after H. B. Brady," although nowhere did Brady describe or figure any specimens referred either to *incertum* or to *umbilicatula*. An examination of the plates of the *Challenger* report shows that the illustration copied from Brady by Cushman was one referred by Brady to *Polystomella striatopunctata* (1884, pl. 109, fig. 23). Cushman did not list this reference of Brady's under the synonymy of *E. incertum*, however, nor did he refer to it in the discussion.

A later British reference to *E. incertum* is that of Macfadyen (1932, pl. 35, figs. 16a,b). This figure shows a form much like the type figures of Williamson, with radial slits at the inner portion of the sutures joining at the depressed umbilicus. American Arctic speci-

mens referred to *E. incertum* (other than those obviously belonging to *E. bartletti*, *clavatum*, or *orbiculare*) almost invariably have an umbonal boss, as well as straighter sutures and more numerous chambers.

The only American Arctic reference to *incertum* which possibly may be correctly identified is that of Phleger (1952, pl. 14, fig. 7), as it has the sutural slits converging at the umbilical depression. Phleger's specimen does have more-numerous chambers, however—11 in the final whorl—whereas Williamson's and Macfadyen's figures show only 9. Unfortunately neither of these later authors give a complete description in their text, so it is impossible to say whether this number is an unchangeable character or an upper or lower limit. In this connection it might be noted that all too often similar misidentifications occur because of the failure of authors to give complete descriptions of new varieties.

Williamson's description of his variety *incertum* discussed important features (the very ones ignored by later authors, in fact), but failed to give such pertinent features as measurements, number of chambers, etc., and only a side view was figured (in spite of Cushman's later inclusion of Williamson's edge view of *umbilicatulula* along with the side view of *incertum*). Thus, until 1932 (almost 75 years later) there were no reliable figures showing both side and edge views, and as yet still no adequate description of the typical *incertum*. Cushman's various descriptions of *incertum* are based on the specimens he had from Greenland, Hudson Bay, the coast of Maine, Massachusetts, etc., which are not *incertum*. Thus his descriptions refer to an umbilical knob, not present in the English specimens, and he differentiated his "variety" *clavatum* of *E. incertum* as differing from the typical form only in possessing several bosses in the umbilical region. Among specimens he referred to var. *clavatum* in the Cushman collection are many specimens with a single central boss, however.

### ELPHIDIUM ORBICULARE (Brady)

Plate 19, figures 1-4

*Nonionina orbicularis* BRADY, 1881, Ann. Mag. Nat. Hist., ser. 5, vol. 8, p. 415, pl. 21, figs. 5a,b; 1882, Denkschr. Akad. Wiss. Wien, math.-nat. Kl., vol. 43, p. 17, pl. 2, figs. 5a,b; 1884, Rep. Voy. *Challenger*, vol. 9 (Zoology), p. 727, pl. 109, figs. 20-21.—CUSHMAN, 1922, Contr. Canadian Biol., No. 9 (1921), p. 13 (145).

*Nonion orbiculare* (Brady) CUSHMAN, 1930, U. S. Nat. Mus. Bull. 104, pt. 7, p. 12, pl. 5, figs. 1-3; 1939, U. S. Geol. Surv. Prof. Pap. 191, p. 23, pl. 6, figs. 17-19; 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 53, pl. 6, fig. 3.

Test free, of medium size, robust, planispirally coiled and involute, sides flat or gently convex, periphery broadly rounded; 9 to 11 chambers in the last whorl, increasing very gradually in size as added; sutures gently curved, distinct, slightly depressed, somewhat thickened and granular in appearance near the umbilical region, or may have a few rather indistinct pores; wall calcareous, hyaline, finely perforate, surface smooth, umbilical area with a granular surface which grades into the sutural granulation; aperture a linear series of pores at the base of the final chamber.

Greatest diameter of hypotype of figure 2, 1.01 mm., greatest thickness 0.62 mm. Greatest diameter of hypotype of figure 3, 0.55 mm., thickness 0.29 mm.

*Remarks.*—This species was placed in the genus *Nonion* by Cushman, although he stated (1939, p. 24), "aperture a long, very narrow slit at the base of the apertural face, sometimes divided into several openings. . . . The aperture tends toward that of *Elphidium*, and some specimens show what may be slight traces of retral processes."

Inasmuch as the different apertural characters, sutural pores and retral processes were the main basis for separation of these genera, it seems that this species would better have been placed in *Elphidium*. This placement is further corroborated by the character of the wall structure. According to Wood (1949), all species of *Nonion* have perforate granular walls, and *Elphidium* has a distinctly perforate radiate wall structure. The writers have examined the wall of the present species and find it to be radiate, and we therefore place the species in *Elphidium*.

*Types and occurrence.*—Figured hypotypes (U.S.N.M. Nos. P2026a-d) from station 18; unfigured hypotypes are recorded from the following stations: 1, 2, 3, 4, 5, 7, 8, 9, 11, 12, 14, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 28, 29, 30, 32, 33, 34, 35, 37, 38, 39, 42, 45, and 50.

#### ELPHIDIUM OREGONENSE Cushman and Grant

Plate 18, figures 1-3

*Polystomella siberica* Goës, CUSHMAN, 1914 (not Goës, 1894), U. S. Nat. Mus. Bull. 71, pt. 4, p. 34, pl. 19, fig. 1.

*Elphidium oregonense* CUSHMAN and GRANT, 1927, Trans. San Diego Soc. Nat. Hist., vol. 5, p. 79, pl. 8, fig. 3.—CUSHMAN, 1939, U. S. Geol. Surv. Prof. Pap. 191, p. 50, pl. 18, figs. 14-16.—VAN VOORTHUYSEN, 1952, Contr. Cushman Found. Foram. Res., vol. 3, pt. 1, p. 22, pl. 5, fig. 5, text fig. 1.

*Elphidiella oregonense* (Cushman and Grant) CUSHMAN, 1941 (part), Contr. Cushman Lab. Foram. Res., vol. 17, pt. 2, p. 34, pl. 9, figs. 8, 9 (not fig. 7).

*Elphidiella oregonensis* (Cushman and Grant) BANDY, 1950, Journ. Paleontol., vol. 24, No. 3, p. 277, pl. 41, figs. 13a,b.

Test free, extremely large, somewhat compressed, biumbonate, the umbilical boss being progressively more prominent with age, the larger specimens having a distinctly projecting boss of clear shell material with occasional pores; chambers numerous, varying from 12 in the last whorl of juvenile specimens to as many as 23 in the larger specimens, all of approximately equal height; sutures distinct, curved, flush to slightly depressed in the later portion of the test, with a large number of sutural pores, and prominent and elongate retral processes; wall calcareous, finely perforate, surface smooth in the later portion, the elongate retral processes often giving a cancellate appearance to the earlier part of the final whorl, the umbonal boss projecting above the remainder of the test; aperture consisting of numerous scattered pores in the apertural face of the final chamber.

Greatest diameter of hypotype of figure 3, 0.75 mm., thickness through umbo 0.34 mm. Greatest diameter of hypotype of figure 2, 1.12 mm., thickness through umbo 0.34 mm. Greatest diameter of hypotype of figure 1, 2.42 mm., thickness through umbo 0.75 mm. Other hypotypes up to 2.26 mm. in diameter.

*Remarks.*—Described originally as an *Elphidium*, this species was placed in *Elphidiella* by Cushman (1941, p. 34) on the basis of specimens with double rows of pores. However, closer examination of these double-pored specimens shows them to actually belong to *Elphidiella groenlandica* (Cushman). One of these was illustrated by Cushman (1941, pl. 9, fig. 7). Later Bandy (1950, p. 277) concurred in placing the species in *Elphidiella*, stating "sutural pores varying from an irregular single row to a double row," although his illustrated specimen shows only a single row. Van Voorthuysen (1952a, p. 23) stated, "Wax-preparations made for the study of the canal system . . . indicate that our form possesses a single row of openings narrowly beginning and broadly ending. . . . Since our *Elphidium oregonense* specimens do not show forking canals they are considered to belong to *Elphidium*."

The specimen figured by Cushman (1914, pl. 19, fig. 1) and referred to *Polystomella siberica* Goës from a dredging at *Albatross* station D 3600 at 9 fathoms (16.5 m.) (erroneously recorded by Cushman as 156 fathoms) in the Bering Sea is like the present species. Unfortunately the specimen figured by Cushman has apparently been lost, as it is not to be found in his collections; however, the specimen of figure 1 is very similar to Cushman's illustration and in fact was picked from the same *Albatross* sample by the present writers. The

slightly evolute appearance of the later chambers surrounding the umbonal boss is characteristic of the present species, but distinct from *Elphidiella siberica*. Gões's species has a smooth surface and the umbonal region is not separated in a distinct elevated boss, and there are two distinct rows of pores.

*Types and occurrence.*—Figured hypotypes (U.S.N.M. Nos. P2109a-c) and unfigured hypotypes from station 44.

#### ELPHIDIUM SUBARCTICUM Cushman

Plate 19, figures 5-7

*Elphidium subarcticum* CUSHMAN, 1944, Cushman Lab. Foram. Res. Spec. Publ. 12, p. 27, pl. 3, figs. 34, 35; 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 58, pl. 6, fig. 12.—F. PARKER, 1952, Bull. Mus. Comp. Zool., vol. 106, No. 9, p. 412, pl. 5, fig. 9.

Test free, discoidal, planispiral and involute, sides flat, periphery broadly rounded, margin slightly lobulate; 8 to 9 chambers visible, the later ones moderately inflated; sutures distinct, slightly depressed, with a row of small sutural pores and a wide opaque band on either side; wall calcareous, finely perforate, translucent, except for the band along the sutures, surface smooth; aperture consisting of a row of pores at the base of the apertural face of the final chamber and additional accessory pores scattered over the face, although not always prominent.

Greatest diameter of hypotype of figure 6, 0.73 mm., thickness 0.26 mm. Greatest diameter of hypotype of figure 5, 0.86 mm., thickness 0.36 mm. Greatest diameter of figure 7, 0.73 mm., thickness 0.29 mm. Other hypotypes range from 0.29 to 0.86 mm. in diameter.

*Remarks.*—Like *E. frigidum* Cushman, this species has scattered apertural pores in the apertural face, in addition to the pores at the base of the face. These scattered pores have not been noted in previous descriptions or figures of either of these species. Unless future restudy of the genotype species of *Elphidium* shows that species to have been erroneously described as possessing such pores in the face, the name *Cribrorhynchium* should be suppressed as a synonym of *Elphidium*. Thus we have retained the present species in the genus *Elphidium*.

*Types and occurrence.*—Figured hypotypes (U.S.N.M. Nos. P2057a,b) from station 1; figured hypotype (U.S.N.M. No. P2058) from station 10; unfigured hypotypes are recorded from stations 1, 3, 4, 5, 6, 7, 8, 9, 10, 12, 15, 17, 18, 19, 20, 24, 27, 30, 34, 38, 45, 46, and 50.

Genus *ELPHIDIELLA* Cushman, 1936***ELPHIDIELLA ARCTICA* (Parker and Jones)**

Plate 20, figures 1-3

*Polystomella arctica* PARKER and JONES, 1864, in H. B. Brady, Trans. Linn. Soc. London, Zool., vol. 24, p. 471, pl. 48, fig. 18.

*Elphidium arcticum* (Parker and Jones) CUSHMAN, 1930, U. S. Nat. Mus. Bull. 104, pt. 7, p. 27, pl. 11, figs. 1-6.

*Elphidiella arctica* (Parker and Jones) CUSHMAN, 1939, U. S. Geol. Surv. Prof. Pap. 191, p. 65, pl. 18, figs. 11-14.—CUSHMAN and TODD, 1947, Contr. Cushman Lab. Foram. Res., vol. 23, pt. 3, p. 65, pl. 15, fig. 20.—CUSHMAN, 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 59, pl. 6, fig. 15.

Test free, large, planispiral, moderately compressed, with nearly flat sides and broadly rounded periphery; chambers numerous, increasing gradually in size as added, 10 to 13 in the final whorl, later ones slightly inflated; sutures distinct, early ones sometimes thickened and slightly raised, later ones slightly depressed so that the margin is somewhat lobulate, two rows of pores along the sutures, about 11 to 13 pairs along the last suture as seen from a single side; wall calcareous, smooth except for the double row of pores, the sometimes slightly elevated sutures and occasionally shallow parallel grooves extending from the sutural pores across the intervening chambers and paralleling the outer margin; aperture consists of a few pores in the face, only about three in the young stages, later with a row of pores across the face, but somewhat above its base, and scattered pores in the face above this row.

Greatest diameter of hypotype of figure 1, 1.56 mm., thickness 0.49 mm.

*Types and occurrence.*—Figured hypotypes (U.S.N.M. Nos. P1056a,b) from station 6; figured hypotype (U.S.N.M. No. P1057) from station 49; unfigured hypotypes are recorded from the following stations: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 15, 18, 19, 20, 21, 22, 23, 24, 26, 28, 29, 30, 31, 32, 34, 35, 39, 42, 49, 50, 51, and 52.

***ELPHIDIELLA GROENLANDICA* (Cushman)**

Plate 19, figures 13, 14

*Elphidium groenlandicum* CUSHMAN, 1933, Smithsonian Misc. Coll., vol. 89, No. 9, p. 4, pl. 1, fig. 10.

*Elphidiella groenlandica* (Cushman) CUSHMAN, 1939, U. S. Geol. Surv. Prof. Pap. 191, p. 66, pl. 19, fig. 3; 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 60, pl. 6, fig. 14.

*Elphidiella oregonense* (Cushman and Grant) CUSHMAN, 1941 (part), Contr. Cushman Lab. Foram. Res., vol. 17, pt. 2, p. 34, pl. 9, fig. 7 (not figs. 8, 9).



Test free, large, planispiral and involute, thickest through the umbilical region, periphery subacute; chambers numerous, low, 14 to 16 in the final whorl; sutures distinct, not depressed, very gently curved, bordered with a double row of sutural pores, which alternate and can be seen extending into the interior of the shell on well-preserved specimens, giving the sutures a characteristic pinnate appearance; wall calcareous, very finely perforate, surface smooth, umbilical region filled with clear shell material; aperture consists of a row of pores along the base of the apertural face of the final chamber.

*Remarks.*—Cushman (1941, p. 35, pl. 9, fig. 7) discussed and figured a specimen of this species as a possible young stage of *Elphidiella oregonense* (Cushman and Grant). On the basis of this specimen, which in no way resembled *Elphidium oregonense* but is a typical example of *Elphidiella groenlandica* Cushman, he erroneously changed the generic position of *oregonense* to *Elphidiella*.

The types of this species are from Greenland. Specimens of this species, recorded as *Elphidiella oregonense*, were found in the Pleistocene from a submarine beach about 1.0 mile north, 60° west of Nome, Alaska. It is rare off the northern coast of Alaska, occurring only in two samples off Point Barrow. As the specimens found there are dead shells and appear somewhat worn, it is possible that they may actually be fossil shells, as this species is much more abundant in the Pleistocene of this part of northern Alaska than in the present seas.

*Types and occurrence.*—Figured hypotype (U.S.N.M. No. P2134) from station 17; figured hypotype (U.S.N.M. No. P2135) from station 18; unfigured hypotypes are recorded from stations 17, 18, 33, 63, 66, and 74.

#### ELPHIDIELLA NITIDA Cushman

Plate 19, figures 11, 12

*Elphidium hannai* CUSHMAN and GRANT, var. 1927, Trans. San Diego Soc. Nat. Hist., vol. 5, p. 78, pl. 8, fig. 2.

*Elphidiella hannai* (Cushman and Grant) CUSHMAN, 1939 (part), U. S. Geol. Surv. Prof. Pap. 191, p. 66, pl. 19, fig. 2 (not fig. 1).—CUSHMAN and McCULLOCH, 1940, Allan Hancock Pacific Exped., vol. 6, No. 3, p. 177, pl. 20, fig. 11.—CUSHMAN and TODD, 1947, Cushman Lab. Foram. Res. Spec. Publ. 21, p. 15, pl. 2, fig. 22.

*Elphidiella nitida* CUSHMAN, 1941, Contr. Cushman Lab. Foram. Res., vol. 17, pt. 2, p. 35, pl. 9, fig. 4.

Test free, lenticular, planispiral and involute, periphery rounded; chambers distinct, numerous, 13 to 15 in the last whorl; sutures distinct, thickened but not raised, radial to slightly curved, bordered by a double row of sutural pores extending to the smooth umbilical region;

wall calcareous, finely perforate, surface smooth, except for numerous fine granules on the periphery of the previous whorl for a short distance just in front of the aperture and up the apertural face; aperture consists of a row of pores at the base of the apertural face of the final chamber.

Greatest diameter of hypotype of figure 12, 0.75 mm., thickness 0.34 mm. Greatest diameter of hypotype of figure 11, 0.60 mm., thickness 0.26 mm. Other hypotypes range from 0.31 to 0.81 mm. in diameter.

*Remarks.*—The fine granules present on the apertural face and on the periphery of the preceding whorl just in front of the aperture have apparently been shown in the illustration of Cushman and McCulloch, but have never been mentioned in any description of this species. Cushman and Grant stated that the aperture consisted of a series of pores at the base of the face and in addition other pores scattered over the apertural face. We have been unable to see these scattered pores on any of the types in the Cushman collection or in our own specimens and suspect that the above-mentioned pustules may have been mistaken for apertural pores.

In 1941 Cushman described the present species as distinct from *E. hannai* (Cushman and Grant), and placed in *E. nitida* the above-listed references of Cushman and Grant, 1927, Cushman, 1939, and Cushman and McCulloch, 1940. However, in 1947 all these references were again listed in the synonymy of *E. hannai* by Cushman and Todd and no mention was made of *E. nitida*, apparently through an oversight. The specimens shown by Cushman and Todd seem also to belong to *E. nitida*.

*Types and occurrence.*—Figured hypotypes (U.S.N.M. Nos. P2143a,b) and unfigured hypotypes from station 44.

#### Family BULIMINIDAE

Genus ROBERTINOIDES Höglund, 1947

#### ROBERTINOIDES (?) CHARLOTTENSIS (Cushman)

Plate 20, figures 6, 7

*Cassidulina charlottensis* CUSHMAN, 1925, Contr. Cushman Lab. Foram. Res., vol. 1, pt. 2, p. 41, pl. 6, figs. 6, 7.

*Robertina charlottensis* (Cushman) CUSHMAN and F. PARKER, 1936, Contr. Cushman Lab. Foram. Res., vol. 12, pt. 4, p. 97, pl. 16, figs. 12a,b.

*Robertina californica* CUSHMAN and F. PARKER, 1936, *ibid.*, figs. 14a,b.

Test free, elongate, spiral, widest at or slightly above the mid-portion; several chambers to a whorl, each subdivided by a vertical

infolding of the wall which gives the external appearance of a suture, but does not completely divide the chamber; sutures distinct, thickened, but not raised; wall calcareous, finely but distinctly perforate, surface smooth; aperture double, consisting of a vertical slit extending into the face of the final chamber from its base, and a second slit almost at right angles to the first, and extending along the base of the chamber, sometimes the two apertural slits are connected and in other specimens the chamber flap is firmly attached between them separating the aperture distinctly.

Length of hypotype of figure 7, 0.49 mm., breadth 0.31 mm. Length of hypotype of figure 6, 0.65 mm., breadth 0.34 mm. Other hypotypes range from 0.29 to 0.83 mm. in length.

*Remarks.*—A study of the holotype and paratype specimens of *Cassidulina charlottensis* Cushman and *Robertina californica* Cushman and Parker, shows no appreciable difference between them. The slight curvature of the axis described as characteristic of the former seems to be merely an individual variation, hence the two forms are here regarded as conspecific.

There is more doubt as to the generic status than the specific one, however. *Robertina* (genotype *R. arctica* d'Orbigny) was described by d'Orbigny as having a virguline aperture on the side of the last chamber. Höglund, 1947, described *Robertinoides* as having a double aperture and he also stated that the majority of species previously referred to *Robertina* belonged to *Robertinoides* as well. Specimens referred by Höglund to *R. arctica* were like the illustration of d'Orbigny in having a single aperture.

Specimens referred to *Robertina arctica* by Cushman and Parker, 1936, have a double aperture like the present species, and Höglund stated that they were not the same as d'Orbigny's form. In a later paper Parker (1952a, p. 416) stated that Höglund's *Robertina arctica* resembled *R. charlottensis* (Cushman), and commented, "I cannot agree with his interpretation of d'Orbigny's species. . . . The specimens referred to *Robertina arctica* by Cushman and Parker (1947) appear to be identical with d'Orbigny's figured form except that there is a narrow apertural opening along the inner part of the chamber division. I believe that it would have been easy for d'Orbigny to overlook this, merely believing it to be a part of the dividing suture. . . . If my interpretation of d'Orbigny's figures is correct, Höglund's genus *Robertinoides* should be placed in the synonymy under *Robertina* and a new genus erected for the single-apertured forms."

Thus the generic designation rests upon which interpretation of

d'Orbigny's species is correct and can only be solved by an examination of d'Orbigny's type specimens. Meanwhile, as d'Orbigny only showed a single aperture in *Robertina* and Höglund described *Robertinoides* as having a double aperture, we are placing this species in *Robertinoides*, although there is at least a possibility that d'Orbigny's illustration and description may be inaccurate and the two generic names synonymous.

*Types and occurrence*.—Figured hypotype (U.S.N.M. No. P2099) from station 12; figured hypotype (U.S.N.M. No. P2100) from station 18; unfigured hypotypes are recorded from stations 1, 3, 4, 6, 13, 18, 19, 20, 21, 22, 23, 26, 27, 31, 35, 37, 50, and 51.

Genus **BULIMINA** d'Orbigny, 1826

**BULIMINA EXILIS** Brady

Plate 20, figures 4, 5

*Bulimina elegans* d'Orbigny var. *exilis* BRADY, 1884, Rep. Voy. *Challenger*, vol. 9 (Zoology), p. 399, pl. 50, figs. 5, 6.—CUSHMAN, 1911, U. S. Nat. Mus. Bull. 71, pt. 2, p. 82, text fig. 135; 1922, U. S. Nat. Mus. Bull. 104, pt. 3, p. 106, pl. 17, figs. 7-12, pl. 19, figs. 2, 3.

*Bulimina exilis* Brady, CUSHMAN and F. PARKER, 1940, Contr. Cushman Lab. Foram. Res., vol. 16, pt. 1, p. 11, pl. 2, figs. 18-21; 1947, U. S. Geol. Surv. Prof. Pap. 210-D, p. 123, pl. 28, figs. 27, 28.—CUSHMAN, 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 62, pl. 7, fig. 1.—F. PARKER, 1948, Bull. Mus. Comp. Zool., vol. 100, No. 2, pl. 4, fig. 9.

Test elongate, slender, tapering to the sometimes apiculate base; chambers numerous, slightly inflated, elongate; sutures distinct, depressed; wall calcareous, finely perforate, translucent and smooth; aperture loop-shaped, rather broad, but elongate.

Length of hypotype of figure 5, 0.47 mm., breadth 0.18 mm. Other hypotypes range from 0.18 to 0.70 mm. in length.

*Types and occurrence*.—Figured hypotypes (U.S.N.M. Nos. P2111a,b) from station 33; unfigured hypotypes are recorded from stations 5, 12, 13, 15, 16, 18, 21, 22, 23, 27, 29, 30, 32, 33, 35, 38, 42, and 52.

Genus **GLOBOBULIMINA** Cushman, 1927

**GLOBOBULIMINA AURICULATA** subsp. **ARCTICA** Höglund

Plate 20, figures 8, 9

*Bulimina ellipsoides* Costa, Goës (part), 1894 (not Costa, 1856), Svenska Vet.-Akad. Handl., vol. 25, No. 9, p. 45.

*Globobulimina auriculata* (Bailey) forma *arctica* HÖGLUND, 1947, Zool. Bidrag Uppsala, vol. 26, p. 254, text figs. 266, 267, 270, 271.

Test free, large, ovate in outline with broadly rounded base, circular in section; chambers arranged in an elongate spiral, triserial, slightly inflated, increasing rapidly in size as added; sutures distinct, slightly depressed; wall calcareous, thin, perforate, surface smooth; aperture loop-shaped, with a doubly folded tongue of which one extremity rises above the aperture like a fan, and the other is extended into the chamber cavity like an "entosolenian" tube, connecting with the aperture of the previous chamber.

Length of hypotype of figure 8, 1.38 mm., breadth 0.70 mm. Length of hypotype of figure 9, 0.88 mm., breadth 0.47 mm.

*Remarks.*—No elaboration need be made on the excellent description of the internal characters of this species given by Höglund, and our specimens seem identical with those referred by Höglund to forma *arctica*.

*Types and occurrence.*—Figured hypotype (U.S.N.M. No. P2112) from station 1; figured hypotype (U.S.N.M. No. P2113) from station 43; unfigured hypotypes are recorded from stations 3 and 18.

#### Genus *BOLIVINA* d'Orbigny, 1839

#### *BOLIVINA PSEUDOPUNCTATA* Höglund

Plate 20, figures 13, 14

*Bolivina punctata* d'Orbigny, Goës (part), 1894 (not d'Orbigny, 1839), Svenska Vet.-Akad. Handl., vol. 25, No. 9, p. 49, pl. 9, figs. 478, 480 (not figs. 475-477).

*Bolivina pseudopunctata* HÖGLUND, 1947, Zool. Bidrag Uppsala, vol. 26, p. 273, pl. 24, fig. 5, pl. 32, figs. 23, 24, text figs. 280, 281, 287.—F. PARKER, 1952, Bull. Mus. Comp. Zool., vol. 106, No. 9, p. 414, pl. 5, figs. 20, 21.—PHLEGER, 1952, Contr. Cushman Found. Foram. Res., vol. 3, pt. 2, p. 83, pl. 14, fig. 19.

Test free, small, narrow and elongate, tapering gradually, slightly compressed, periphery rounded; chambers low and broad at first, increasing in relative height as added, later chambers of greater height than breadth; sutures distinct, depressed, strongly oblique; wall calcareous, thin, translucent, surface smooth, the lower portion of each chamber with numerous fine pores, the upper portion imperforate; aperture elongate, with a tongue.

Length of hypotype of figure 13, 0.43 mm., breadth 0.10 mm., thickness 0.08 mm. Length of hypotype of figure 14, 0.44 mm., breadth 0.16 mm.

*Types and occurrence.*—Figured hypotypes (U.S.N.M. Nos. P2145a,b) from station 21; unfigured hypotypes are recorded from stations 20, 21, 22, 23, 26, 29, 30, 31, 32, 39, and 42.

Genus *ANGULGERINA* Cushman, 1927*ANGULGERINA FLUENS* Todd

Plate 20, figures 10-12

*Angulogerina fluens* TODD, 1947, in Cushman and Todd, Contr. Cushman Lab. Foram. Res., vol. 23, pt. 3, p. 67, pl. 16, figs. 6, 7; 1948, in Cushman and McCulloch, Allan Hancock Pacific Exped., vol. 6, No. 5, p. 288, pl. 36, fig. 1.

*Angulogerina angulosa* (Williamson) CUSHMAN, 1948 (not *Uvigerina angulosa* Williamson, 1858), Cushman Lab. Foram. Res. Spec. Publ. 23, p. 66, pl. 7, fig. 8.

Test free, elongate, slightly flaring to fusiform, triangular in section in the early portion, the angles becoming rounded in the later portion; chambers numerous, triserially arranged, inflated, of nearly equal height and breadth, early chambers closely appressed, and later ones more separated; sutures distinct, constricted, particularly in the later portion; wall calcareous, finely and distinctly perforate, ornamented by numerous low, vertical costae, curving with the chambers, sometimes nearly dying out over the final chamber, so that the surface is smooth and the perforations seem relatively more distinct; aperture terminal, elongate oval, on a very short neck with a thickened rim.

Length of hypotype of figure 11, 0.73 mm., breadth 0.29 mm. Length of hypotype of figure 10, 0.55 mm., breadth 0.26 mm. Length of hypotype of figure 12, 0.42 mm., breadth 0.22 mm. Other hypotypes range from 0.21 to 0.78 mm. in length.

*Remarks.*—This species is much less angular than *A. angulosa* (Williamson), and the specimen figured by Cushman (1948b) from the Arctic apparently belongs with the present species.

*Types and occurrence.*—Figured hypotype (U.S.N.M. No. P2002) from station 18; figured hypotype (U.S.N.M. No. P2003) from station 20; figured hypotype (U.S.N.M. No. P2004) from station 21; unfigured hypotypes are recorded from stations 1, 3, 5, 12, 18, 20, 21, 22, 23, 24, 25, 26, 27, 29, 30, 31, 32, 34, 35, 36, 38, 39, 42, 44, and 45.

## Family SPIRILLINIDAE

Genus *SPIRILLINA* Ehrenberg, 1843*SPIRILLINA VIVIPARA* Ehrenberg

Plate 21, figures 2, 3

*Spirillina vivipara* EHRENBURG, 1843, Abh. Akad. Wiss. Berlin (Jahrg. 1841), pt. 1, pp. 323, 422, pl. 3, VII, fig. 41.—PARKER and JONES, 1865, Philos. Trans. Roy. Soc. London, vol. 155, p. 397, pl. 15, fig. 28.—BRADY, 1884, Rep. Voy. *Challenger*, vol. 9 (Zoology), p. 630, pl. 85, figs. 1-5.—CUSHMAN, 1915, U. S. Nat. Mus. Bull. 71, pt. 5, p. 3, text figs. 1a,b, pl. 1, figs. 1, 2; 1931, U. S. Nat. Mus. Bull. 104, pt. 8, p. 3, pl. 1, figs. 1-4.

*Spirillina arctica* CUSHMAN, 1933 (part), Smithsonian Misc. Coll., vol. 89, No. 9, p. 6, pl. 2, fig. 2 (not fig. 1); 1948 (part), Cushman Lab. Foram. Res. Spec. Publ. 23, p. 66, pl. 7, fig. 10 (not fig. 9).

Test free, small, discoidal, nearly planispiral, consisting of a globular proloculus and long, undivided, spirally coiled tubular second chamber which increases gradually in diameter as added; spiral suture distinct; wall calcareous, hyaline, with fine to medium perforations, occasionally with transverse growth wrinkles in the latter portion, surface otherwise smooth; aperture at the open end of the tubular chamber.

Greatest diameter of hypotype of figure 3, 0.31 mm., thickness 0.05 mm. Greatest diameter of hypotype of figure 2, 0.18 mm. Other hypotypes range from 0.16 to 0.44 mm. in diameter.

*Remarks.*—The holotype of *Spirillina arctica* Cushman is a *Turrispirillina*, but Cushman's figured paratype is a true *Spirillina* and seems close to *Spirillina vivipara* as figured by Brady. Ehrenberg's original illustration is a drawing of a specimen mounted in balsam and does not show the surface characters. It is most probably the same however.

*Types and occurrence.*—Figured hypotype (U.S.N.M. No. P2081) from station 34; figured hypotype (U.S.N.M. No. P2082) from station 39; unfigured hypotypes are recorded from stations 28 and 29.

Genus **TURRISPIRILLINA** Cushman, 1927

**TURRISPIRILLINA ARCTICA** (Cushman)

Plate 21, figure 1

*Spirillina arctica* CUSHMAN, 1933, Smithsonian Misc. Coll., vol. 89, No. 9, p. 6, pl. 2, fig. 1 (not fig. 2); 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 66, pl. 7, fig. 9 (not fig. 10).

Test free, small, circular in outline, consisting of a globular proloculus and long undivided tubular second chamber, increasing gradually in diameter as added and tightly coiled into a low hollow cone; spiral suture distinct, slightly depressed; wall calcareous, thin, hyaline, translucent and very finely perforate; aperture formed by the open end of the tube, somewhat higher than broad because of the slightly compressed tubular chamber.

Greatest diameter of figured hypotype 0.23 mm., least diameter 0.21 mm., height of spire 0.05 mm.

*Remarks.*—Cushman (1933a, p. 6) in describing this species states "close coiled, overlapping very slightly on the dorsal side leaving a

depressed hollow cone as it revolves." This character alone distinguishes members of the genus *Turrispirillina* Cushman, 1927, from those belonging to *Spirillina*, which is close-coiled in a single plane. To further complicate the matter Cushman's holotype slide contains two specimens, both typical specimens of the genus *Turrispirillina*, but the figured paratype specimen (1933a, pl. 2, fig. 2; 1948b, pl. 7, fig. 10) is a typical *Spirillina* and bears no close relation to the "holotype" slide. The unfigured paratypes in the Cushman collection are all specimens of *Turrispirillina*.

*Types and occurrence*.—Figured hypotype (U.S.N.M. No. P1062) from station 29; unfigured hypotypes are recorded from stations 29, 38, and 42.

Genus **PATELLINA** Williamson, 1858

**PATELLINA CORRUGATA** Williamson

Plate 21, figures 4, 5

*Patellina corrugata* WILLIAMSON, 1858, Recent Foraminifera of Great Britain, p. 46, pl. 3, figs. 86-89.—CUSHMAN, 1930, Contr. Cushman Lab. Foram. Res., vol. 6, p. 15, pl. 3, figs. 5a-c; 1931, U. S. Nat. Mus. Bull. 104, pt. 8, p. 11, pl. 2, figs. 6, 7; 1944, Cushman Lab. Foram. Res. Spec. Publ. 12, p. 30, pl. 4, fig. 14.—CUSHMAN and TODD, 1947, Cushman Lab. Foram. Res. Spec. Publ. 21, p. 20, pl. 3, fig. 13; 1947, Contr. Cushman Lab. Foram. Res., vol. 23, p. 67, pl. 16, fig. 9.—CUSHMAN, 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 67, pl. 7, fig. 11.—F. PARKER, 1952, Bull. Mus. Comp. Zool., vol. 106, No. 9, p. 420, pl. 6, figs. 16, 17.

Test free, low, scalelike, planoconvex or concavoconvex, and ventrally umbilicate, periphery acute, with a slight keel; the globular proloculus is followed by a long, undivided tubular second chamber of approximately 2 to 3 whorls, and then by crescentic-shaped chambers arranged in two alternating series, each covering slightly over one-half the circumference of the preceding whorl, final chamber may be completely annular, many internal secondary septa partially subdividing these later chambers; sutures distinct; wall calcareous, hyaline, very thin and translucent, finely perforate; aperture ventral, elongate, at the base of the final chamber.

Greatest diameter of hypotype of figure 4, 0.44 mm., height of spire 0.18 mm.; greatest diameter of hypotype of figure 5, 0.31 mm., height of spire 0.10 mm. Other hypotypes range from 0.13 to 0.47 mm. in diameter.

*Types and occurrence*.—Figured hypotype (U.S.N.M. No. P2029) from station 34; figured hypotype (U.S.N.M. No. P2030) from station 51; unfigured hypotypes are recorded from the following sta-



tions; 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 18, 19, 20, 21, 22, 23, 26, 27, 28, 29, 30, 31, 32, 35, 36, 37, 42, 45, 50, and 51.

Family ROTALIIDAE

Genus **BUCCELLA** Andersen, 1952

**BUCCELLA FRIGIDA** (Cushman)

Plate 22, figures 2, 3

*Pulvinulina frigida* CUSHMAN, 1922, Contr. Can. Biol. No. 9 (1921), p. 12 (144).

*Eponides frigida* (Cushman) CUSHMAN, 1931, U. S. Nat. Mus. Bull. 104, pt. 8, p. 45.

*Eponides frigidus* (Cushman) CUSHMAN, 1941, Contr. Cushman. Lab. Foram. Res., vol. 17, pt. 2, p. 37, pl. 9, figs. 16, 17.

*Eponides frigida* (Cushman) var. *calida* CUSHMAN and COLE, 1930, Contr. Cushman Lab. Foram. Res., vol. 6, No. 4, p. 98, pl. 13, figs. 13a-c.—CUSHMAN, 1931, U. S. Nat. Mus. Bull. 104, pt. 8, p. 47; 1944, Cushman Lab. Foram. Res. Spec. Publ. 12, p. 34, pl. 4, figs. 19, 20.

*Buccella frigida* (Cushman) ANDERSEN, 1952, Journ. Washington Acad. Sci., vol. 42, No. 5, p. 144, figs. 4a-c, 5, 6a-c.

Test free, small, trochoid, biconvex, periphery rounded; all chambers of the  $2\frac{1}{2}$  to 3 whorls visible dorsally, only the 5 to 8 of the final whorl visible ventrally, increasing gradually in size as added; sutures distinct, thickened, flush, oblique and curved backward on the periphery on the dorsal side, on the ventral side radial and filled with granular material which continues into the umbilical region; wall calcareous, finely perforate, smooth and polished dorsally, with the sutures, umbilical area, and basal margin of the final chamber granular in appearance on the ventral side; aperture concealed by the pustulose material, but worn specimens show an arched aperture at the basal margin of the final chamber, about midway between the umbilicus and periphery, with supplementary apertures at the outer margin of the sutures near the periphery.

Greatest diameter of lectotype 0.46 mm., thickness 0.20 mm. Hypotypes range from 0.21 to 0.47 mm. in diameter.

*Remarks.*—The structure and relationships of this species were well described by Andersen and need no elaboration here.

*Types and occurrence.*—Lectotype (Cushman Coll. No. 3032) from a depth of 18.3 m. in bay on east coast (south of Black Whale Harbor), Canadian Arctic. Figured hypotype (U.S.N.M. No. P2144) from station 17; unfigured hypotypes are recorded from stations 5, 6, 7, 9, 12, 13, 16, 17, 18, 20, 21, 23, 24, 25, 27, 28, 30, and 37.

## BUCCELLA INUSITATA Andersen

Plate 22, figure 1

*Eponides frigidus* (Cushman) CUSHMAN and TODD, 1947 (not *Pulvinulina frigida* Cushman, 1922), Cushman Lab. Foram. Res. Spec. Publ. 21, p. 21.—CUSHMAN, 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 71, pl. 8, fig. 7.

*Buccella inusitata* ANDERSEN, 1952, Journ. Washington Acad. Sci., vol. 42, No. 5, p. 148, figs. 10a-11c.

Test of medium size, trochoid, biconvex to nearly planoconvex, with a relatively high dorsal spire, periphery acute and with a narrow keel, peripheral margin of the later chambers lobulate; all chambers of the 3 to 4 whorls visible dorsally, only the 7 to 9 chambers of the last whorl visible ventrally; sutures distinct, limbate, oblique and curved backward strongly at the periphery on the dorsal side, radial ventrally and covered with granular material; wall calcareous, finely perforate, the dorsal side smooth and polished in appearance, the ventral side more coarsely perforate and with a considerable amount of granular material along the sutures, umbilical area, and back margin of the final chamber; apertures at the outer margin of each suture on the ventral side.

Greatest diameter of figured hypotype 0.52 mm., thickness 0.29 mm. Other hypotypes range from 0.21 to 0.94 mm. in greatest diameter.

*Remarks.*—This species differs from the associated *B. frigida* in being larger, more sharply keeled and more strongly convex.

*Types and occurrence.*—Figured hypotype (U.S.N.M. No. P2102) from station 18; unfigured hypotypes are recorded from stations 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 34, 35, 36, 38, 39, 42, 44, 45, 50, 51, and 52.

TRICHOHYALUS <sup>†</sup> Loeblich and Tappan, new genus

Synonyms: *Discorbis* Cushman, 1933 (part) (not Lamarck, 1804).

*Discorinopsis* Cushman, 1948 (not Cole, 1941).

Genotype (type species): *Discorbis bartletti* Cushman, 1933.

Test free, trochoid, planoconvex, all whorls visible dorsally, ventral side obscured by a secondary growth of shell material, forming a vesicularlike plate over the umbilical region and extending over the other chambers nearly to the periphery, with pores extending through this vesicular tissue into the cavity beneath, and the exterior ornamented with nodes, ridges, and furrows; wall calcareous, hyaline, coarsely perforate-granular in structure, smooth dorsally, the ventral

<sup>†</sup> From Gr. *thrix*, *trichos*, hair; *hyalos*, glass.

side ornamented by the grooves, ridges, and nodes of the vesicular secondary growth; aperture absent or obscured by secondary growth on the final chamber, but can be seen on earlier chambers by dissection, as an arch at the base of the chamber, slightly ventral from the periphery.

*Occurrence.*—Recent.

### TRICHOHYALUS BARTLETTI (Cushman)

Plate 23, figures 1-7

*Discorbis bartletti* CUSHMAN, 1933, Smithsonian Misc. Coll., vol. 89, No. 9, p. 6, pl. 2, figs. 3-6.

*Discorinopsis bartletti* (Cushman) CUSHMAN, 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 70, pl. 7, fig. 15, pl. 8, figs. 1-3.

Test free, trochoid, planoconvex, with rounded periphery and slightly lobulate margin; all chambers of the  $1\frac{1}{2}$  whorls visible on the strongly convex dorsal side, only those of the last whorl visible ventrally, increasing gradually in size as added, and increasing also in number per whorl from 4 in juvenile specimens to as many as 10 in the adult; sutures distinct, slightly depressed and gently curved on the dorsal side, early sutures obscured ventrally; wall calcareous, hyaline, but granular in structure, coarsely perforate, but smooth on the dorsal side, ornate ventrally with many fine radial ridges on the outer portion of the chambers, some continuous, others broken and giving the outer margin of the test a fimbriatelike edge, the grooves between these ridges tracing into pores toward the umbilical area, the umbilical area being filled with a vesicular secondary growth which covers all the earlier chambers and is externally nodose in appearance, with pores running to the interior of the test and a definite cavity between this growth and the actual chamber walls; no aperture visible on the final chamber, but dissection shows the presence of a low arched opening at the base of the penultimate chamber somewhat ventral from the periphery, which is doubtless obscured on the final chamber by the vesicular tissue.

Greatest diameter of hypotype of figure 1, 1.51 mm., thickness 0.70 mm. Greatest diameter of hypotype of figure 5, 1.22 mm. Greatest diameter of hypotype of figure 7, 0.78 mm. Greatest diameter of hypotype of figure 6, 0.60 mm. Greatest diameter of hypotype of figure 2, 1.48 mm.

*Remarks.*—This species was originally described as a *Discorbis*, later was referred to *Discorinopsis* Cole, 1941. Thin sections of the genotype species of *Discorinopsis* show that it is an arenaceous form,

hence the present species is quite distinct, and is here made the genotype species of *Trichohyalus*, new genus.

*Types and occurrence.*—Figured hypotypes (U.S.N.M. Nos. P1065a-d) from station 34; figured hypotypes (U.S.N.M. Nos. P1066a-c) from station 29; unfigured hypotypes are recorded from stations 23, 28, 29, 30, 31, 34, 39, and 45.

**TRICHOHYALUS PUSTULATA** Loeblich and Tappan, new species

Plate 23, figures 8, 9

Test free, trochoid, biconvex, periphery subacute, margin serrate in appearance due to the ventral pustules extending beyond the edge; chambers numerous, about 7 chambers in the final whorl in the adult, with about  $1\frac{1}{2}$  whorls present, all whorls visible dorsally; sutures gently curved backward on the dorsal side, obscure, slightly thickened but not raised, completely obscured by the surface ornamentation on the ventral side; wall calcareous, finely perforate, dorsal surface smooth, ventral surface covered by numerous pustules, larger and more irregular ones toward the umbilical region and smaller and more elevated granules toward the peripheral margin; aperture ventral, at the base of the apertural face of the final chamber, about half the distance from the periphery.

Greatest diameter of holotype 0.88 mm., least diameter 0.73 mm., thickness 0.42 mm. Greatest diameter of juvenile paratype 0.36 mm., thickness 0.16 mm.

*Remarks.*—This species differs from *T. bartletti* (Cushman) in being smaller, more biconvex, and in the different character of the ventral ornamentation. In *T. bartletti* the central part of the ventral side is pustulose, the outer part is deeply grooved, whereas in *T. pustulata* the outer part is strongly pustulose, and the central part blistered in appearance with large irregular swellings. The sutures are much less distinct dorsally in the present species. Only two specimens of the present species have been found.

*Types and occurrence.*—Holotype (U.S.N.M. No. P2014) and figured paratype (U.S.N.M. No. P2015) from station 44.

Family CASSIDULINIDAE

Genus CASSIDULINA d'Orbigny, 1826

CASSIDULINA ISLANDICA Nørvang

Plate 24, figure 1

*Cassidulina islandica* NØRVANG, 1945, Foraminifera, Zoology of Iceland, vol. 2, pt. 2, p. 41, text figs. 7, 8d-f.

*Cassidulina islandica* Nørvang forma *minuta* NØRVANG, 1945 (not *Cassidulina minuta* Cushman, 1933), Foraminifera, Zoology of Iceland, vol. 2, pt. 2, p. 43, text figs. 8a-c.—F. PARKER, 1952, Bull. Mus. Comp. Zool., vol. 106, No. 9, p. 421, pl. 6, figs. 22a-23.—PHLEGER, 1952, Contr. Cushman Found. Foram. Res., vol. 3, pt. 2, p. 83, pl. 14, fig. 30.

*Cassidulina islandica* Nørvang var. *nørvangi* THALMANN, 1952, in Phleger, Contr. Cushman Found. Foram. Res., vol. 3, pt. 2, p. 83 (footnote).

Test free, of small to medium size, not much compressed, periphery broadly rounded; chambers inflated, about 4 pair in the last whorl, alternate chambers extending to the umbilicus on one side with only a small triangular portion visible on the opposite side; wall calcareous, translucent, distinctly perforate, surface smooth; aperture an elongate triangular slit, appearing alternately on each side of the periphery, provided with a thin tooth extending upward from the lower margin of the chamber.

Greatest diameter of figured hypotype 0.35 mm., thickness 0.21 mm. Other hypotypes range from 0.16 to 0.39 mm. in diameter.

*Remarks.*—Although Nørvang divided his species into the typical *C. islandica* and a forma *minuta* (later recognized as a variety and renamed *nørvangi*) he also questioned the validity of this separation, stating (1945, p. 43), "Differs from the typical form in the small size of the test. These are possibly starved specimens of *C. islandica*." He recorded only two of the small specimens, one each from depths of 28 to 30 meters and 37 meters, off Keflavik, Iceland.

In our material from off Point Barrow, Alaska, this species is abundant, and specimens of all sizes can be found in the assemblage, showing a definite size gradation from *C. islandica* to the variety *nørvangi*. We therefore believe the "variety" to be an artificial separation, and consider all our specimens to belong to *C. islandica*. Many earlier references to *Cassidulina crassa* d'Orbigny are undoubtedly this species, including many of the Cushman types in the National Museum collections. It differs from *C. crassa* in being somewhat smaller and differs particularly in the shape and position of the aperture. *C. crassa* was described from the Falkland Islands and both d'Orbigny's original figures and those of Heron-Allen and Earland (1932) from that area show the aperture to be a curved slit extending from the dorsal angle on the periphery in the direction of the umbilicus. The aperture thus shows on the periphery as a reentrant even when seen from the temporarily aboral side. In the present species the aperture is close against the base of the chamber, paralleling the sutural margin below it, and extending from the suture only about

two-thirds the distance toward the periphery and completely obscured when the test is viewed from the aboral side. It also contains the very distinctive tooth mentioned by Nørvang, which is not found in *C. crassa*.

*Types and occurrence.*—Figured hypotype (U.S.N.M. No. P2115) from station 18; unfigured hypotypes are recorded from stations 1, 2, 3, 4, 5, 6, 7, 9, 12, 13, 14, 16, 18, 19, and 50.

### CASSIDULINA NORCROSSI Cushman

Plate 24, figure 2

*Cassidulina norcrossi* CUSHMAN, 1933, Smithsonian Misc. Coll., vol. 89, No. 9, p. 7, pl. 2, figs. 7a-c; 1944, Cushman Lab. Foram. Res. Spec. Publ. 12, p. 35, pl. 4, fig. 26.—NØRVANG, 1945, Foraminifera, Zoology of Iceland, vol. 2, pt. 2, p. 44, text fig. 10.—CUSHMAN, 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 75, pl. 8, fig. 12.—F. PARKER, 1948, Bull. Mus. Comp. Zool., vol. 100, No. 2, pl. 6, figs. 2a,b; 1952, *ibid.*, vol. 106, No. 9, p. 422, pl. 6, figs. 24, 25.

not *Cassidulina norcrossi* Cushman, PHILEGER, 1952, Contr. Cushman Found. Foram. Res., vol. 3, pt. 2, p. 83, pl. 14, fig. 22 (= *C. teretis* Tappan).

Test free, lenticular, periphery subacute, with a narrow keel; chambers distinct and alternating from one side to the opposite side, although more nearly equal on the two sides than is usual for the genus; sutures distinct, limbate, flush, nearly straight, but oblique, so that chambers appear triangular in side view; wall calcareous, finely perforate, translucent, surface smooth; aperture elongate, paralleling and just adjacent to the peripheral margin of the apertural face and alternately to one side or the other.

Greatest diameter of figured hypotype 0.31 mm., thickness 0.14 mm. Other hypotypes range from 0.21 to 0.44 mm. in diameter.

*Remarks.*—The specimen figured by Phleger (1952) and referred to this species does not have the chambers overlapping nearly equally on the two sides as is true in typical *C. norcrossi*. Phleger's specimen also has 10 or 11 chambers visible in the final whorl (about 5 pairs) and half of these appear bandlike or ovate on each side rather than triangular, whereas *C. norcrossi* has only 4 pairs (8 chambers) in the final whorl, and all chambers appear triangular in side view on both sides.

*Types and occurrence.*—Figured hypotype (U.S.N.M. No. P2142) from station 37; unfigured hypotypes are recorded from stations 1, 5, 15, 22, 24, 37, 51, and 52.

## CASSIDULINA TERETIS Tappan

Plate 24, figures 3, 4

*Cassidulina laevigata* d'Orbigny, BRADY, 1884 (not d'Orbigny, 1826), Rep. Voy. Challenger, vol. 9 (Zoology), p. 428, pl. 54, figs. 1-3.—CUSHMAN (part), 1948, Cushman Lab. Foram. Res. Spec. Publ. 23, p. 73, pl. 8, fig. 8.

*Cassidulina teretis* TAPPAN, 1951, Contr. Cushman Found. Foram. Res., vol. 2, pt. 1, p. 7, pl. 1, figs. 30a-c; 1952, in Payne et al., U. S. Geol. Surv., Oil and Gas Invest. Map OM-126, sheet 3, fig. 21 (3a-c).

*Cassidulina norcrossi* Cushman, PHLEGER, 1952 (not Cushman, 1933), Contr. Cushman Found. Foram. Res., vol. 3, pt. 2, p. 83, pl. 14, fig. 22.

Test free, lenticular, biumbonate, coiled, slightly evolute; chambers biserially arranged and coiled, with 4 to 5 pairs of chambers in the final whorl, chambers extending from the clear umbilical region across the peripheral keel and about halfway to the boss on the opposite side, appearing ovate in outline on the side where they reach the umbo, and only a small subtriangular portion appearing on the opposite side; sutures distinct and thickened, but flush with the surface, gently curved; wall calcareous, perforate, translucent, surface smooth, with a narrow peripheral keel; aperture elongate, narrow and crescentic, extending upward three-fourths the distance from the base of the apertural face to the keel of the final chamber, and paralleling the anterior margin of the chamber.

Greatest diameter of hypotype of figure 3, 0.60 mm., thickness 0.23 mm. Greatest diameter of hypotype of figure 4, 0.60 mm., thickness 0.29 mm. Other hypotypes range from 0.21 to 0.73 mm. in diameter.

*Remarks.*—Although recorded from the Arctic by Brady and Cushman as *Cassidulina laevigata* d'Orbigny, the present species is quite distinct in having a peripheral keel and a less lobulate periphery, and in being somewhat evolute so that an umbonal boss occurs, through which may be seen the earlier whorls in the translucent living specimens. D'Orbigny's type figure shows the chambers to extend completely over the central portion. Furthermore, the aperture is not as elongate in d'Orbigny's species.

A more similar form is *Cassidulina laticamerata* Voloshinova, from the Pliocene of the Kamchatka Peninsula, U.S.S.R., but it is described as having a rounded periphery and slightly depressed sutures, and is a more-compressed species. It is possibly ancestral to *C. teretis*, however. The present species was originally described from the Pleistocene Gubik formation on the coast of northern Alaska and is found living offshore in the same region.

*Types and occurrence.*—Figured hypotypes (U.S.N.M. Nos. P2107 a,b) from station 18; unfigured hypotypes are recorded from stations 1, 3, 4, 5, 7, 9, 10, 12, 13, 15, 16, 17, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 35, 36, 37, 38, 39, 40, 42, 45, 46, 50, and 51.

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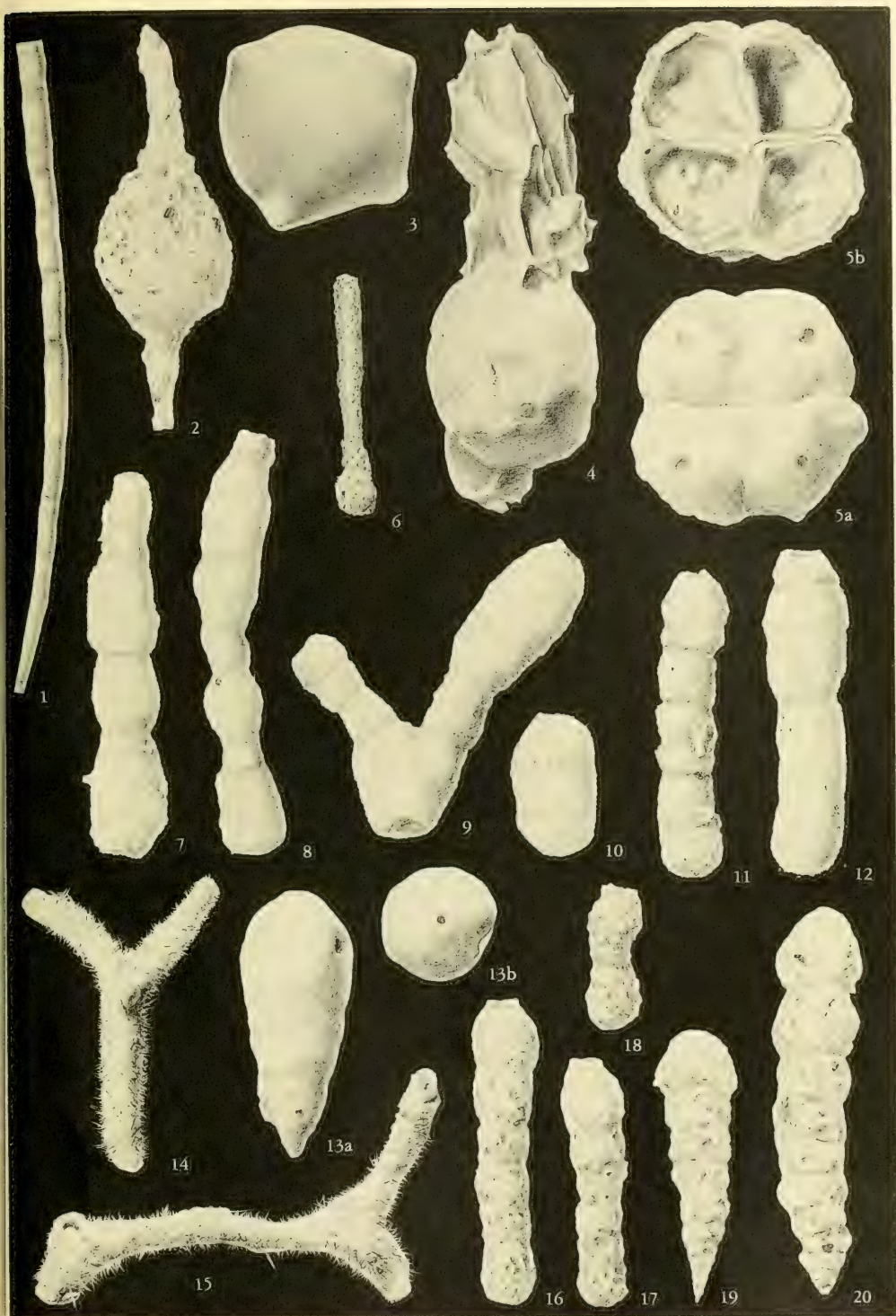
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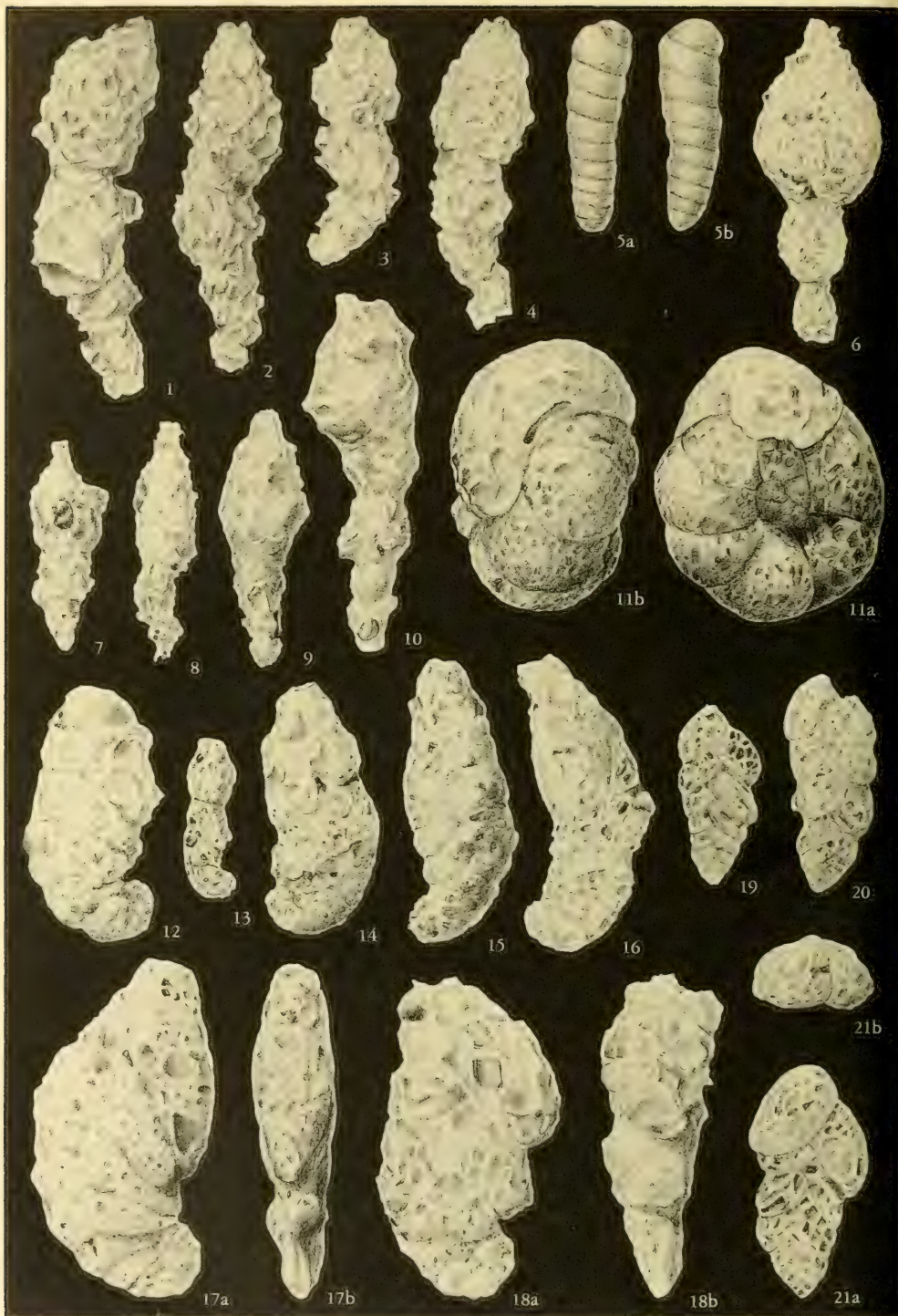
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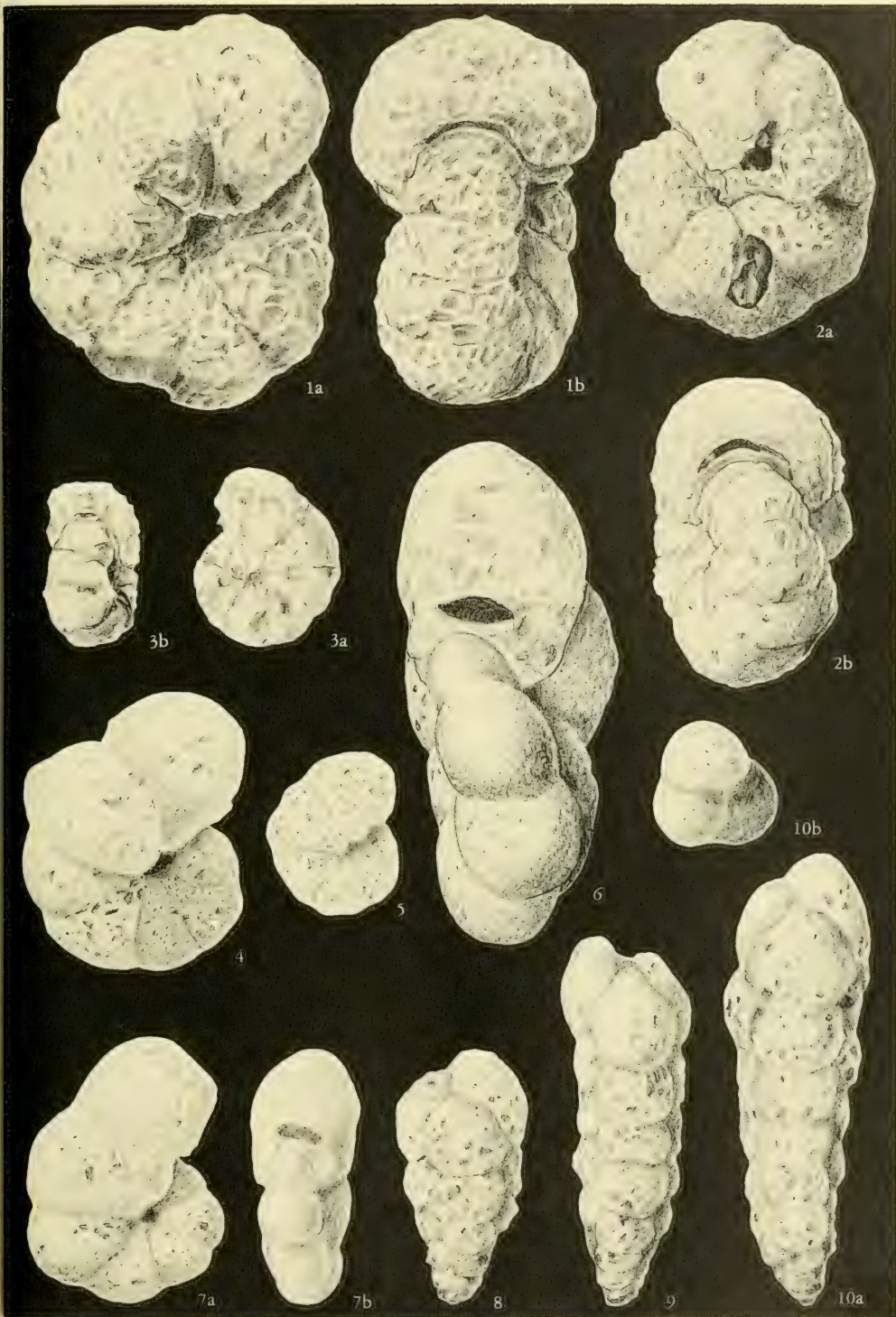
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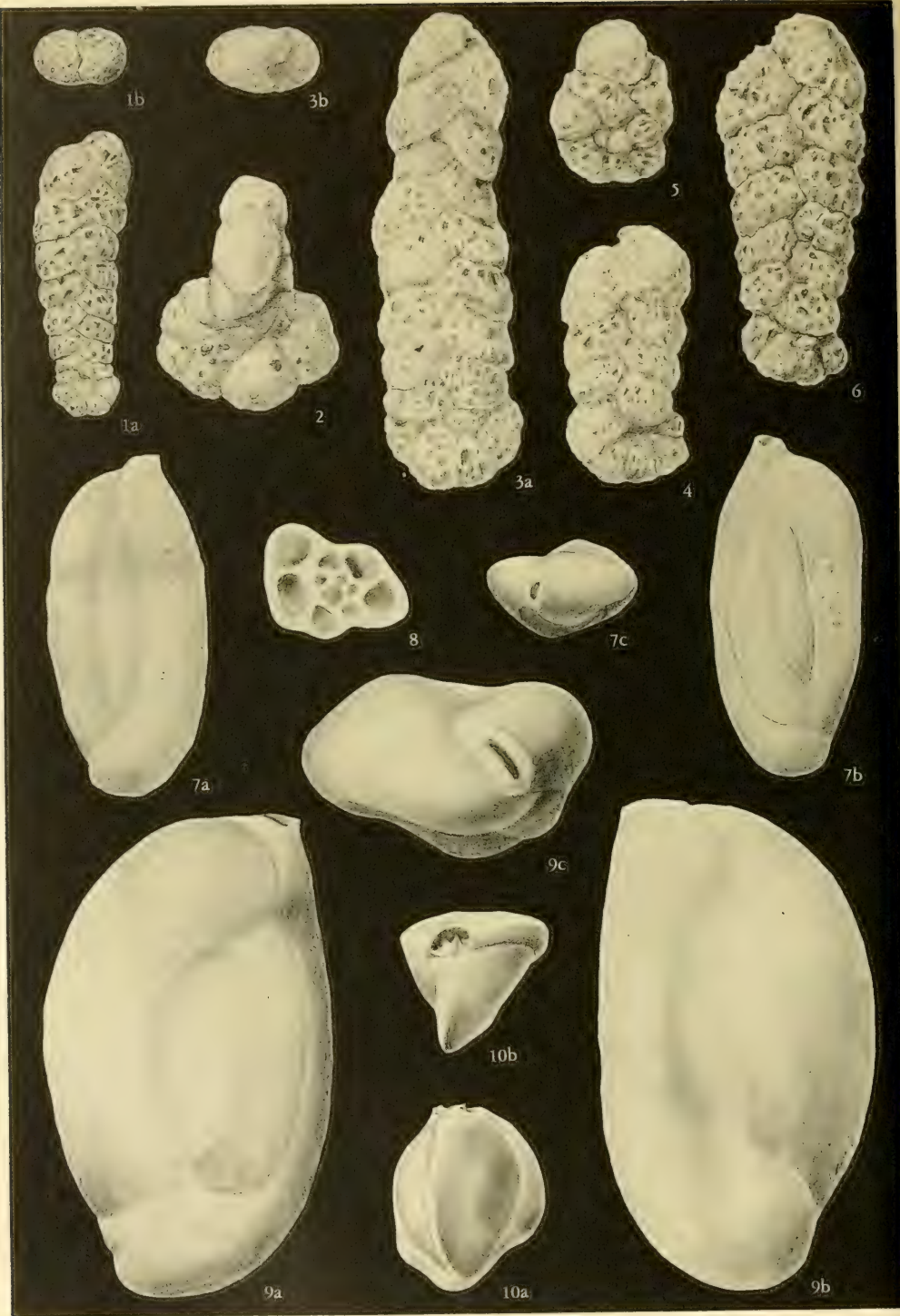
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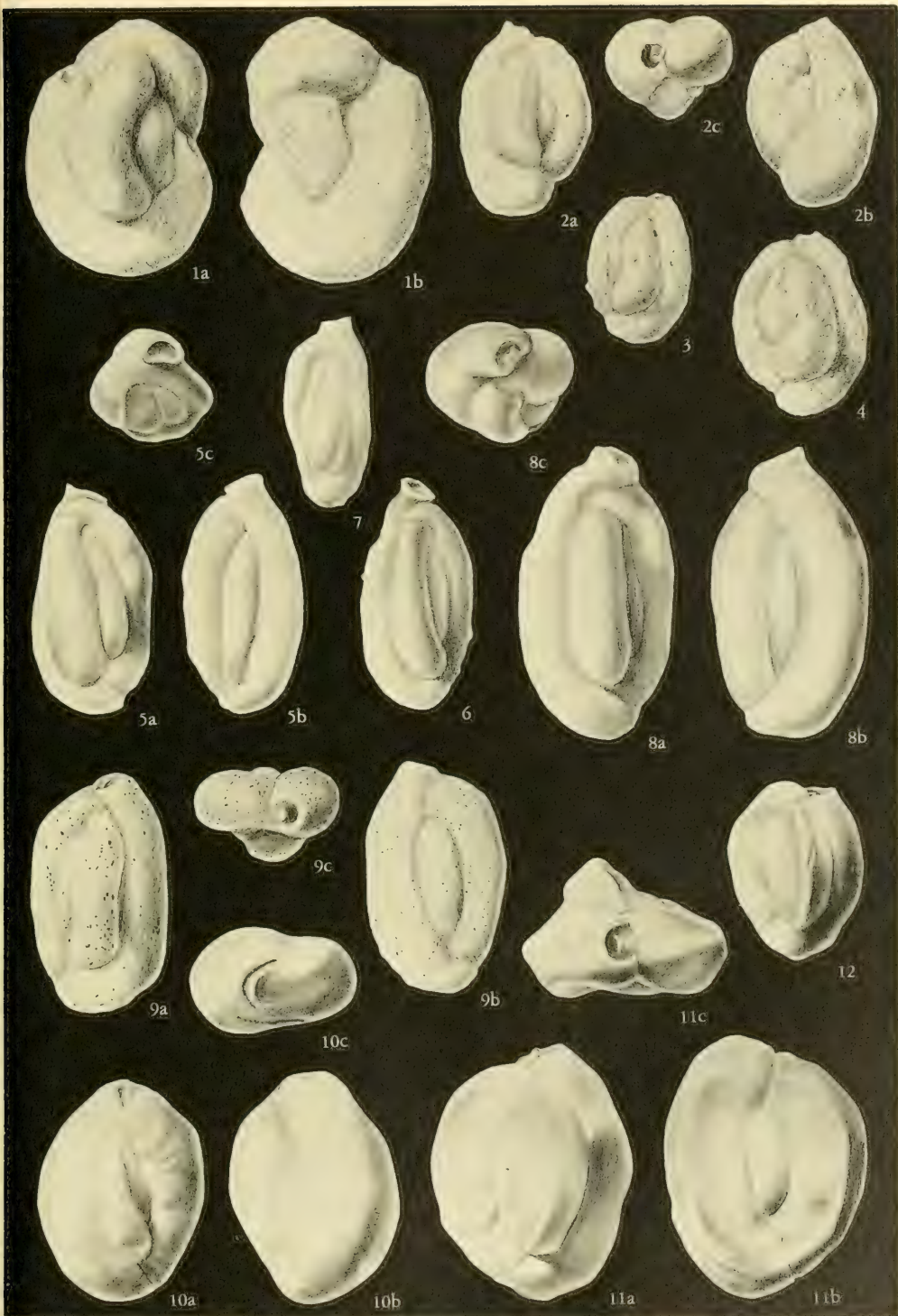


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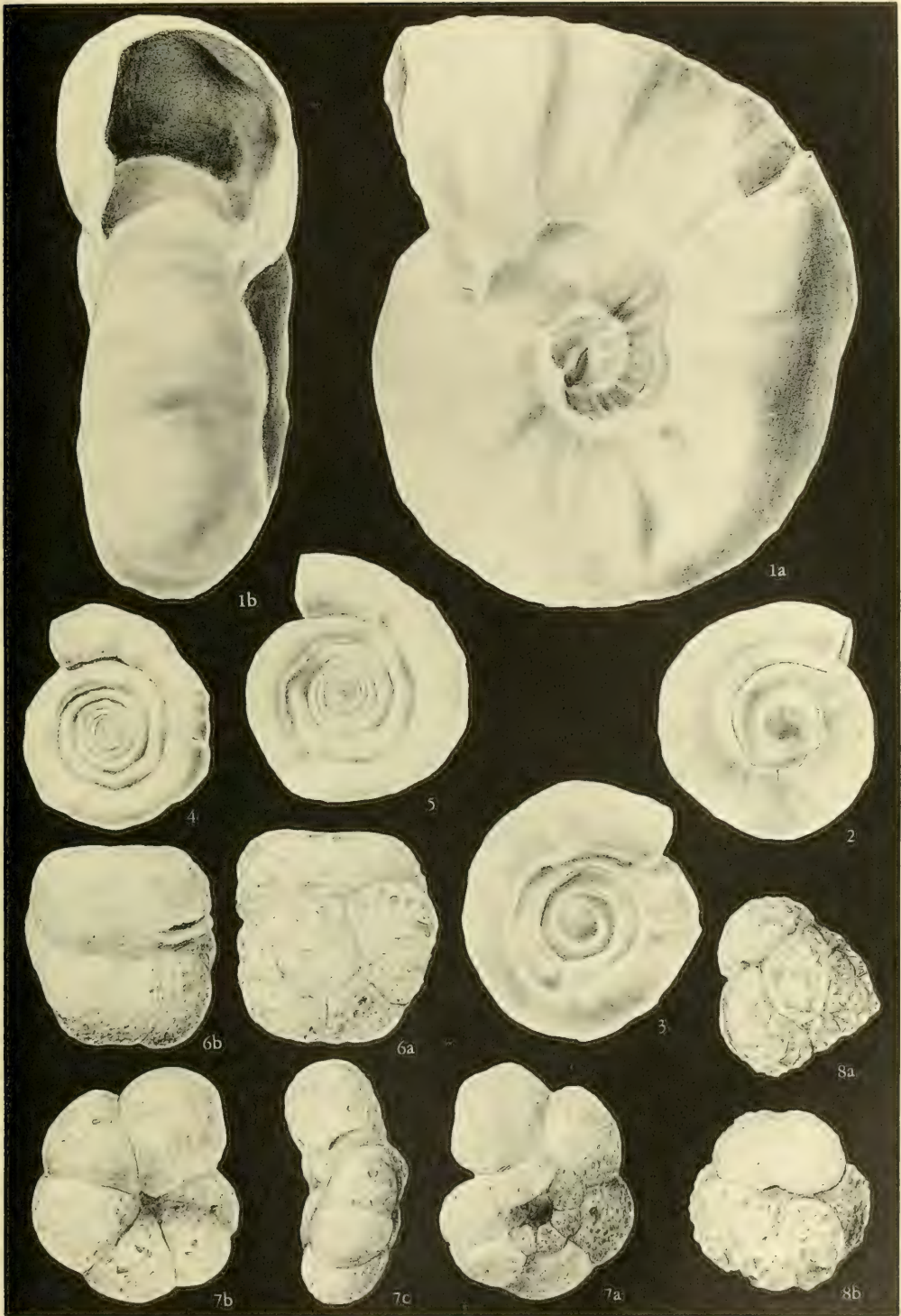
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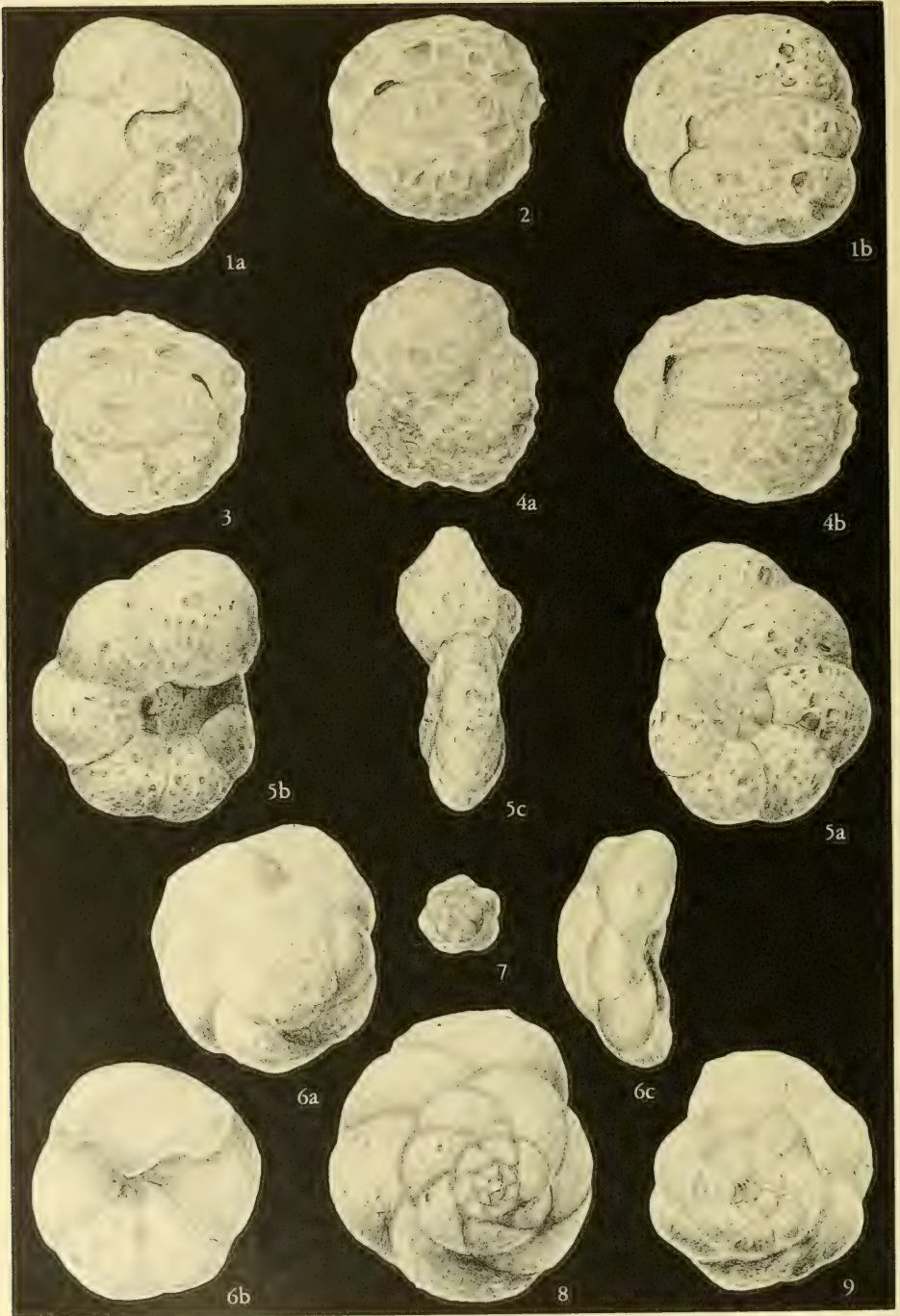


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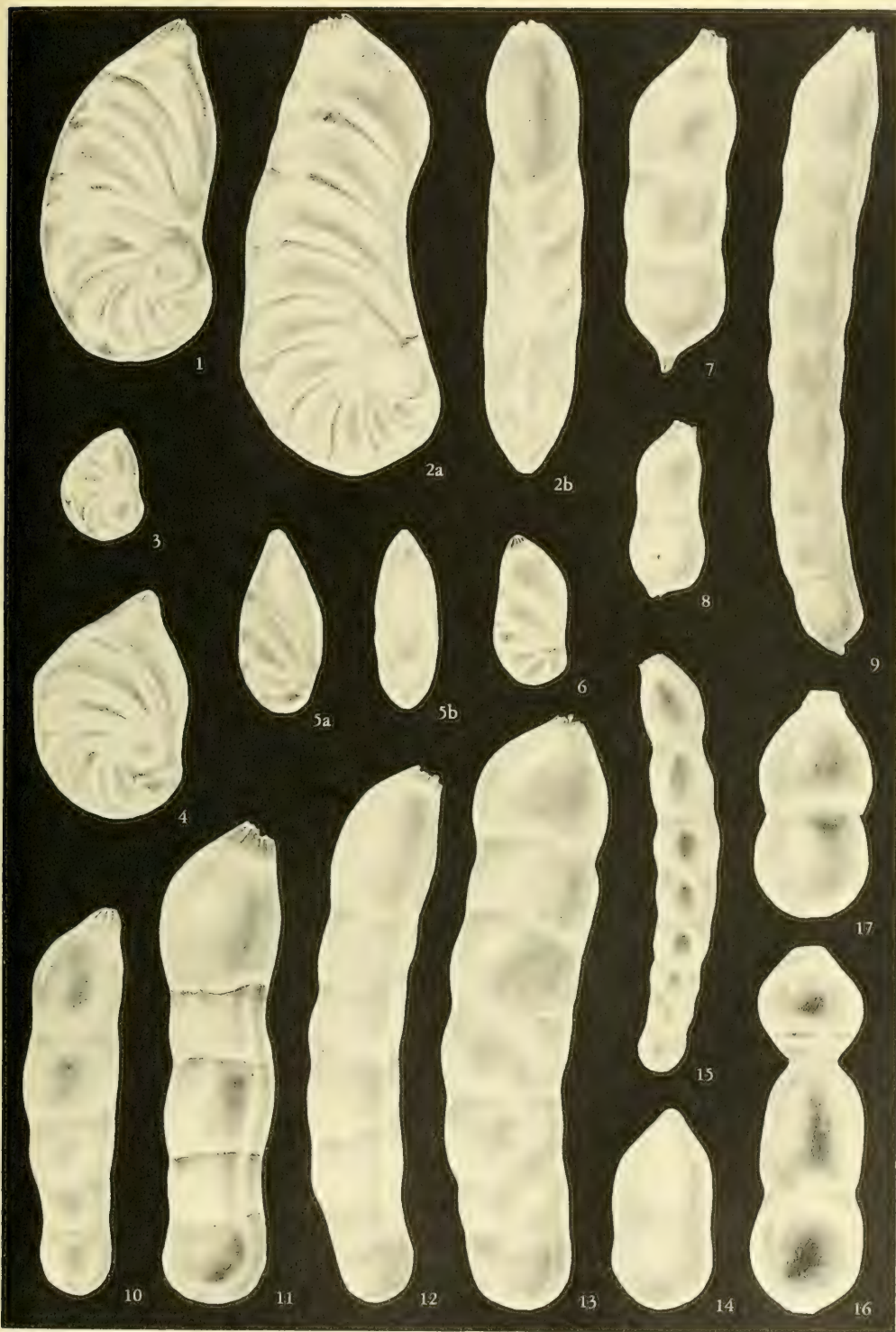


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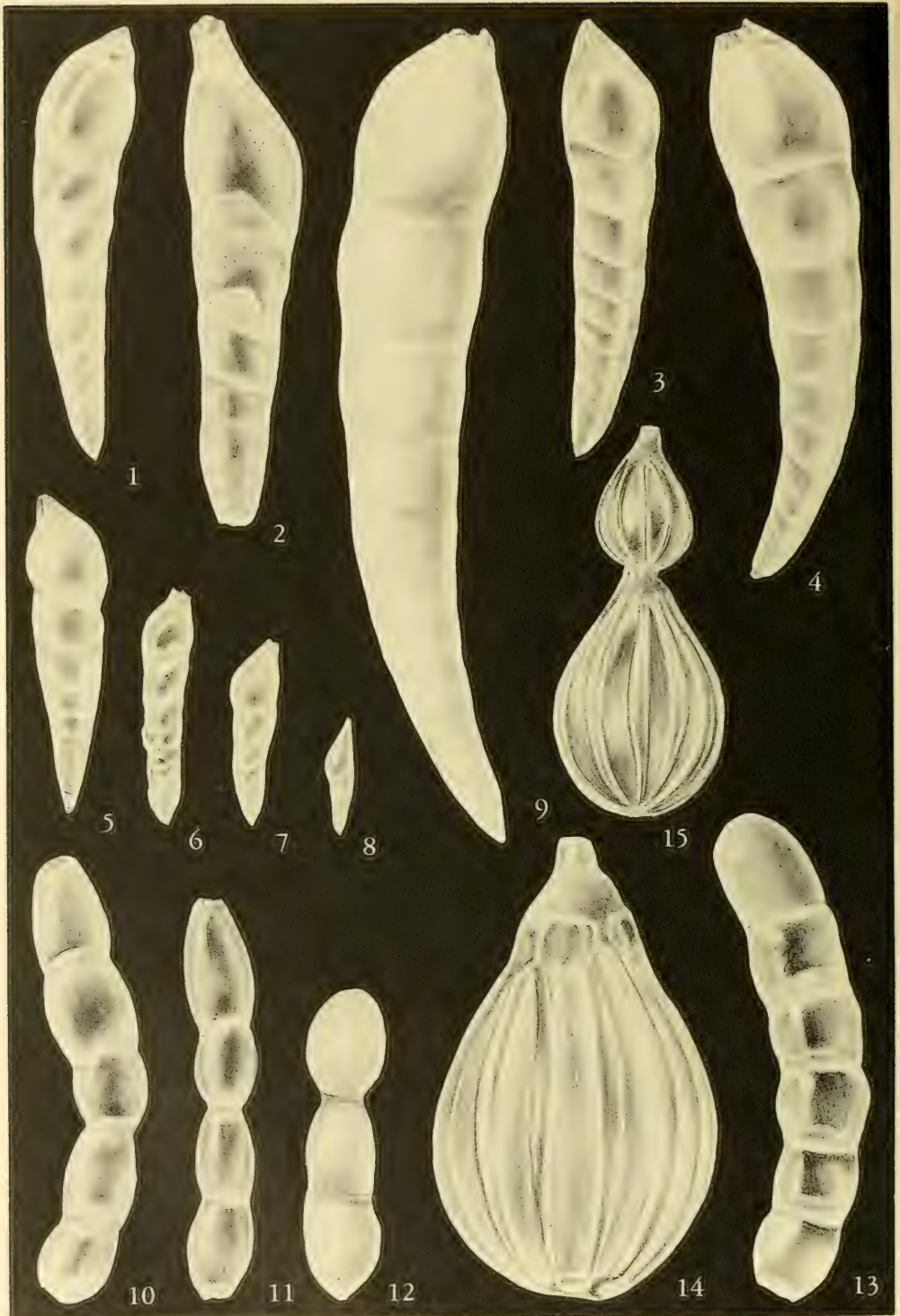
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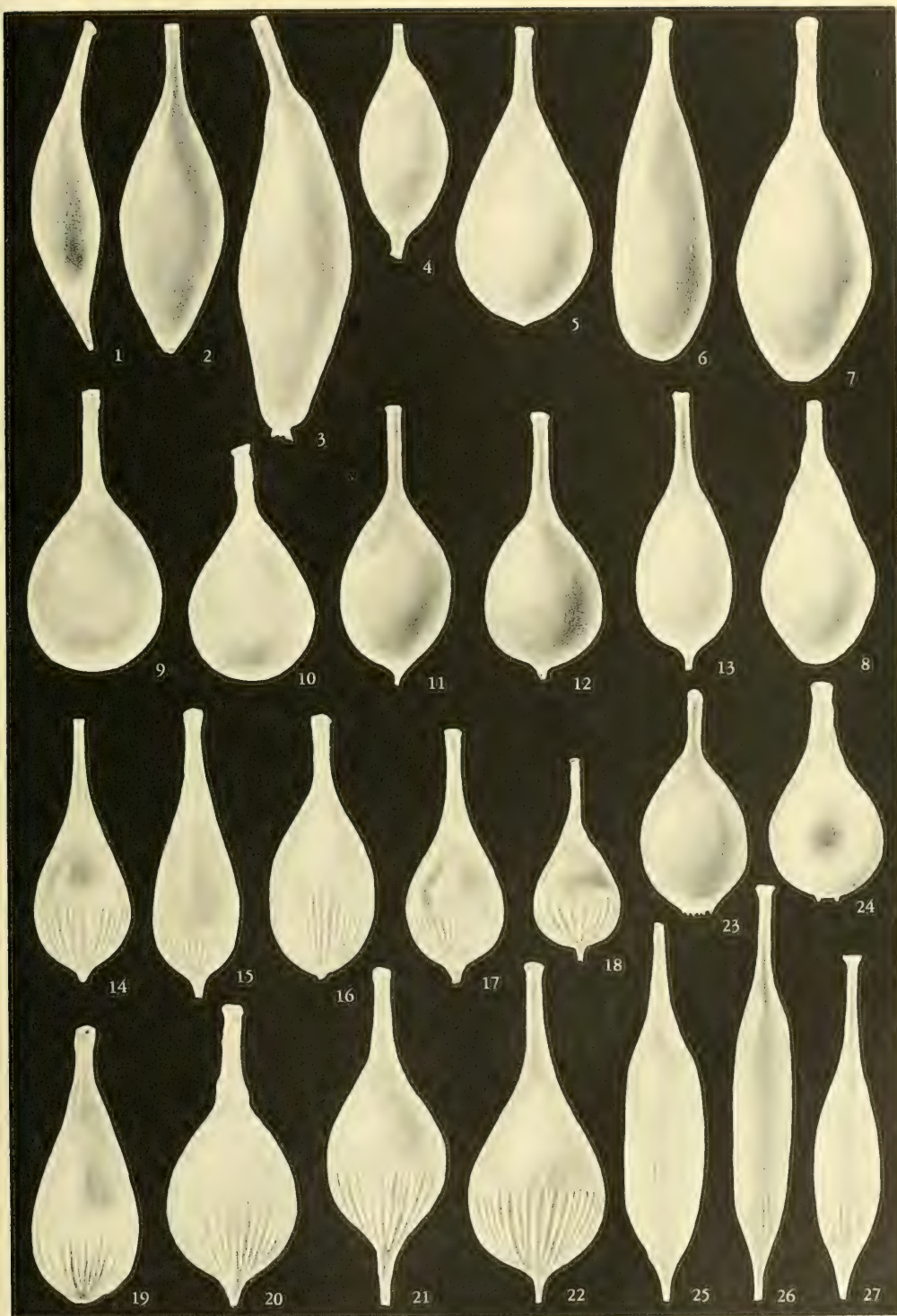
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LAGENIDAE

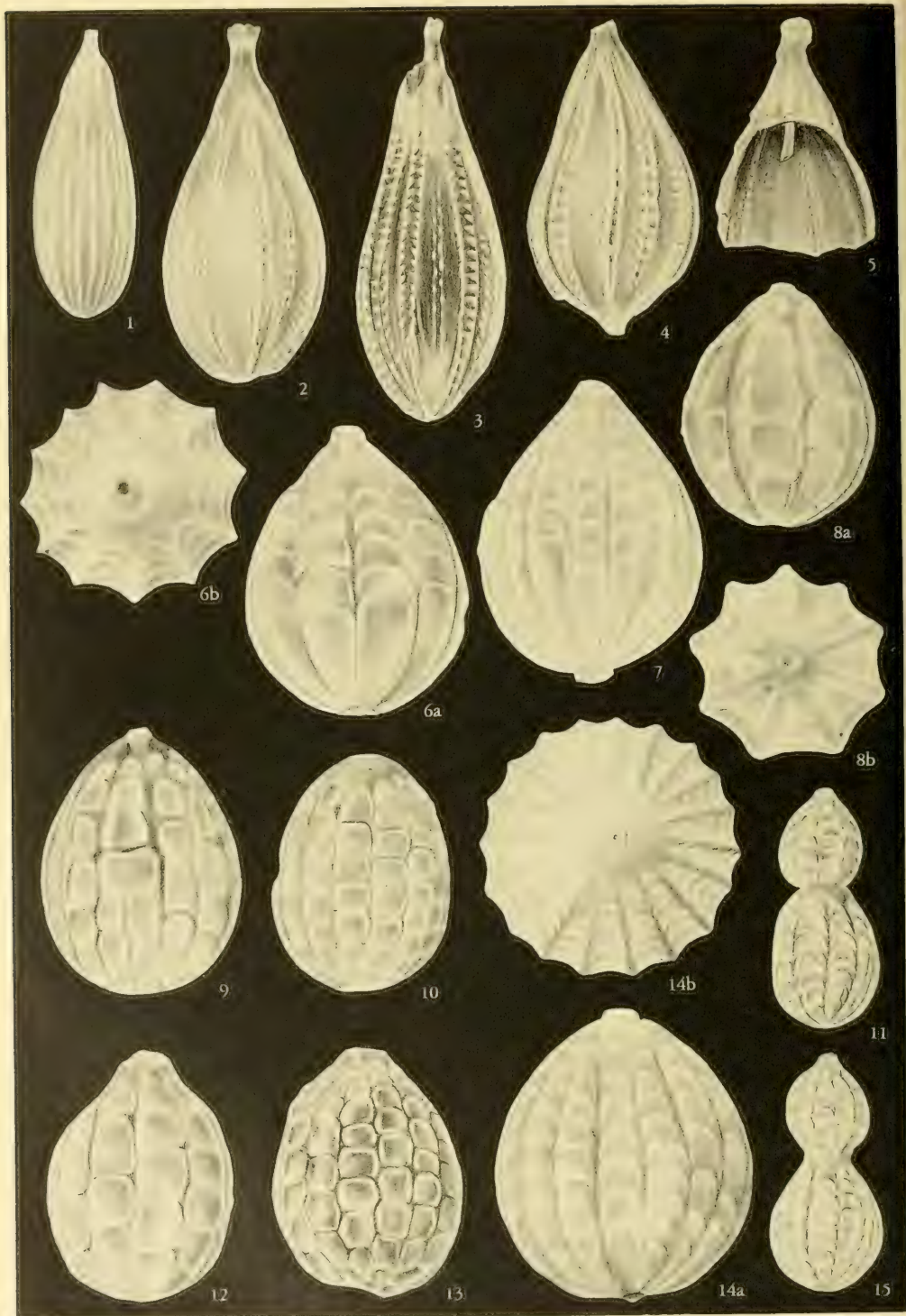
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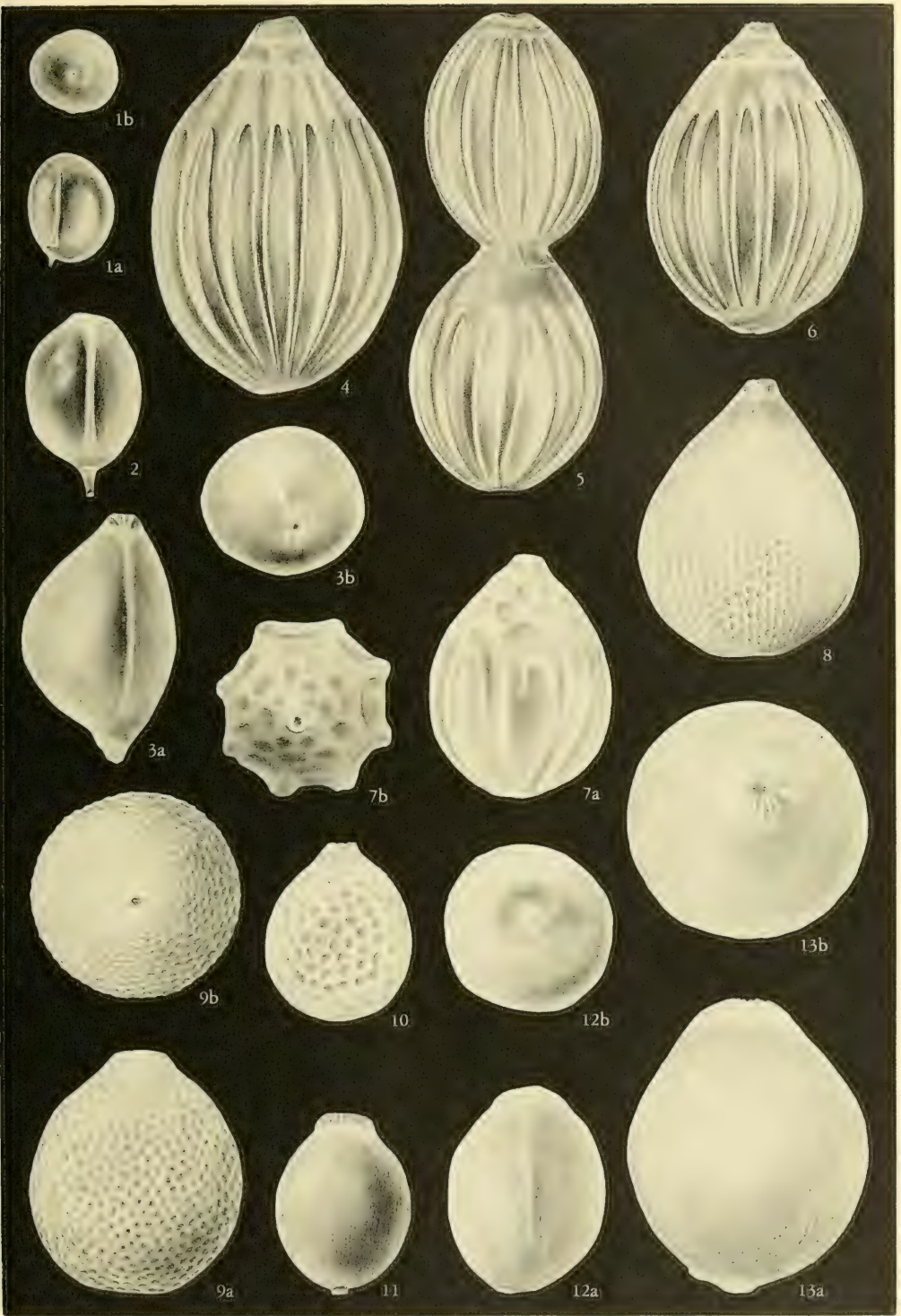
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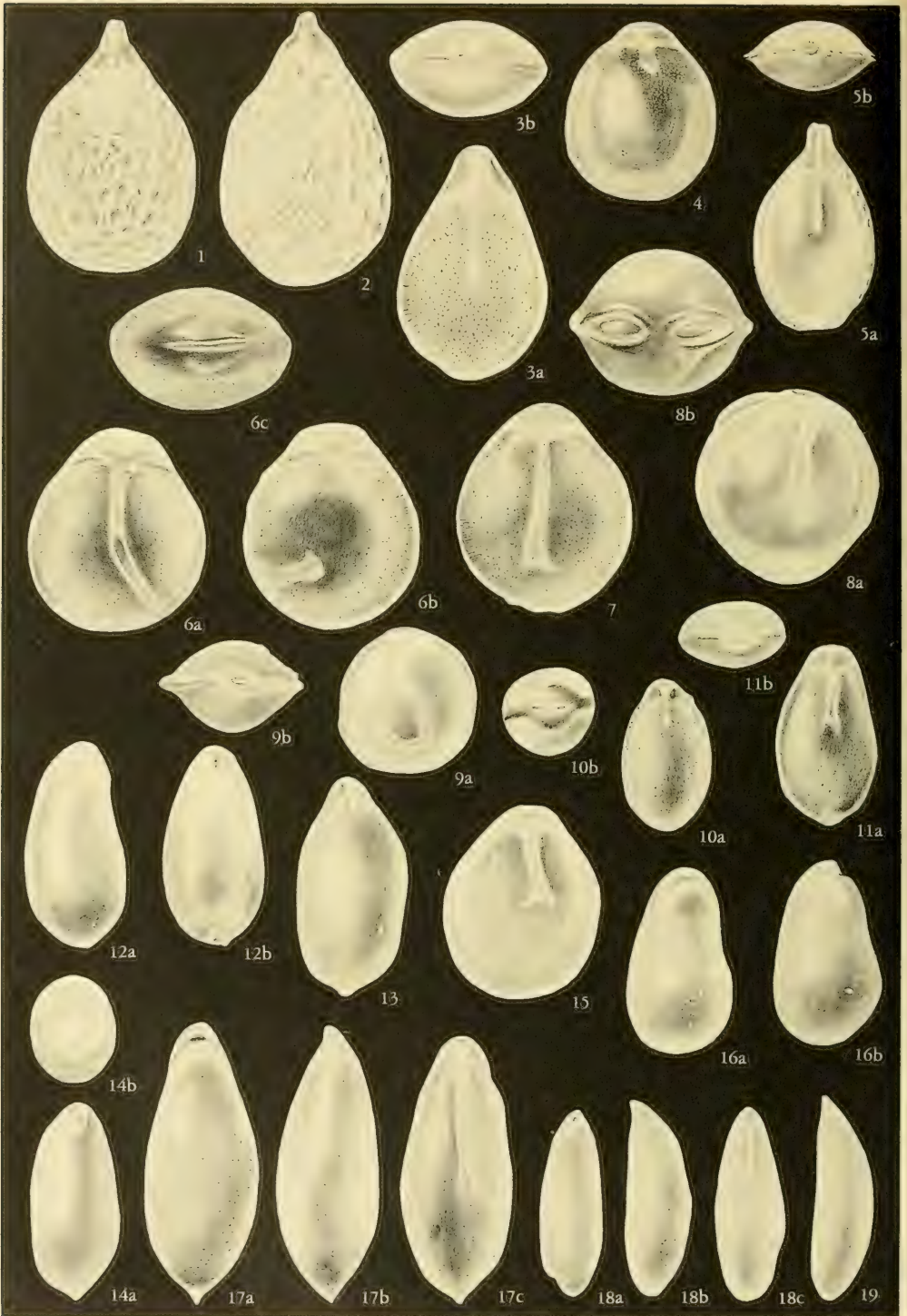
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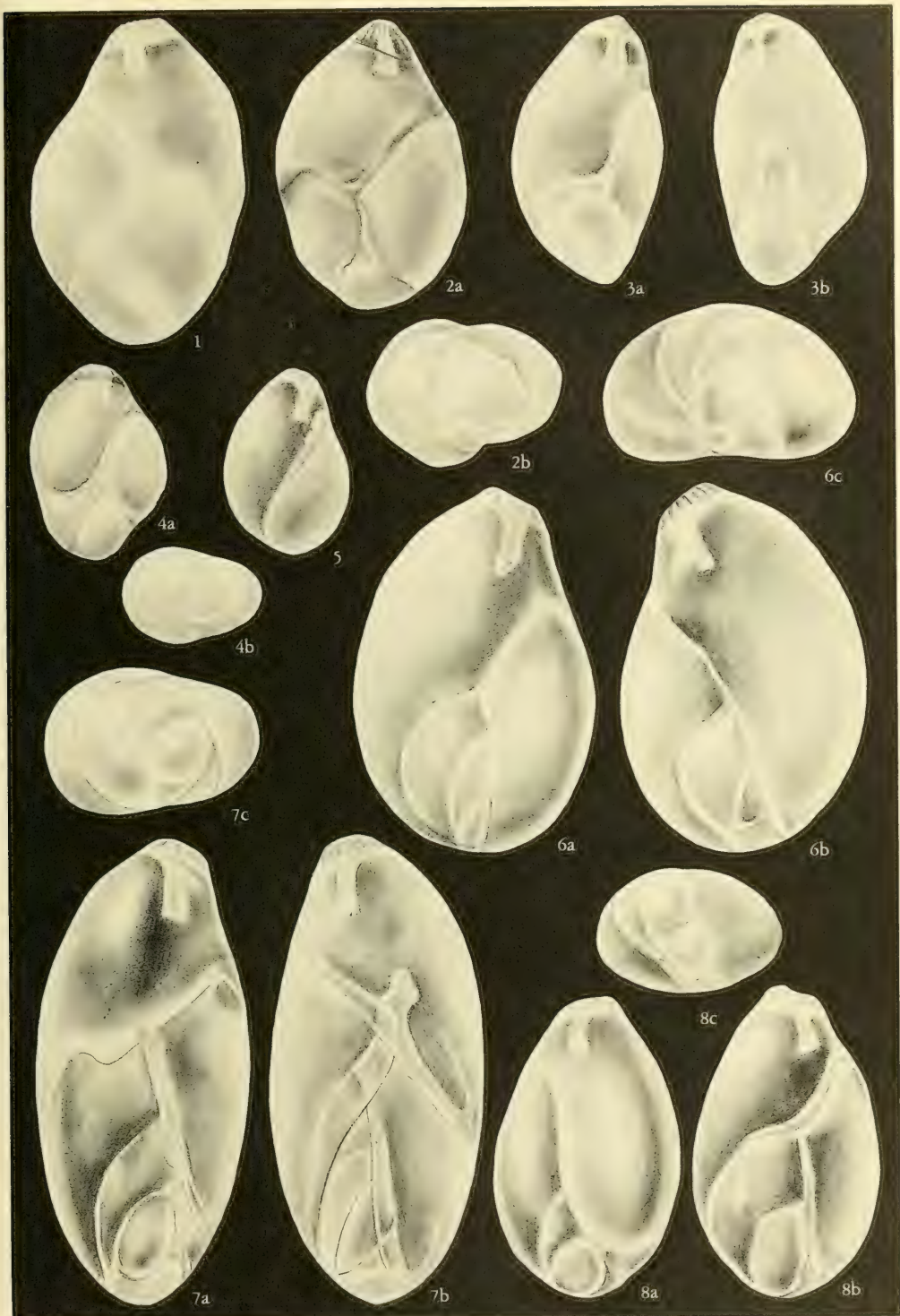
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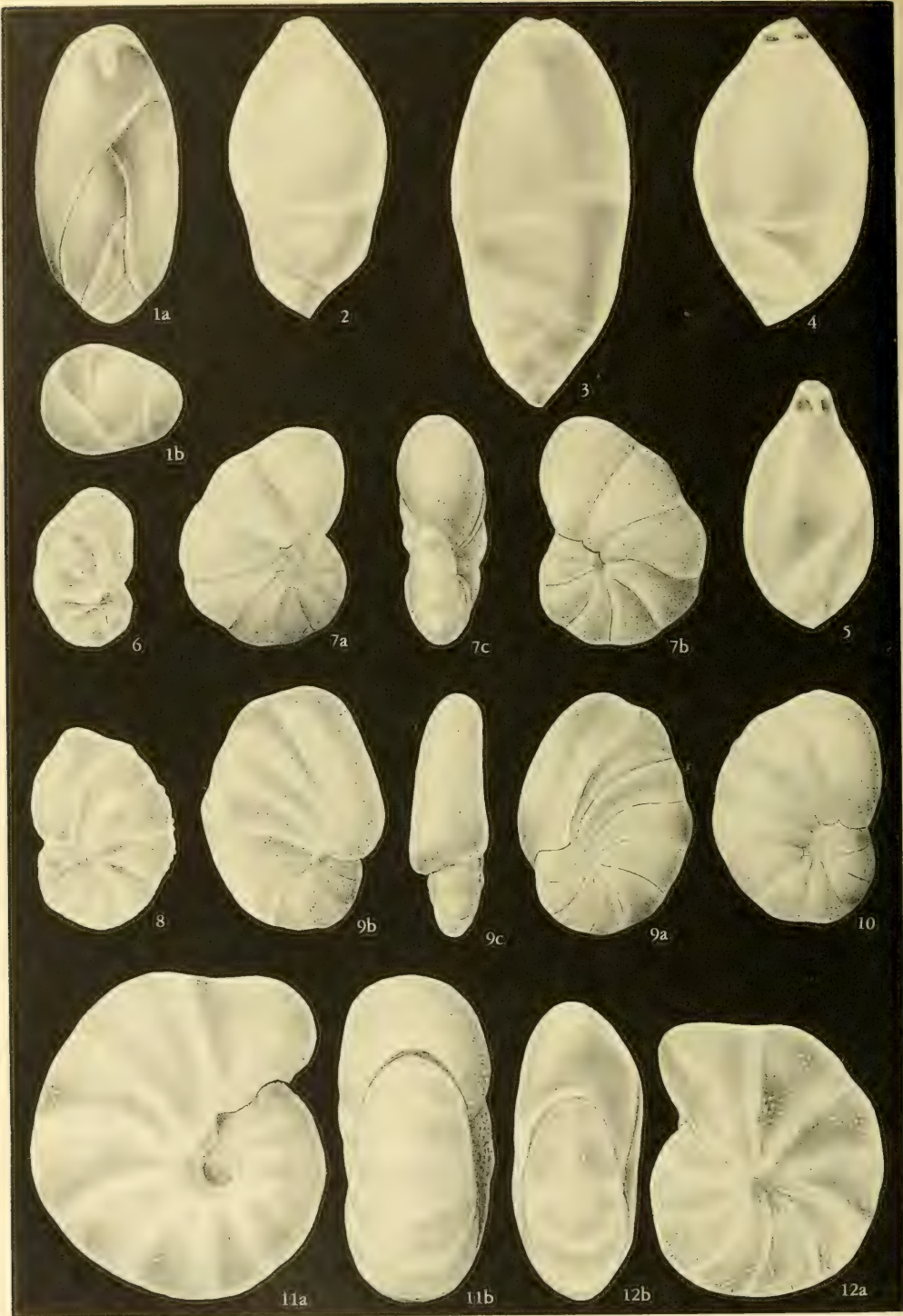
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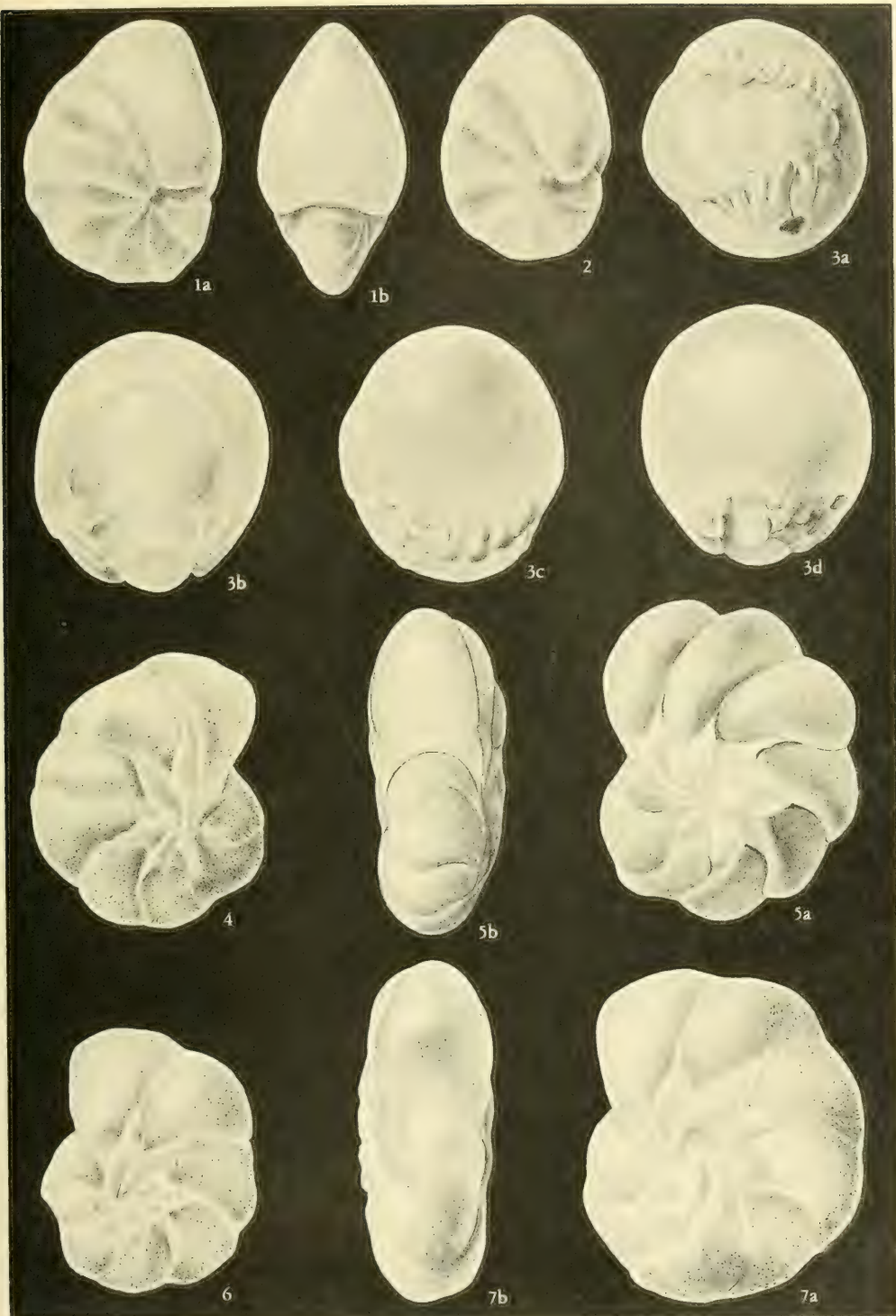
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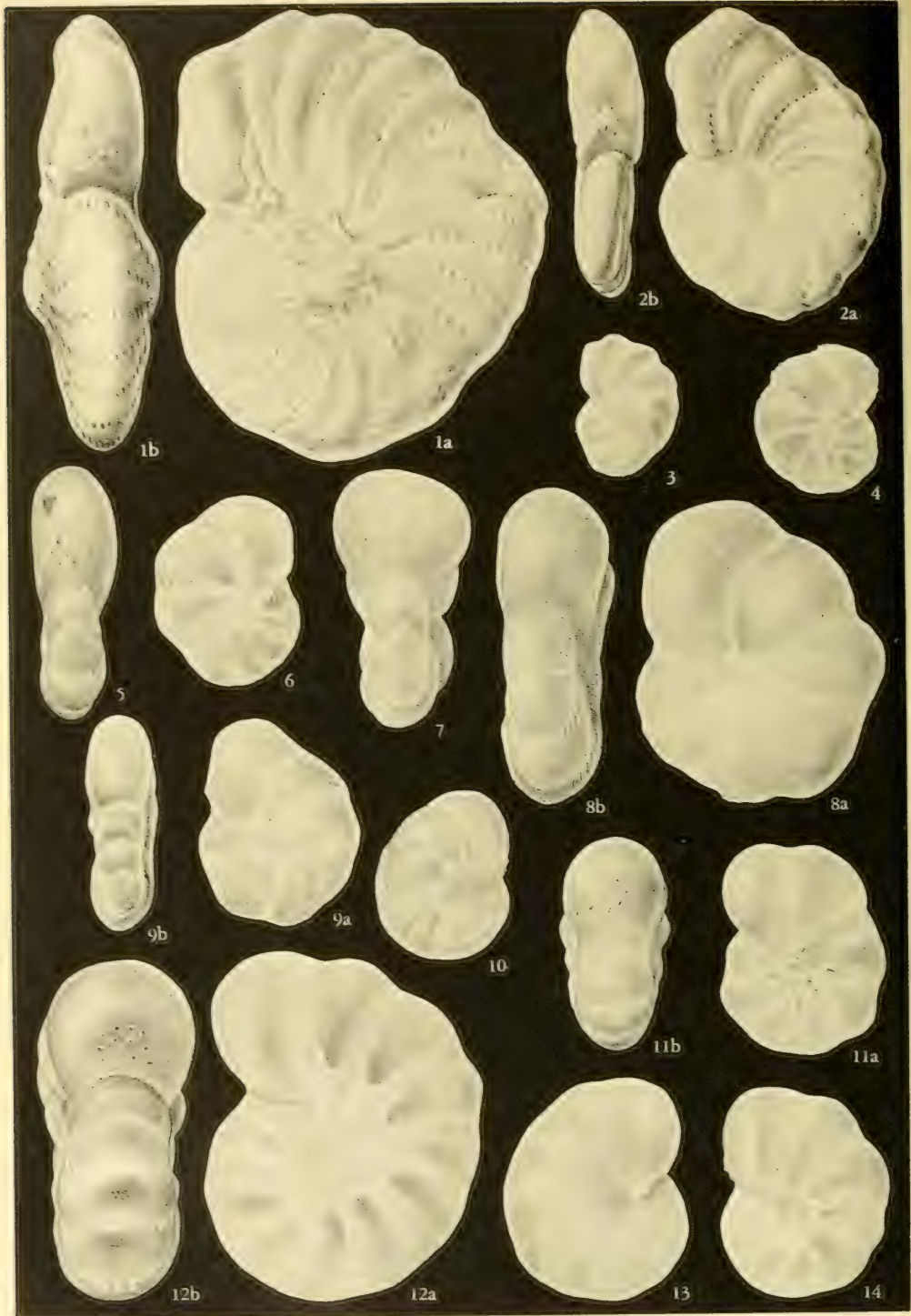
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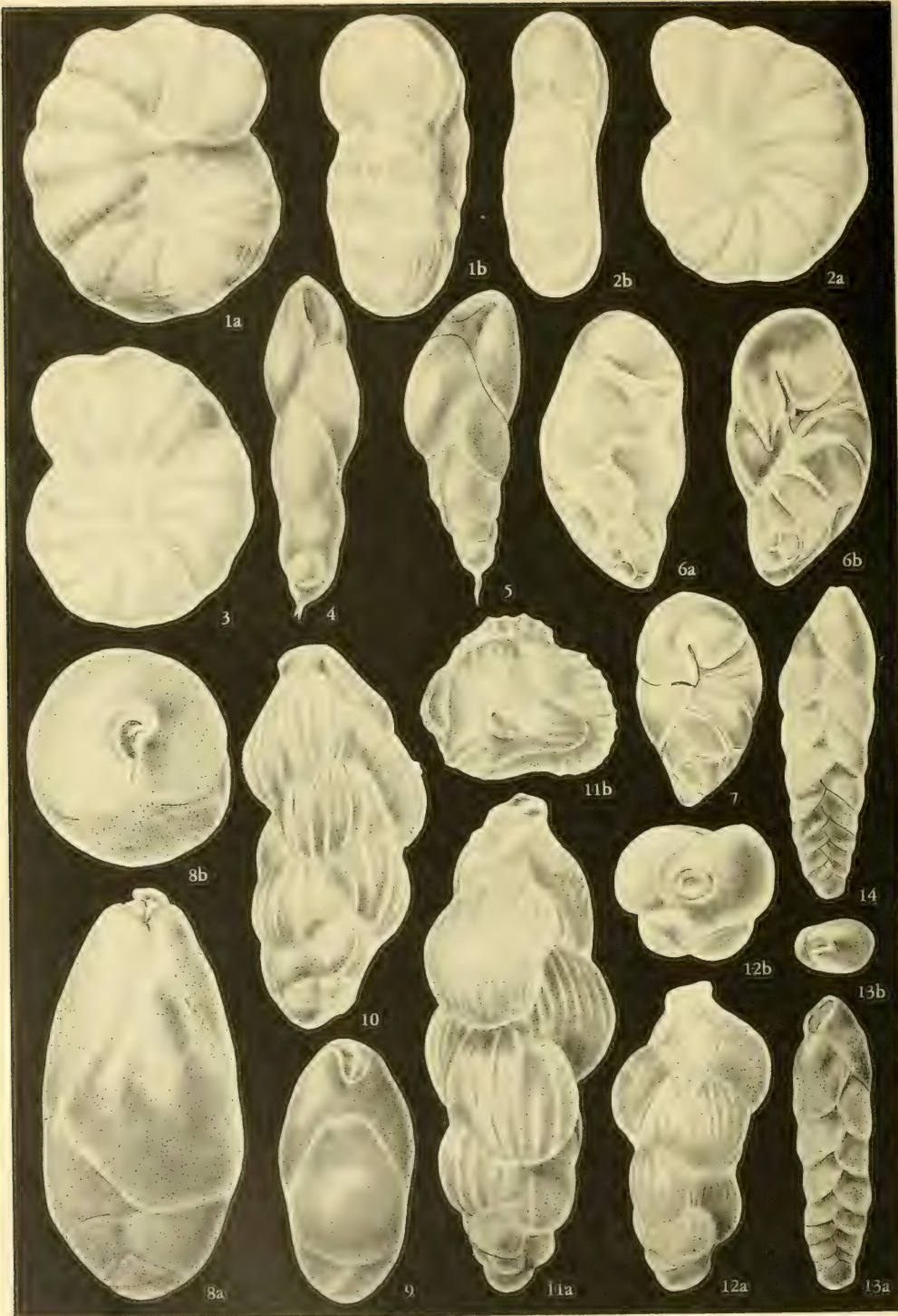
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## ELPHIDIIDAE

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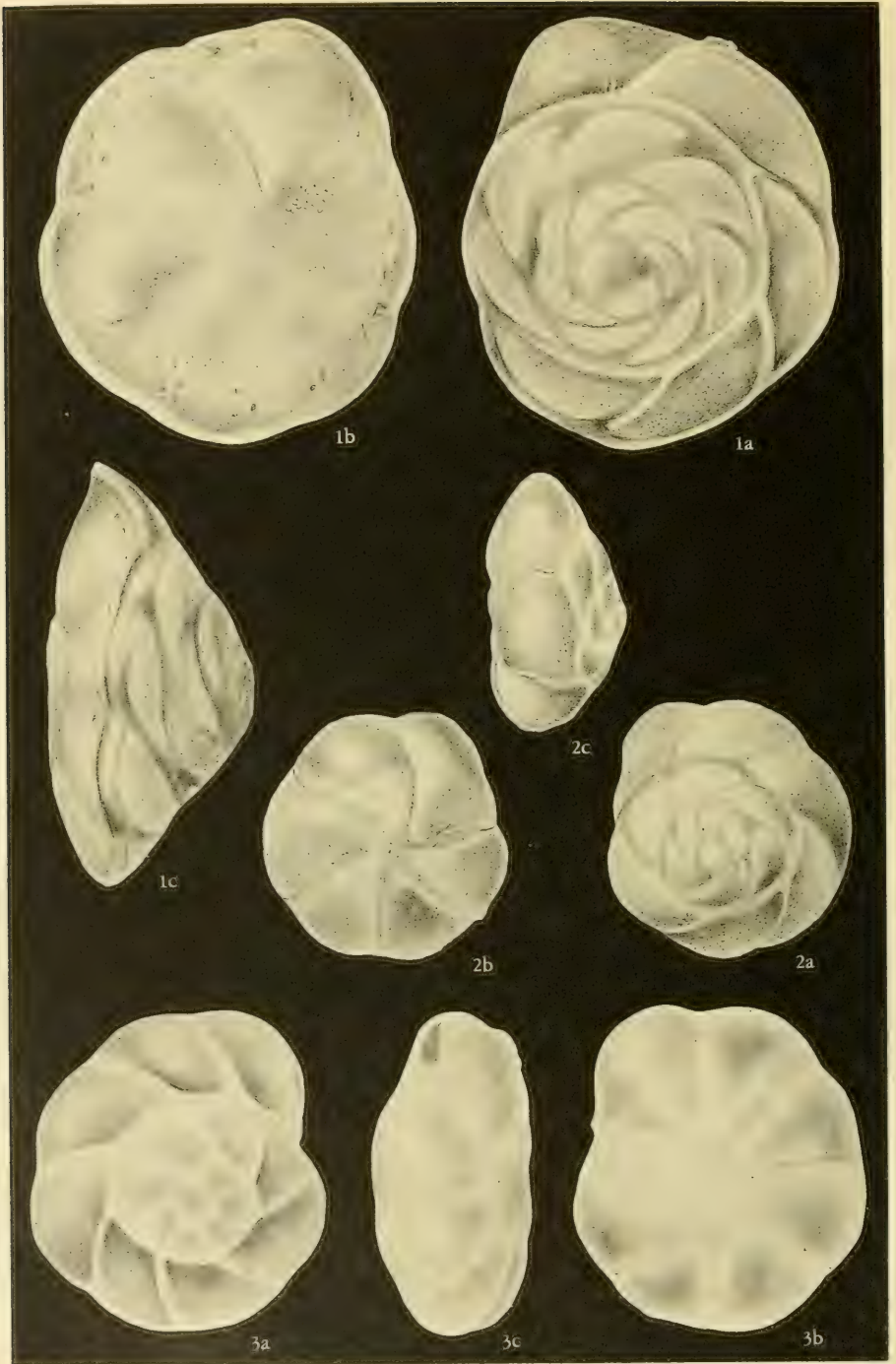
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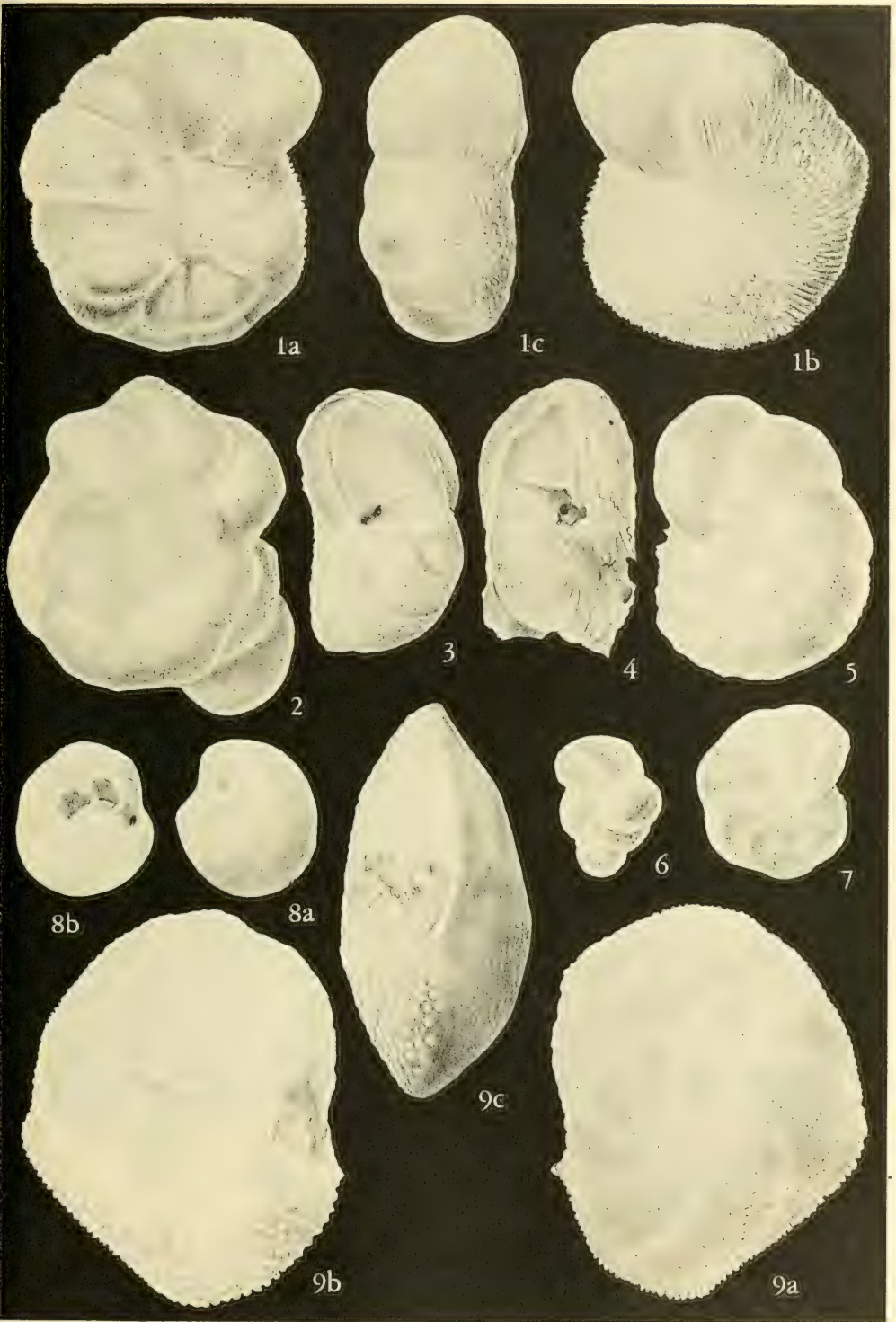
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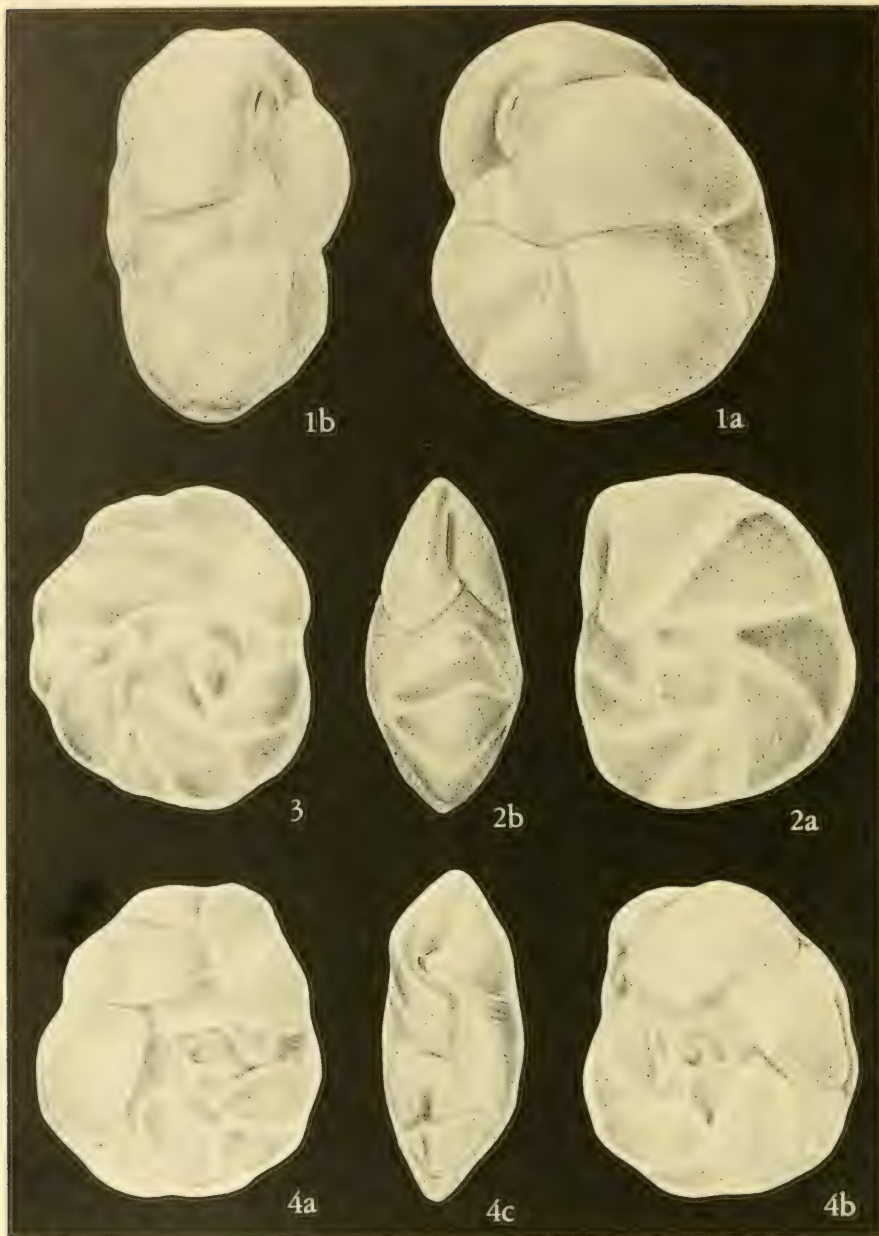
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SMITHSONIAN MISCELLANEOUS COLLECTIONS  
VOLUME 121, NUMBER 8

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BY  
ISAAC GINSBURG  
U. S. Fish and Wildlife Service



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## INTRODUCTION

The present state of the taxonomy of the western Atlantic scorpaenids leaves much to be desired. The literature is filled with inadequate original or supplementary descriptions of species, containing many unessential details of little or no practical use for the correct determination of the species, while the critical characters that distinguish the species often are not considered adequately. I found it well-nigh impossible to identify and distinguish the species properly by the use of current accounts. One of the main factors that operate to bedevil the taxonomist who conscientiously tries to identify his specimens is the undue multiplication by past authors of the number of fictitious species. Such untenable "species" have been established, in large measure, as a result of failure to elaborate properly, or even to take into consideration, the intraspecific range of variability of taxonomic characters, or their change with growth which, in the scorpaenids, is considerable. The multiplication of names that have been proposed for scorpaenid species that have no existence in fact is as confusing as the grouping of two or more closely related species under one name that has entered into the literature of other families.

As a result of this study it was found necessary to reduce to synonymy here for the first time 18 names that have been proposed for supposedly new species, all except one within the past 40 years. The type specimens of 13 of these nominal species have been examined and compared. The other five names are placed in synonymy on the basis of the original descriptions. Three of these descriptions include unique specific characters that indicate their proper placement with assurance, while the other two do not include enough details to make certain their position until the original specimens are reexamined. Where a name is reduced to synonymy the reasons for doing so are discussed under the accounts of the several species concerned.

One doubtful species, *Scorpaenodes floridae*, is here tentatively treated. One specimen, the proper placement of which is doubtful,

is described under *Scorpaena albifimbria*. Also, no specimens of *Pontinus corallinus* Miranda Ribeiro are available for study, as noted under the account of that genus. Three species and subspecies not occurring in the western Atlantic, two European and one from the American Pacific coast, are here treated in order to compare them with their near western Atlantic relatives.

It is of interest and value to compare the results of this study with my recent (1951) revision of the western Atlantic tonguefishes, *Symphurus*. Of the 14 species of *Symphurus* distinguished, 6 proved to be new. On the other hand, 23 scorpaenid species are here distinguished from the same faunal region, and not a single new species has been found, while 17 names established in comparatively recent years are reduced to synonymy. The difference in the results obtained is readily explicable by the difference in the subject matter. The species of *Symphurus* are very similar in general appearance, and most species are hardly distinguishable on sight. It is only after an accurate determination of the numbers of fin rays and scales is made, aided by other characters of lesser importance, that the species become distinguishable properly. This is at least one of the reasons why relatively so many species remained undescribed. Scorpaenid species, on the other hand, are subject, to an extraordinary extent, to a wide range of intraspecific individual variability and growth changes. As a consequence, individual variants, or specimens representing different growth stages of the same species, have been erroneously described as distinct species. The difference in the taxonomic treatment hitherto afforded these two families furnishes an enlightening commentary on current taxonomic methods.

For an adequate account of western Atlantic scorpaenids, a study of the specimens in the National Museum is indispensable. The national collection includes the types of 26 valid or nominal species that have been described, 22 of which are holotypes, the other 4 cotypes or paratypes. What is just as important, in a number of species the specimens in the collection are of sufficient extent to serve as a basis for the determination, with a measure of satisfaction, of the intraspecific range of variability of important specific characters, or the determination of growth changes in such characters. I was fortunate in being able to study this valuable scorpaenid collection from the western Atlantic, and this paper is based largely on this collection. I also examined types and other specimens in the American Museum of Natural History, Bingham Oceanographic Collection, New York Zoological Society, Academy of Natural Sciences of Philadelphia, University of Michigan Museum of Zoology, and the Chicago Natural

History Museum. I am deeply grateful to the authorities of all these institutions for the privilege of studying their material.

The illustrations accompanying this paper were drawn by Mrs. Mildred H. Carrington.

The family Scorpaenidae has been considered hitherto a difficult group from a taxonomic viewpoint, and it is particularly so when current accounts are used for the purpose of identifying the species. By way of illustration of existing uncertainties and errors in the taxonomy of the species concerned, I found about half of the many lots of specimens in the National Museum were either misidentified or identified as to genus only, some of them bearing even an erroneous generic identification. The number of names proposed during the last 40 years, which it was found necessary to reduce to synonymy, as discussed above, is remarkable. However, after determining intra-specific variability and growth changes the difficulties largely disappear, and scorpaenid fishes are then not more difficult to distinguish than species in many another family. In some respects they are easier to distinguish, because the spinous armature of the head furnishes valuable generic and specific characters, as discussed below, that are not present in other families. Characters common to the genera and species here treated are as follows.

## SYSTEMATIC DESCRIPTIONS

### Family SCORPAENIDAE

Elongate, moderately deep to rather slender, moderately to well compressed. Snout short to rather long. Eye medium to large, smaller to larger than snout. Interorbital differing with the species from subequal to eye to one-third the eye. Upper jaw with a broad notch at the symphysis slightly to well developed, tip of lower jaw fitting into the notch; lower jaw with an external knob near its end, slightly to well developed; notch and knob hardly perceptible in individual variants of some species. Mouth of medium extent, moderately inclined, terminal, the jaws subequal, the lower very slightly projecting to very slightly included. Maxillary of moderate length, ending under anterior margin of pupil to under posterior margin of eye or a little behind. Teeth in jaws on vomer and palatines, except palatine teeth lacking in *Scorpaenodes*; small, subequal or inner teeth in jaws slightly enlarged in some species; those in jaws in narrow bands of medium width, those on vomer and palatines differing from one row to bands of medium width. Opercle with 2 spinous points, not extending beyond its margin; the 2 spines forming tips of divergent ridges in most

species, the ridges faint or absent in some species. Head with spines occupying definite positions. (The spines and their nomenclature being of much taxonomic importance are treated separately below.) Upper outer corner of interopercle and lower outer corner of subopercle ending in an acute angle or rather sharp spinous point as an individual variation in some species. Cheek with a lengthwise bony stay extending from preorbital to preopercle forming a ridge externally, usually bearing spinous points (hereafter designated as the suborbital ridge). Gill opening wide, branchiostegal membranes forming a slight fold under eye. No gill slit on inner side of fourth arch or a small slit present. Pseudobranchiae well or moderately developed. Gill rakers in most species short, broad, comparatively few, those at both ends of arch very short, tubercle-like, the gill rakers grading very gradually into the tubercles or a rather indefinite line of demarcation between them, rather well delimitable in some species. Various appendages on head, body, and also upper part of eyeball, varying from rather long, stout tentacles on upper margin of orbit to short, broad tabs and slender filaments, their development varying widely and to a large extent dependent on individual variability; also governed by average species differences, only of limited value for the definitive distinction of the species. Lateral line normal except in *Setarches parmatius* (see account of this species). Scales ctenoid or cycloid, in 40-110 transverse rows; body scaled all over, including chest and fleshy pectoral base (more or less embedded in latter two situations in some species, sometimes not visible at the surface); head partly or almost wholly scaled; caudal and pectoral moderately scaled at their base; dorsal and anal moderately or slightly scaled at their base in some species; fins otherwise scaleless. Dorsal typically or predominantly with 12, 13, or 15 spines, depending on the genus, the number of variants from the predominating counts very few, except in *Sebastes*; with 7-15 soft rays; first three spines rapidly graduated, fourth spine usually longest in most species, slightly longer than third or fifth, sometimes third or fifth slightly longer than fourth as a slight average specific difference or as an individual variation (except in *Pontinus longispinis* and in the males of *Neomerinthe beanorum* the third spine notably prolonged beyond the others), thence decreasing in length to penultimate; last spine considerably or moderately longer than penultimate, emargination of fin between last two spines moderate or pronounced, depending on the species. Anal with 3 spines; normally with 5 rays, the number of variants from the normal very few, except with 7-10 rays in *Sebastes marinus*; first spine much shorter than second; third varying between moderately longer or



shorter than second. Outer ventral angle under lower pectoral angle differing a little both ways, its end reaching anal origin or falling short of vent. Pectoral with 15-24 rays, the upper 4-10 rays, except uppermost 1-3, branched, the lower ones unbranched, more or less thickened and free at their tips, or all unbranched (in *Pontinus*); end of fin on a vertical differing from moderately in front of anal base to a little behind, its shape differing to some extent with the genus (see fig. 4). Caudal rounded or slightly emarginate.

#### SOME TAXONOMIC CHARACTERS, THEIR DEFINITION AND METHODS OF STUDY

*Spines on head.*—The distribution and development of the spines on the head constitute valuable specialized characters that aid in the distinction of the species and genera of this family. This is in addition to the taxonomic characters generally employed in ichthyology for the distinction of species and genera, such as the nature and extent of the dentition; counts of fin ray supports, gill rakers and scales; the shape and extent of the fins and parts of the head and body; proportional measurements; etc. As a consequence, scorpaenid genera and species are potentially distinguishable with greater ease and adequacy than those in some other families of fishes. One of the main reasons this has not proved to be so hitherto and the resultant unsatisfactory state of scorpaenid taxonomy at present is the general lack of a uniform nomenclature in designating the various spines, which often makes it virtually impossible to correlate accounts by different authors, or to understand adequately the precise structure of the species from the description given by any one author. To overcome this difficulty, the nomenclature of the spines as used in this paper is hereafter stated and the relative positions of the different spines are illustrated in figures 1 and 2, which represent *Scorpaena plumieri*. This species has been selected for illustration because it is a widespread species which is not uncommon, and it has the full complement of the important spines possessed by the species here treated, with the exception of the inter-orbital spines that, among these species, are present only in *Scorpaenodes*. In the species figured, a so-called spine is often not a spine in the true sense of the word—that is, it is not a slender bony structure with a sharp point. It is rather a blunt point at the summit of a flat, somewhat shelflike bony projection. However, the real spinelike projections and the broad, blunt projections are evidently homologous, and all are hereafter spoken of as spines. The nomenclature here used for the spines follows.

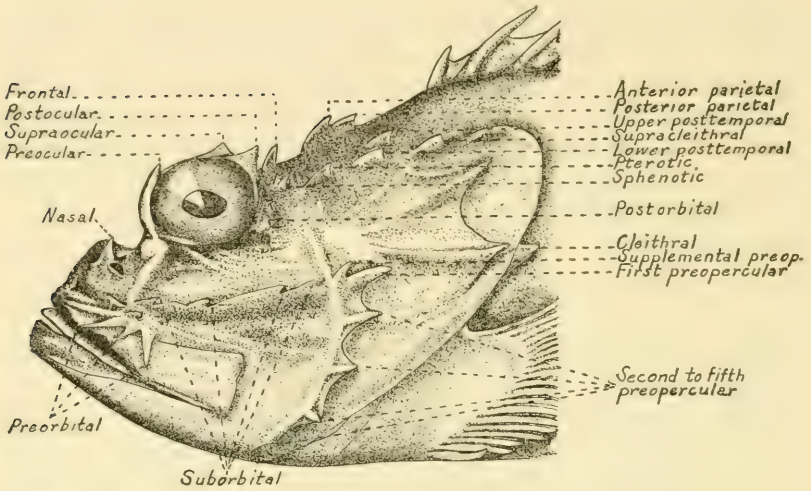


Fig. 1.—Side view of the head of *Scorpaena plumieri* showing the spines and their nomenclature as used in this paper. Semidiagrammatic. Drawn by Mildred H. Carrington.

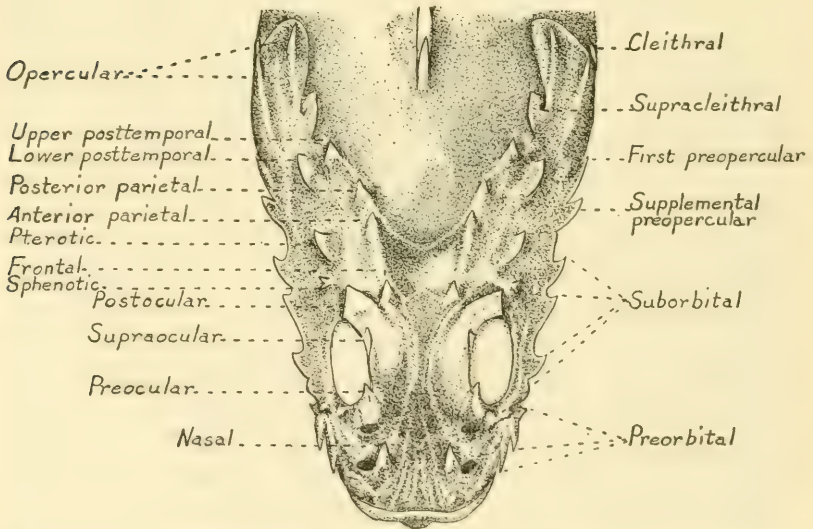


Fig. 2.—Dorsal aspect of the head of *Scorpaena plumieri* shown in figure 1. Drawn by Mildred H. Carrington.

**NASAL:** A spine located dorsad of the nostrils, nearer to one or the other nostril or equally distant from the two. It is present in all the species here treated, but its extent of development differs with the species. The presence of this spine is not further mentioned under the accounts of the genera and species, except where its degree of development is unusual.

**PREOCULAR, SUPRAOCULAR, POSTOCULAR:** Three spines on the upper orbital rim, one approximately over the anterior margin of the pupil; the posterior two much closer to each other than to the anterior one, placed approximately over the posterior margin of the pupil. The preocular is present in all the species here treated; the supraocular and postocular are present in all except *Setarches parmatius*. Therefore, the presence of these spines is not especially mentioned under the accounts of the other genera and species.

**INTERORBITAL:** Two spinous points on interorbital space, each at the end of a ridge, one on each side of the midline. These spines are present only in *Scorpaenodes* and are not further mentioned under the accounts of the other genera and species.

**PARIETAL, ANTERIOR AND POSTERIOR:** The parietal ridge is placed a little to the side of the middorsal line, between the eye and the dorsal origin and a little nearer the eye. It is split into two parts, both ending in spines, except in *Sebastes marinus* and *Setarches parmatius* in which it is entire, ending in a single spinous point. The two spines are hereafter designated as the anterior and posterior parietal, the anterior one lacking in the two exceptional species mentioned.

**FRONTAL:** A spine placed at a short distance behind postocular; in front of and in a line with parietal ridge, or nearly in a line with postocular and somewhat laterad of parietal ridge. This spine is present in all species except *Setarches parmatius*, and disappears with growth in *Scorpaena grandicornis*.

**SPHENOTIC:** A comparatively small spine or spinule directly behind eye at a moderate distance below frontal. It is often bifid, or it consists of a group of spinules or asperities. It is subject to considerable intraspecific individual variation and is of only secondary importance in classification.

**PTEROTIC:** When present it is usually in the form of a ridge ending in a spinous point, placed at a moderate distance behind the sphenotic.

**POSTTEMPORAL, UPPER AND LOWER:** Two spinous points, one above the other, at a rather short distance in front of angle formed by the attachment of the opercle to the side. Often each forms the end point of a ridge. Both are subject to considerable intraspecific individual variability in some species.

**SUPRACLEITHRAL:** Placed at the upper angle of the gill opening. It is usually a blunt bony angle rather than a spine. In *Scorpaenodes* the exposed part of the supracleithrum is long, tapering, and ends in a sharp point.

In the species of *Scorpaena*, on the dorsal aspect of the head behind the eyes, the above spines in general are arranged in three somewhat irregular lengthwise rows; an inner row near the midback including the frontal and anterior and posterior parietal; an outer row approximately through the upper margin of the pupil consisting of the sphenotic, pterotic, and lower posttemporal; a row in between comprising the upper posttemporal and supracleithral. In *S. calcarata* the arrangement differs somewhat, and it is not altogether the same in other species of *Scorpaena*. In species of other genera the arrangement does not always quite follow the pattern outlined above.

**POSTORBITAL:** A spinule, entire or bifurcate or doubled, or a group of spinules or asperities, or one or more small tuberosities placed on a horizontal approximately through middle of eye and behind it. This is subject to a good deal of individual variability and is not of much importance in classification.

**CLEITHRAL:** A projection on the cleithrum in a position a little above the pectoral base, with a blunt apex or ending in a rather sharp spinous point. This projection is subject to change with growth, at least in some species. It is of moderate importance in distinguishing some of the species.

**SUBORBITAL:** The suborbital ridge, that is, the ridge on the "bony stay" on the cheek, has 0-7 spinous points, the number differing with the species, but also varying intraspecifically to a considerable extent. The ridge and its spines also change markedly with growth in some species. (See accounts of *Pontinus castor* and *Neomerinthe pollux*.)

**PREORBITAL:** The preorbital bone has a number of radiating ridges two or three of which end in free spinous points at its outer margin. Another free spinous point is sometimes present in a line with the suborbital row of spines and is hereafter included in the count of that row.

Two scales on the lateral line directly behind the supracleithral spine have well-developed ridges which often end in spinous points or nearly so. Homologically these are not spines and are not considered as such. The anterior one of the two scales forms the starting point of the scale count as recorded in this paper.

The terminology of the spines outlined above follows that of the bones of which they are a part, except the spines on the upper rim of the orbit, on the interorbital, and that behind the middle of the

eye which it seems best to designate according to their position, namely, preocular, supraocular, postocular, interorbital, and postorbital. (For illustrations and descriptions of scorpaenid skulls, see Gregory 1933, pp. 241 and 323.) Previous attempts have been made by authors to introduce a uniform system of nomenclature for the spines, two of the later ones being by Schultz (1943, p. 168, fig. 14) and by Clemens and Wilby (1949, pp. 16-18, fig. 8). The nomenclature here adopted is in the main a combination of that used by previous authors with the introduction of some modifications in detail. It is hoped that the nomenclature here proposed will contribute toward the final adoption of a general uniform system of nomenclature to be used for the family as a whole.

*Preopercular spines.*—The spinous structure of the preopercular margin furnishes valuable taxonomic characters. The preopercle has a basic 5-spined pattern, and modifications within this basic pattern are of importance in distinguishing the genera and species. In *Sebastes* and *Helicolenus* the second spine is the longest, in *Setarches* the upper three spines are subequal or nearly so, while in the other five genera the first spine is the longest. In *Ncomerithe* and *Pontinus* the second spine is present or absent depending on the species and on intraspecific individual variability in some species. The fourth and fifth spines are sharply marked in some species and much reduced and variable or virtually absent in others. The presence or absence of a supplementary spine or spur attached to the first spine is sometimes a fairly good specific character. It is also important to bear in mind that the supplementary spine is homologically not the first spine as discussed below under the account of *Scorpaena plumieri mystes*. Specific and generic differences in the outline of the posterior margin of the preopercle are shown in figure 3.

In two species at least, *Pontinus longispinis* and *P. rathbuni* (see accounts of these), the spines on the preopercle of juveniles, about 20-30 mm. specimens examined, differ markedly from that in the larger specimens, the upper three spines in general being of approximately the same size, similar to that of grown specimens of *Setarches parmatius*. This growth change is important, as the relative size of the spines is here used as a major character in the division of the genera.

*Dorsal fin.*—The penultimate dorsal spine is shorter than the last and the dorsal fin is emarginate between the spinous and soft parts or rather between the last two spines. The extent of emargination differs in degree among the different species, with all gradations between the extremes. Therefore, for descriptive purposes and in

the formulas at the head of the accounts of the different species, the dorsal is treated as though it formed a single fin, although in the more extreme species it might as well be treated as consisting of two fins.

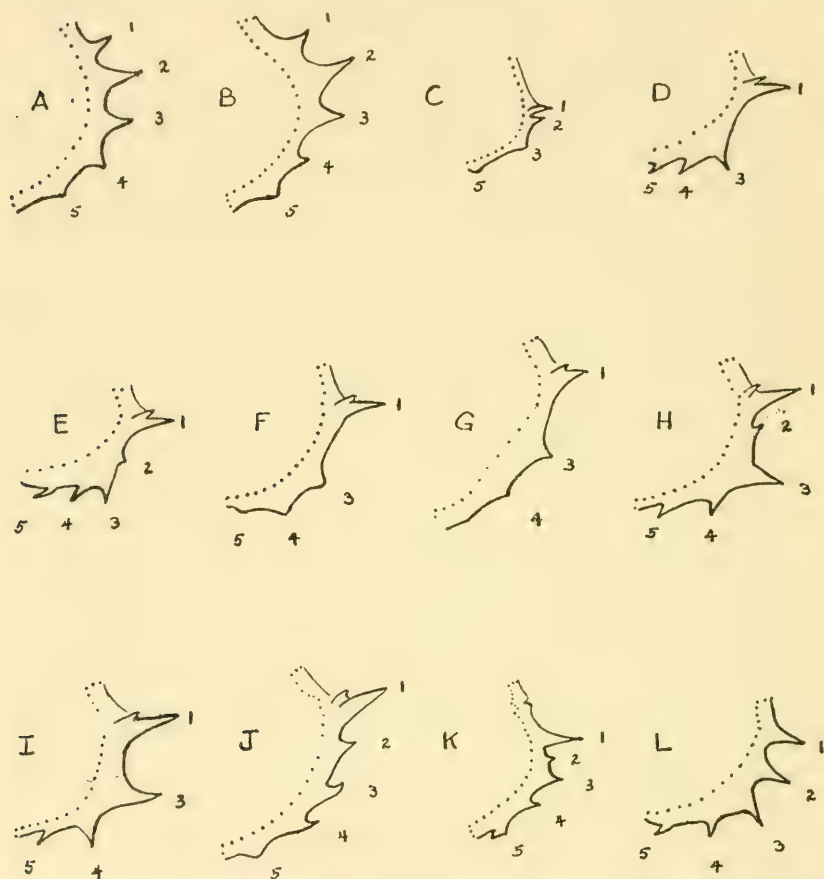


Fig. 3.—Preopercular outline of scorpaenid species: A, *Sebastes marinus*. B, *Helicolenus maderensis*. C, *Scorpaenodes caribbaeus*. D, *Neomerinthe beanorum*, usual condition, second spine absent. E, *Neomerinthe beanorum*, variant showing a very moderate second spine. F, *Neomerinthe pollux*. G, *Pontinus castor*. H, *Pontinus longispinis*, usual condition, a small second spine present. I, *Pontinus longispinis*, a variant lacking second spine. J, *Trachyscorpia cristulata*. K, *Scorpaena calcarata*, second spine usually present and small as figured, sometimes absent. L, *Setarches parmatius*. Drawn by Mildred H. Carrington.

The number of spines constitutes a generic character of some value, typically being 12 or 13, depending on the genus, with comparatively few variants from the typical (table 1), except in *Sebastes* in which the modal number is 15 and the variants from that count are com-

TABLE I.—Frequency distribution of the number of dorsal spines and dorsal and anal rays in western Atlantic scorpenoids and three others

Species and subspecies	Dorsal spines					Dorsal rays										Anal rays					
	11	12	13	14	15	7	8	9	10	11	12	13	14	15	4	5	6	7	8	9	10
<i>Sebastes marinus</i> .....	..	..	..	6	62	..	..	..	..	..	..	27	30	8	..	..	..	46	17	4	1
<i>Helicolenus dactylopterus</i> .....	7	..	..	..	..	..	..	..	..	7	..	..	..	..	..	7	..	..	..	..	..
“ <i>maderensis</i> .....	2	174	4	..	..	..	..	..	1	28	144	6	..	..	2	179	..	..	..	..	..
“ <i>lahillei</i> .....	8	1	..	..	..	..	..	..	..	1	7	1	..	..	..	9	..	..	..	..	..
<i>Scorpaenodes caribbaeus</i> .....	..	3	..	..	..	..	2	..	..	..	..	..	..	..	..	2	..	..	..	..	..
“ <i>tridecimspinosus</i> .....	..	1	..	..	..	..	..	1	..	..	..	..	..	..	..	1	..	..	..	..	..
“ <i>floridæ</i> .....	..	2	..	..	..	..	1	..	..	..	..	..	..	..	..	2	..	..	..	..	..
<i>Pontinus macrolepis</i> .....	..	4	..	..	..	..	..	4	..	..	..	..	..	..	..	4	..	..	..	..	..
“ <i>longispinis</i> .....	79	..	..	..	..	..	77	2	..	..	..	..	..	..	79	..	..	..	..	..	..
“ <i>rathbuni</i> .....	1	27	..	..	..	..	26	2	..	..	..	..	..	..	28	..	..	..	..	..	..
“ <i>castor</i> .....	4	..	..	..	..	..	..	..	4	..	..	..	..	..	..	4	..	..	..	..	..
<i>Neomerinthe pollix</i> .....	14	..	..	..	..	..	..	..	16	..	..	..	..	..	..	16	..	..	..	..	..
“ <i>beanorum</i> .....	6	..	..	..	..	..	..	6	..	..	..	..	..	..	..	6	..	..	..	..	..
<i>Trachyscorpia echinata</i> .....	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
“ <i>cristulata</i> .....	13	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Scorpaena inermis</i> .....	18	..	..	..	..	..	..	12	..	..	..	..	..	..	..	13	..	..	..	..	..
“ <i>calcarata</i> .....	3	204	1	..	..	..	3	14	1	..	..	..	..	..	..	18	..	..	..	..	..
“ <i>agassizi</i> .....	103	1	..	..	..	..	23	181	3	..	..	..	..	..	3	200	5	..	..	..	..
“ <i>brasiliensis</i> .....	125	2	..	..	..	..	4	100	..	..	..	..	..	..	2	104	..	..	..	..	..
“ <i>grandicornis</i> .....	65	2	..	..	..	..	1	3	124	..	..	..	..	..	1	125	2	..	..	..	..
“ <i>bergi</i> .....	1	37	..	..	..	..	..	2	64	1	..	..	..	..	3	64	..	..	..	..	..
“ <i>albifimbria</i> .....	1	..	..	..	..	..	..	1	37	..	..	..	..	..	38	..	..	..	..	..	..
“ <i>dispar</i> .....	1	15	..	..	..	..	..	14	..	..	..	..	..	..	16	..	..	..	..	..	..
“ <i>plumieri</i> .....	67	..	..	..	..	..	2	65	..	..	..	..	..	..	67	2	..	..	..	..	..
“ <i>mystes</i> .....	12	..	..	..	..	..	..	12	..	..	..	..	..	..	11	..	..	..	..	..	..
“ <i>microlepis</i> .....	1	..	..	..	..	..	..	1	..	..	..	..	..	..	1	..	..	..	..	..	..
<i>Setarches parnatus</i> .....	40	..	..	..	..	..	..	11	30	..	..	..	..	..	1	41	..	..	..	..	..

paratively more numerous. The number of soft rays in most species is also remarkably constant as compared with species in other families; and it is of some value, in a more limited way, as a specific and generic character. The last two rays, which are closely approximated at their bases and appear to be the two main branches of a ray that is split to its base, have been counted as one ray in both the dorsal and anal.

*Anal fin.*—The number of anal spines, 3, is virtually constant. In routine counts made during this investigation on 1,139 specimens, only 2 differed from the normal count of 3. In one specimen each of *Pontinus longispinis* and *P. rathbuni*, out of 79 and 28 examined of those two species, respectively, the first short anal spine is missing. The number of rays is nearly always 5, the number of variants being comparatively few (table 1), except in *Sebastes marinus* which has 7 to 10 rays. The relative length of the second and third spine is of moderate importance as a specific character:

*Development of third anal spine.*—An important point that has a bearing on the classification of fishes in general was observed on two specimens, 24-25 mm., of *Pontinus longispinis* (155999-155300).<sup>1</sup> The third anal fin support is flexible and partly jointed for some distance at its distal end. In the next size examined of the same species, 30 mm., the third anal spine is as in the adult. This developmental phenomenon was heretofore well known in the species of *Mugil*. I have also observed it in the family Haemulonidae, in the species of *Orthopristes*, *Haemulon*, and *Bathystoma*. This noteworthy development, therefore, seems to be widespread in fishes. As the number of anal spines, 1, 2, or 3, is sometimes used as a family character, it is of interest to know that it depends on ontogenetic development in families of fishes which are otherwise widely divergent in the scheme of classification.

In specimens examined of *Pontinus rathbuni*, *Scorpaena calcarata*, and *S. agassizi*, 18-22 mm., the third anal spine is as in the adult. *P. rathbuni* is a smaller species than *longispinis* and this developmental change probably occurs at a smaller size. In the species of *Scorpaena*, on the other hand, it is possible that the third anal spine is as in the adult to begin with.

*Pectoral fin.*—The pectoral shape differs with the genus to a certain extent, although this character is not altogether stable because of the irregularity in the relative contraction or expansion of the interradiial membrane in preserved specimens, which influences the shape of the

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<sup>1</sup> Numbers of specimens examined are U. S. National Museum catalog numbers unless otherwise indicated.



fin. Nevertheless, allowing for this difficulty of the subject matter and for a considerable latitude in accounting for specific differences and

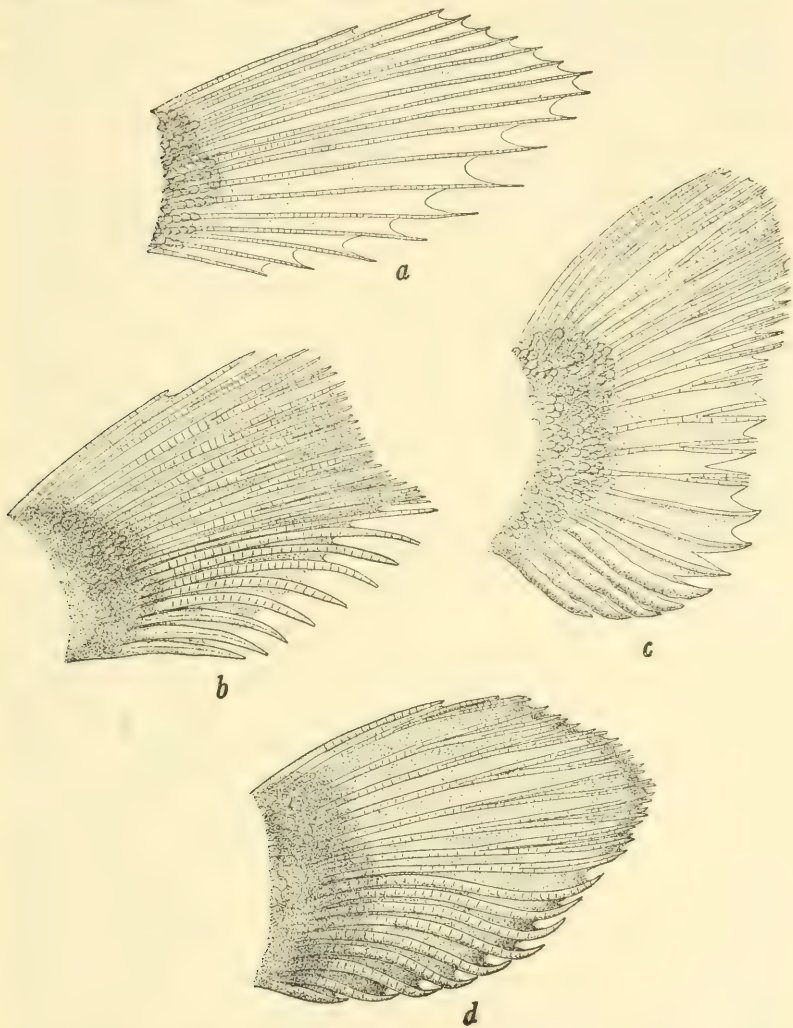


Fig. 4.—Pectoral fins of four scorpaenid species. The shape of the pectoral fin is generic to some extent. *a*, *Pontinus longispinis*; *b*, *Helicolenus maderensis*; *c*, *Trachyscorpia cristulata*; *d*, *Scorpaena grandicornis*. Drawn by Mildred H. Carrington.

intraspecific variability, this character still has some generic value. The pectorals of four genera are illustrated in figure 4.

One genus, *Pontinus*, is separable from the others here treated by having all the pectoral rays unbranched. The number of pectoral rays

is, on the whole, of considerable importance as a specific character (table 2), although related species often overlap in this count.

*Scales.*—The structure of the scales, cycloid or ctenoid, appears to be of considerable value as a generic character and it is here so used. This character was inadequately treated heretofore. Jordan and Evermann (1898, p. 1759), in their key to the genera, use the structure of the scales on top of the head, ctenoid or cycloid, as a character in separating *Helicolenus* from *Scorpaena*. This character as used by the authors cited is unsatisfactory for this purpose and was the cause of some misapprehension by later authors in the treatment of the species. By the use of the structure of the scales on the body as a generic character the species fall into what seem to be natural groups. In the species with cycloid scales, which are here placed in the genus *Scorpaena*, the scales on the dorsal aspect extend only to opposite the parietal ridge; the occiput, interorbital, and snout being scaleless. The other genera here treated, excepting the highly specialized *Setarches*, have ctenoid scales on the body and the ctenoid scalation on the dorsal aspect extends to opposite the posterior part of the eye. On the greater part of the top of the head, on the interorbital and snout, the scalation in the species of these genera differs in its extent and structure with the species, from being scaled with weakly ctenoid or cycloid scales to being nearly scaleless.

The scale counts here given refer to the number of vertical rows above the lateral line, beginning with the row which is partly or wholly just behind the supraclithral spine, and ending at the caudal base. The two scales in the lateral line directly behind the supraclithral spine are more or less ridged and sometimes rather spinous. The rows standing over these two modified scales are included in the count. Usually the rows deviate somewhat from the vertical, running slightly forward or backward, often in different parts of the same specimen. Very often the scales are somewhat irregularly arranged instead of being alined in clear-cut rows, and in such cases the number of vertical rows counted is a rather rough approximation instead of being precise. However, by using throughout the same method of counting, the figures obtained yield fairly regular frequency distributions, and the scale count is useful as a specific character. The number of modified scales in the lateral line is much less than the number of vertical rows above it, does not differ much as between related species, and is not of much importance as a specific character.

*Gill rakers.*—In the Scorpaenidae the gill rakers on the outer gill arch usually gradually decrease in size from the angle forward or upward, and in most species it is not possible to draw a consistent line

between the gill rakers and the so-called rudiments or tubercle-like outgrowths. On the other hand, the tubercles are generally well defined, except that in some species, toward the anterior part of the lower limb, they are not sharply marked in individual variants. On the whole, the combined number of gill rakers and tubercles is deter-

TABLE 2.—Frequency distribution of the number of pectoral rays in western Atlantic scorpaenids and three others

Species and subspecies	Distribution									
	15	16	17	18	19	20	21	22	23	24
<i>Sebastes marinus</i> .....	..	..	..	13	51	4	..	..	..	..
<i>Helicolenus dactylopterus</i> .....	..	..	..	..	6	1	..	..	..	..
“ <i>maderensis</i> .....	..	..	2	29	142	8	..	..	..	..
“ <i>lahillei</i> .....	..	..	..	1	8	..	..	..	..	..
<i>Scorpaenodes caribbaeus</i> .....	..	..	..	2	4	..	..	..	..	..
“ <i>tridecimspinosus</i> .....	..	..	2	..	..	..	..	..	..	..
“ <i>floridae</i> .....	..	..	4	..	..	..	..	..	..	..
<i>Pontinus macrolepis</i> .....	1	3	..	..	..	..	..	..	..	..
“ <i>longispinis</i> .....	..	1	73	2	..	..	..	..	..	..
“ <i>rathbuni</i> .....	..	..	21	1	..	..	..	..	..	..
“ <i>castor</i> .....	..	..	4	..	..	..	..	..	..	..
<i>Neomerinthe pollux</i> .....	..	..	16	..	..	..	..	..	..	..
“ <i>beanorum</i> .....	..	..	6	..	..	..	..	..	..	..
<i>Trachyscorpia echinata</i> .....	..	..	..	..	..	1	..	..	..	..
“ <i>cristulata</i> .....	..	..	..	..	..	..	..	1	9	3
<i>Scorpaena inermis</i> .....	..	..	..	..	4	13	1	..	..	..
“ <i>calcarata</i> .....	..	..	..	1	23	152	29	..	..	..
“ <i>agassizi</i> .....	..	..	..	..	10	84	10	..	..	..
“ <i>brasilensis</i> .....	..	..	1	13	95	19	..	..	..	..
“ <i>grandicornis</i> .....	..	..	4	56	7	..	..	..	..	..
“ <i>bergi</i> .....	..	5	32	1	..	..	..	..	..	..
“ <i>albifimbria</i> .....	..	..	..	..	1	..	..	..	..	..
“ <i>dispar</i> .....	..	..	2	9	4	..	..	..	..	..
“ <i>plumieri</i> .....	..	..	..	2	38	26	3	..	..	..
“ <i>mystes</i> .....	..	..	..	..	..	12	..	..	..	..
“ <i>microlepis</i> .....	1	..	..	1	..	..	..	..	..	..
<i>Setarches parmatius</i> .....	..	..	..	..	..	..	..	3	27	12

minable with a fair or high degree of precision, except for the relatively few individual variants noted. Therefore, the combined number of gill rakers and tubercles is given under each species in the formula and the text and also in tables 2-4, as this count yields the best results in adequately distinguishing the species and genera of this family. *Setarches parmatius* forms an exception in regard to the relative development of gill rakers and tubercles and these structures are discussed separately under the account of that species.

In counting the gill rakers the one at the angle is included in the count of the lower limb.

*Gill slit behind fourth arch.*—The presence or absence of a small slit behind the fourth gill arch is of some generic or specific value. This character does not constitute an absolute difference. In *Pontinus* the slit is either altogether open or it is bridged over at its outer side

TABLE 3.—Frequency distribution of the combined number of gill rakers and tubercles on the upper limb of western Atlantic scorpaenids and three others

Species and subspecies	Distribution						
	3	4	5	6	7	8	9
<i>Helicolenus dactylopterus</i> .....	..	..	..	..	6	1	..
“ <i>maderensis</i> .....	..	..	..	..	58	60	5
“ <i>lahillei</i> .....	..	..	..	..	2	7	..
<i>Scorpaenodes caribbaeus</i> .....	..	..	..	1	3	2	..
“ <i>tridecimspinosus</i> .....	..	..	2	..	..	..	..
“ <i>floridae</i> .....	..	1	3	..	..	..	..
<i>Pontinus macrolepis</i> .....	..	..	..	..	3	1	..
“ <i>longispinis</i> .....	..	..	..	25	20	..	..
“ <i>rathbuni</i> .....	..	..	1	11	8	1	..
“ <i>castor</i> .....	..	..	..	..	3	1	..
<i>Neomerinthe pollux</i> .....	..	..	..	15	1	..	..
“ <i>beanorum</i> .....	..	..	..	6	..	..	..
<i>Trachyscorpia echinata</i> .....	..	..	1	..	..	..	..
“ <i>cristulata</i> .....	..	..	..	13	..	..	..
<i>Scorpaena inermis</i> .....	1	13	4	..	..	..	..
“ <i>calcarata</i> .....	1	74	65	..	..	..	..
“ <i>agassizi</i> .....	..	6	62	5	..	..	..
“ <i>grandicornis</i> .....	..	6	36	24	1	..	..
“ <i>brasiliensis</i> .....	..	116	12	..	..	..	..
“ <i>bergi</i> .....	6	32	..	..	..	..	..
“ <i>albifimbria</i> .....	..	..	1	..	..	..	..
“ <i>dispar</i> .....	..	..	15	..	..	..	..
“ <i>plumieri</i> .....	..	5	59	2	..	..	..
“ <i>mystes</i> .....	..	1	10	..	..	..	..
“ <i>microlepis</i> .....	..	..	1	..	..	..	..
<i>Setarches parmatius</i> .....	..	..	..	6	36	..	..

with a thin, easily torn membrane. In *Scorpaenodes* its presence appears to differ with the species, judged by the very few specimens examined. Moreover, this character is not easy to apply in practice. In examination it often requires some pressure to move the fourth arch sufficiently to expose and examine its line of attachment, and an artificial slit might be made in doing so.

*Appendages of skin.*—The species of this family have soft appendages of skin in various stages of development that may be designated

as tentacles, filaments, or tabs, depending on their relative length or thickness. They are often situated at the base of the various spines on the head, along the course of the lateral line, on the upper part of the eyeball, or irregularly scattered on the head and body. These appendages have been used often as taxonomic characters in distinguishing species or even genera and are sometimes used in keys. How-

TABLE 4.—Frequency distribution of the combined number of gill rakers and tubercles on the lower limb of western Atlantic scorpaenids and three others

Species and subspecies	Distribution														
	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
<i>Helicolenus dactylopterus</i> .....												1	3	3	..
“ <i>maderensis</i> .....												7	66	50	..
“ <i>lahillei</i> .....													2	6	1
<i>Scorpaenodes caribbaeus</i> .....					3	..	2	1	..	..	..	..	..	..	..
“ <i>tridecimspinosus</i> ..					2	..	..	..	..	..	..	..	..	..	..
“ <i>floridæ</i> .....						4	..	..	..	..	..	..	..	..	..
<i>Pontinus macrolepis</i> .....							1	3	..	..	..	..	..	..	..
“ <i>longispinis</i> .....							8	28	8	1	..	..	..	..	..
“ <i>rathbuni</i> .....							12	8	1	..	..	..	..	..	..
“ <i>castor</i> .....									3	1	..	..	..	..	..
<i>Neomerinthe pollux</i> .....				1	2	4	9	..	..	..	..	..	..	..	..
“ <i>beanorum</i> .....				4	2	..	..	..	..	..	..	..	..	..	..
<i>Trachyscorpia echinata</i> .....								1	..	..	..	..	..	..	..
“ <i>crisulata</i> .....								13	..	..	..	..	..	..	..
<i>Scorpaena inermis</i> .....	1	12	5	..	..	..	..	..	..	..	..	..	..	..	..
“ <i>calcarata</i> .....		2	20	78	38	2	..	..	..	..	..	..	..	..	..
“ <i>agassizi</i> .....			6	23	39	5	..	..	..	..	..	..	..	..	..
“ <i>brasiliensis</i> .....			7	98	23	..	..	..	..	..	..	..	..	..	..
“ <i>grandicornis</i> .....		1	5	43	18	..	..	..	..	..	..	..	..	..	..
“ <i>bergi</i> .....		2	7	25	4	..	..	..	..	..	..	..	..	..	..
“ <i>albifimbria</i> .....					1	..	..	..	..	..	..	..	..	..	..
“ <i>dispar</i> .....					7	7	1	..	..	..	..	..	..	..	..
“ <i>plumieri</i> .....			3	14	29	17	3	..	..	..	..	..	..	..	..
“ <i>mystes</i> .....				1	6	4	..	..	..	..	..	..	..	..	..
“ <i>microlepis</i> .....						1	..	..	..	..	..	..	..	..	..
<i>Setarches parmatus</i> .....					3	8	6	13	7	5	..	..	..	..	..

ever, their use as distinguishing characters has been exaggerated hitherto with misleading results. They are generally so variable intra-specifically that in only a few instances can they be used constructively in distinguishing related congeneric species. On the whole, it would serve best the advancement of scorpaenid taxonomy not to put undue emphasis on these structures as taxonomic characters.

The following examples might be briefly cited in regard to the use of these structures as taxonomic characters. The tentacle between the

TABLE 5.—Frequency distribution of the combined total number of gill rakers and tubercles of western Atlantic scorpaenids and three others

Species and subspecies	Distribution																		
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	
<i>Helicolenus dactylopterus</i> .....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
“ <i>maderensis</i> .....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
“ <i>lahillei</i> .....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Scorpaenodes curibacus</i> .....	..	..	..	..	..	..	1	2	..	..	3	..	..	..	..	..	..	..	..
“ <i>tridecimspinosis</i> .....	..	..	..	..	..	2	..	..	..	..	..	..	..	..	..	..	..	..	..
“ <i>floridae</i> .....	..	..	..	..	..	1	3	..	..	..	..	..	..	..	..	..	..	..	..
<i>Pontinus macrolepis</i> .....	..	..	..	..	..	..	..	..	..	1	2	1	..	..	..	..	..	..	..
“ <i>longispinis</i> .....	..	..	..	..	..	..	..	..	5	20	13	7	..	..	..	..	..	..	..
“ <i>rathbuni</i> .....	..	..	..	..	..	..	..	..	8	5	7	..	..	..	..	..	..	..	..
“ <i>castor</i> .....	..	..	..	..	..	..	..	..	..	..	..	2	2	..	..	..	..	..	..
<i>Ncomeriithe pollux</i> .....	..	..	..	..	..	1	2	4	8	1	..	..	..	..	..	..	..	..	..
“ <i>beanorum</i> .....	..	..	..	..	..	4	2	..	..	..	..	..	..	..	..	..	..	..	..
<i>Trachyscorpia cchinata</i> .....	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..
“ <i>crisolata</i> .....	..	..	..	..	..	..	..	..	..	13	..	..	..	..	..	..	..	..	..
<i>Scorpaena inermis</i> .....	2	8	7	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
“ <i>calcarata</i> .....	..	2	16	48	47	26	1	..	..	..	..	..	..	..	..	..	..	..	..
“ <i>agassizii</i> .....	..	..	1	8	20	38	4	2	..	..	..	..	..	..	..	..	..	..	..
“ <i>brasilensis</i> .....	..	..	6	90	30	2	..	..	..	..	..	..	..	..	..	..	..	..	..
“ <i>grandicornis</i> .....	..	..	2	7	24	26	8	..	..	..	..	..	..	..	..	..	..	..	..
“ <i>bergi</i> .....	1	2	10	21	4	..	..	..	..	..	..	..	..	..	..	..	..	..	..
“ <i>albifimbria</i> .....	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..
“ <i>dispar</i> .....	..	..	..	..	..	7	7	1	..	..	..	..	..	..	..	..	..	..	..
“ <i>plumieri</i> .....	..	..	1	3	14	29	15	4	..	..	..	..	..	..	..	..	..	..	..
“ <i>mystes</i> .....	..	..	..	..	2	5	4	..	..	..	..	..	..	..	..	..	..	..	..
“ <i>microlepis</i> .....	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..
<i>Setarches parnatus</i> .....	..	..	..	..	..	..	..	5	7	6	13	7	4	..	..	..	..	..	..



supraocular and postocular spines is on the average better developed in *Scorpaena grandicornis* than in *S. plumieri*; but in frequent individual variants of *plumieri* it is nearly as well developed as in most specimens of *grandicornis*, while in other variants it is hardly developed. The same situation is also found in comparing other pairs of species. On the other hand, the relative development of the tentacles at the supraocular spine is of some value in separating *grandicornis* from *bergi* and *albifimbria* and it is so used in the key here given, as an addition to other characters.

*Measurements.*—Proportional measurements given in the body of the report, the key, and the tables, are expressed as a percentage of the standard length. The methods used in obtaining some of the measurements here given are as follows.

In some thick-skinned species it is difficult to determine externally the point of articulation of the middle pectoral rays, and the precise length of such rays could not be well determined. Therefore, measurements of the pectoral given hereafter were made from the point of articulation of the upper rays to the posterior apical point of the fin, that is, to the end of the ray extending farthest backward. The given measurement deviates somewhat from that of the longest ray.

The eye measurement here given refers to the greatest horizontal diameter of the ridge surrounding the eye. This measurement is most nearly susceptible of approaching accuracy. The size of the eyeball is subject to a great deal of individual variability in these species. In preserved specimens of the same species the eyeball fills the orbit or even bulges out of its limits, or it is variably shrunken within the orbit. These individual differences are most probably caused partly by some of the specimens having been brought up from rather deep water, and partly by preservation. At any rate, the size of the eyeball is not accurately determinable, and the term "eye" as used in this paper is synonymous with orbit.

The head was measured from its anterior margin, at the side of the notch when the latter is well developed, to its posteriormost point on its flexible marginal part. The depth was measured at the ventral base.

#### KEY TO THE GENERA AND SPECIES

- 1a. Lateral line normal, consisting of a series of modified channeled scales. Supraocular and postocular spines present. Spinous and soft part of dorsal more or less connected. Scales ctenoid, when cycloid (in *Scorpaena*) not more than 76.



- 2a. Second preopercular spine longest, the first more or less shorter. (The relative size of the preopercular spines is different in juveniles, of some species at least; see above.)
- 3a. Dorsal spines usually 15, sometimes 14. Anal rays 7-10. Scales 87-110; accessory scales profuse except in small specimens (only species having accessory scales). Parietal ridge typically entire. Gill rakers 32-38 altogether. Pectoral rounded posteriorly, roughly wedge-shaped.  
*Sebastes marinus* (p. 26)
- 3b. Dorsal spines normally 12, infrequently 11 or 13. Anal rays normally 5, rarely 4. Scales 60-79, without accessory scales. Parietal ridge divided into two parts. Total number of gill rakers 23-27. Pectoral broad, distal edge of its upper half emarginate; the lower rays thick, well separated distally (fig. 4b).....*Helicolenus* (p. 30)
- 4a. Suborbital ridge usually without a spine. Scales 66-73. Maxillary 21.5-22.5. Interorbital 2.9-3.2 times in eye (for size of specimens measured see under subspecies). Eastern Atlantic and Mediterranean.  
*Helicolenus dactylopterus dactylopterus* (p. 32)
- 4b. Suborbital ridge usually with a spine.
- 5a. Scales 60-71. Maxillary 20.0-22.5. Interorbital 2.1-3.4 times in eye. East coast of the United States.  
*Helicolenus dactylopterus maderensis* (p. 33)
- 5b. Scales 68-79. Maxillary 18.5-20.5. Interorbital 1.9-2.7 times in eye. Atlantic coast of South America.  
*Helicolenus dactylopterus lahillei* (p. 36)
- 2b. First preopercular spine longest.
- 6a. Dorsal spines normally 13. Palatine teeth absent. Interorbital spinous points present or obsolescent. Scales ctenoid, 40-42. (Only genus lacking palatine teeth, having spinous points on interorbital, and normally having 13 dorsal spines).....*Scorpaenodes* (p. 37)
- 7a. Suborbital ridge with 4-5 spinous points and 2 points in a line below main row. Gill rakers and tubercles on upper limb 6-8 in combined number. Pectoral rays 18-19. Interorbital ridges and spines well developed. Upper posttemporal spine small. Interorbital and snout rather well scaled.....*Scorpaenodes caribbaeus* (p. 38)
- 7b. Suborbital ridge with 1-3 spinous points and no secondary row of spines below main row. Gill rakers and tubercles on upper limb 4-5. Pectoral rays 17. Interorbital ridges and spinous points moderate or obsolescent. Upper posttemporal absent. Interorbital and snout very sparsely scaled.
- 8a. Suborbital ridge with 3 spinous points.  
*Scorpaenodes tridecimspinosus* (p. 40)
- 8b. Suborbital ridge with 1 spinous point, at its end.  
*Scorpaenodes floridae* (p. 41)

- 6b. Dorsal spines normally 12. Palatine teeth present. No spinous points on interorbital.
- 9a. Scales ctenoid; occiput scaled. Occipital pit absent.
- 10a. Pectoral not broad, irregularly wedge-shaped; with 15-18 rays. A small slit behind fourth gill arch, sometimes bridged over by a thin membrane in individual variants of *Pontinus*.
- 11a. All pectoral rays unbranched (only genus having all such rays in pectoral). Total number of gill rakers and tubercles 18-22.....*Pontinus* (p. 42)
- 12a. Snout short or moderate 12.6-14.4; eye 1.3 times in snout as a maximum, differing to a little larger than snout. Second preopercular spine normally present, except in some individual variants of *longispinis*. Dorsal rays usually 9, rather infrequently 10.
- 13a. Pectoral rays 15-16. Spines on suborbital ridge 3. Eye 12.9-15.4; interorbital 3.1-3.6 times in eye. Scales 45.....*Pontinus macrolepis* (p. 44)
- 13b. Pectoral rays usually 17, infrequently 18, rarely 16. Spines on suborbital ridge usually 4, occasionally 3. Eye 11.0-13.6; interorbital 2.3-3.2 times in eye.
- 14a. Third dorsal spine notably prolonged, except in specimens less than 115 mm. Scales 47-51. Depth 28-34 in specimens 51-174 mm. First preorbital spine usually directed downward or slightly forward. Tentacle at supraocular spine short and slender or absent. Typically spotted.  
*Pontinus longispinis* (p. 45)
- 14b. Third dorsal spine not notably prolonged. Scales 43-48. Depth 33-39 in specimens 55-145 mm. First preorbital spine usually directed sharply backward. Tentacle at supraocular spine thick, broad, and rather long. Typically shaded or light-colored, spots usually absent; sometimes a few small spots; pectoral in small specimens with an elongate dusky smudge.  
*Pontinus rathbuni* (p. 47)
- 12b. Snout notably long, 16-16.5; eye 1.4-1.6 times in snout. Second preopercular spine absent. Dorsal rays 10. Pectoral rays 17. Spines on suborbital ridge 3, except in large fish. Scales 50-54.....*Pontinus castor* (p. 49)
- 11b. Pectoral having 1 or 2 uppermost rays unbranched, next 5-8 rays branched, lower 7-10 rays unbranched; total number of rays 17. Total number of gill rakers and tubercles 15-19. Second pre-

- opercular spine usually absent in the larger specimens, sometimes present in *beanorum*. Suborbital ridge with 3-4 spines.....*Neomerinthe* (p. 51)
- 15a. Scales 62-68. Dorsal rays 10. Upper posttemporal spine absent. Fourth preopercular spine obtuse, not antrorse; fifth poorly developed or obsolescent.....*Neomerinthe pollux* (p. 53)
- 15b. Scales 41-46. Dorsal rays 9. Upper posttemporal spine present. Fourth and fifth preopercular spines sharply pointed, antrorse.  
*Neomerinthe beanorum* (p. 56)
- 10b. Pectoral broad, not wedge-shaped, the longest rays a little below upper margin, its posterior edge slightly emarginate (fig. 4c), with 20-24 rays. No slit behind fourth gill arch.....*Trachyscorpia* (p. 57)
- 16a. Head 43.5 (in one specimen 433 mm.). Pectoral rays 20. Body and head spotted. Eastern Atlantic.....*Trachyscorpia echinata* (p. 59)
- 16b. Head 47.5-48.0 (in 2 specimens 319-400 mm.; for measurements of other specimens see text). Pectoral rays 22-24. Without spots. Western Atlantic.....*Trachyscorpia cristulata* (p. 61)
- 9b. Scales cycloid, 41-76; occiput not scaled. Occipital pit present, except in *inermis* and *calcarata* (the only genus containing species with a pit).....*Scorpaena* (p. 63)
- 17a. Preorbital spinous points 2.
- 18a. Occiput somewhat broadly depressed, without a definite pit. First preopercular spine without a supplemental spine.
- 19a. Inverted, mushroom-shaped, whitish figures extending downward from base of ocular tentacles at lengthwise boundary between upper opaque and lower transparent parts of cornea (these figures sometimes absent in smaller specimens; see account of species). First preopercular spine extending about half the distance or less from its base to opercular margin. Dorsal rays modally 8, varying 7-9. Combined number of gill rakers and tubercles on lower limb modally 7, varying 6-8. Interorbital 3.6-4.3 (in 5 specimens 71-89 mm.; for other sizes see species account). Without a definite spot behind head; caudal with 2 cross bands.  
*Scorpaena inermis* (p. 65)
- 19b. Short, oblong, whitish areas extending downward on transparent part of cornea sometimes present, more often absent. First preopercular spine usually extending for more than half the distance from its base to opercular margin. Dorsal rays modally 9, varying 8-10. Com-

- bined number of gill rakers and tubercles on lower limb modally 9, varying 7-11. Interorbital 4.6-6.5 (in 5 specimens 65-75 mm.). Usually with a dark spot a little behind head, sometimes faint or imperceptible; caudal usually without cross bands, sometimes a faint trace of such bands.....*Scorpaena calcarata* (p. 68)
- 18b. Occiput with a well-developed pit (rather shallow in *Microlepis*), except in young specimens. First preopercular spine with a supplemental spine or spur (often very small and infrequently virtually absent in *brasiliensis*).
- 20a. Eye notably large, snout 1.4-1.6 times in eye (1.5-2.2 in small fish). Pectoral long, 44.0-48.5 in the larger specimens, reaching to over end of anal or nearly so (34.5-35.0 in two specimens 31-36 mm.). In the larger specimens chest notably wrinkled in a cerebriform manner and scales on chest very deeply embedded, appearing scaleless at the surface. Posterior preorbital spine notably well developed. Scales 43-53.....*Scorpaena agassizi* (p. 71)
- 20b. Eye moderately large, snout 0.9-1.3 in eye. Pectoral 29.5-37.0 in the larger specimens, reaching to over base of third anal ray as a maximum (28-34 in small fish). Chest with an even surface and normally scaled. Posterior preorbital spine moderate or small.
- 21a. Scales 50-62. With a characteristic and rather unique color pattern, region at inner pectoral angle with small dark spots against a lighter background and side usually with 2, often 3 or 4, dark blotches, color pattern sometimes obscure. Upper posttemporal spine often absent.....*Scorpaena brasiliensis* (p. 74)
- 21b. Scales 42-49.
- 22a. Frontal spine absent in large specimens, notably small in the smaller specimens. Region at inner pectoral angle with light, small spots against a darker background. Tentacle at supraocular spine notably large.....*Scorpaena grandicornis* (p. 77)
- 22b. Frontal spine well developed. Without light spots at pectoral axil. Tentacle at supraocular spine small to well developed, sometimes large in individual variants of *bergi*. Small species.
- 23a. Depth 35.5-41.5 (in 37 specimens 33-92 mm.). Combined number of gill rakers and tubercles on upper limb usually 4, often 3. Body with light and

- dark shades; spinous dorsal with a blotch, better marked in faded specimens. Pectoral rays modally 17, often 16, infrequently 18. . . . . *Scorpaena bergi* (p. 79)
- 23b. Depth 43.5. Combined number of gill rakers and tubercles on upper limb 5. Body very moderately shaded; fins almost uniformly light-colored. Pectoral rays 19. (One specimen 43 mm. examined.) . . . . . *Scorpaena albifimbria* (p. 82)
- 17b. Preorbital with 3 free spinous points (except in specimens of *plumieri* under 65 mm.; such small specimens being separable from the other species by the distinctive color pattern of *plumieri* and the combination of its structural characters as given under its account).
- 24a. Scales 42-49. Occipital pit large, comparatively rather deep except in small and very large specimens. Upper posttemporal spine rather well developed. Frontal spine nearly in a line with parietal ridge.
- 25a. Without a pit under eye. Eye larger than interorbital. Almost plain-colored. Head and anterior part of body rather well compressed.  
*Scorpaena dispar* (p. 84)
- 25b. A pit under anterior margin of eye, just over suborbital ridge (not definitely formed in specimens under 60 mm.). Eye smaller than interorbital. Region at inner lower pectoral angle black with whitish spots (white spots not well marked in small specimens); body spotted and mottled with light and dark areas. Head and anterior part of body notably tumescent.  
*Scorpaena plumieri* (p. 86)
- 26a. Occipital pit often elongate and fairly deep; small dark spots on lower part of body absent or rather sparse. Atlantic.  
*Scorpaena plumieri plumieri* (p. 88)
- 26b. Occipital pit often oblong and rather shallow; small spots on lower part of body more often present and frequently rather numerous. Pacific. . . . . *Scorpaena plumieri mystes* (p. 92)
- 24b. Scales 76. Occipital pit small and shallow. Upper posttemporal spine slight. Frontal spine placed laterad of parietal ridge. . . . . *Scorpaena microlepis* (p. 95)
- 1b. Lateral line unusually modified, consisting of a continuous ditchlike depression roofed over by a membranous cover without channeled scales. Supraocular, and postocular spines absent. Dorsal virtually forming two separate fins. Scales cycloid and small, 88-103. Upper 3 preopercular spines subequal or nearly so. . . . . *Setarches parmatius* (p. 97)

Genus **SEBASTES** Cuvier

*Sebastes* CUVIER, Règne animal, ed. 2, vol. 2, p. 166, 1829 (two species included, *norvegicus* and *dactylopterus*, genotype by later designation).

*Sebastes* BLEEKER, Versl. Akad. Amsterdam, vol. 9, p. 294, 1876 (*Sebastes norvegicus* Cuvier and Valenciennes, designated as genotype).

*Comparison*.—Among the western Atlantic scorpaenids this genus is nearest *Helicolenus*, and the differences between them are discussed under that genus. The generic characters are included below under the description of the one western Atlantic species of *Sebastes*.

**SEBASTES MARINUS** (Linnaeus)

*Perca marina* LINNAEUS, Systema naturae, ed. 10, vol. 1, p. 290, 1758 (Norway, Italy).

*Sebastes fasciatus* STORER, Proc. Boston Soc. Nat. Hist., vol. 5, p. 31, 1854 (Provincetown, Mass.).

*Sebastes marinus* JORDAN and EVERMANN (in part), U. S. Nat. Mus. Bull. 47, p. 1760, pl. 268, fig. 653, 1898 (include 2 species according to the given distribution and synonymy).—BIGELOW and WELSH, Bull. U. S. Bur. Fish., vol. 40, pt. 1, p. 304, figs. 141-147, 1925 (general account, including life history).

D.XIV-XV 13-15. A.III 7-10. P.18-20. Sc.87-110. GR.9-11+23-27.

*Description*.—Eye large and interorbital rather wide (proportional measurements differing with population; see below). Maxillary ending at a point under pupil. Knob on chin becoming notably prolonged and tapering in large specimens. Palatine teeth present. No slit behind fourth gill arch. Gill rakers long in comparison with the other scorpaenids here treated; 9-11 on upper limb; 23-27 on lower limb, including one short, stumpy, tubercle-like outgrowth often present at anterior end of arch; 32-38 in total number. Occiput flat, without a pit. Parietal ridge long, usually continuous, ending in a single point, sometimes a second moderate spinous point a little in front of posterior spine; frontal spine in a line with postocular, placed laterad of parietal ridge; upper posttemporal ridge and spine rather well developed, lower posttemporal spinous point slight or moderate, not preceded by an external ridge; sphenotic, pterotic, and postorbital spines absent; preorbital with 2 moderate free spinous points; suborbital ridge slight, short, confined to part of cheek behind eye, without a spinous point; cleithrum with a moderate spinous point or a slight blunt projection. First preopercular spine moderately smaller than second, third subequal to first, fourth and fifth smaller but rather well developed in comparison with some other species. Subopercle very often with a moderate spinous point at its lower posterior corner,

interopercle very often with a similar spine at its upper posterior corner, in juxtaposition to like spine on subopercle, sometimes a second spinous point on subopercle at a short distance above spine at angle (the 1 or 2 spines at lower part of subopercle present in addition to the 2 opercular spines on its upper part, characteristic of the family). Tentacles or flaps absent. Scales rather small, 87-110, ctenoid, with very small supplementary scales except in small specimens; snout, maxillary, mandible, soft area between mandibles, and branchiostegals partly scaled; rest of head almost completely scaled; fins moderately scaled. Penultimate dorsal spine about five-sixths as long as last; longest dorsal spine subequal to postorbital part of head or slightly shorter. Second anal spine subequal in length to third. Ventral about reaching anus, its outer angle placed moderately behind lower pectoral angle. Pectoral reaching a vertical a little behind end of ventral, its posterior margin rounded or somewhat wedge-shaped, the middle rays longest; usually its upper 2 rays unbranched, sometimes upper 1 or 3 rays unbranched, next 7-13 rays branched, lower 5-10 rays unbranched. Caudal emarginate.

Measurements of 6 American specimens 200-361 mm.; 2, 3, and 1 from samples A, B, and C, respectively (for origin of samples see below): caudal 21.0-22.5, ventral 20.0-23.5, pectoral 29.0-31.5, depth 35.5-39.5, head 36.5-39.0, maxillary 17.0-18.7, snout 8.2-9.9, eye 11.9-13.0, interorbital 7.2-8.1; snout 1.2-1.5 and interorbital 1.5-1.7 times in eye.

Measurements of 3 European specimens 258-395 mm. (sample D): caudal 21.0-22.5, ventral 20.5-24.0, pectoral 26-29, depth 33.5-34.5, head 37-38, maxillary 17.1-18.2, snout 9.7-10.4, eye 10.1-11.8, interorbital 7.7-8.4; snout 1.0-1.2 and interorbital 1.2-1.4 times in eye.

Color of preserved specimens examined a nearly uniform yellowish or golden, probably faded after long immersion in preservative. It is said to be of an orange or red color in life with some irregular dark shadings on head and back.

*Development.*—The pectoral rays are damaged in many small specimens examined. As far as determinable they appear to begin to branch at about 100 mm. The accessory scales begin to appear at about 120 mm.; they are very few in the smaller specimens and become very profuse with growth.

*Specimens examined.*—For the purpose of analyzing intraspecific population differences the specimens examined have been divided into four composite samples as follows.

Sample A: Taken off Long Island, N. Y., between latitudes 39° 49' and 40° 05' N., and longitudes 68° 48' and 71° 10' W., in 144

to 420 fathoms; 10 specimens 288-359 mm., in 9 constituent samples (31614, 31679-81, 31683, 31714-16, 35493).

Sample B: Taken on the coast of New England, from off Nantucket Island, Mass. (lat.  $41^{\circ} 25' 30''$  N., long.  $69^{\circ} 01'$  W.) to Eastport, Maine; 44 specimens 40-364 mm., in 20 constituent samples (5374, 13850, 21814, 23264, 31539, 31567-8, 33381, 43078, 46075, 46079, 46084, 74117, 83928-9, 88463, 89019, 120984, 125419, 143784). Depth records are available for 9 of the 20 constituent samples and range 35-105 fathoms.

Sample C: Taken from off Cape Sable, Nova Scotia, to off St. Johns, Newfoundland, in 78-215 fathoms; 11 specimens 76-264 mm., in 7 constituent samples (21003, 33389, 38089, 46077, 84499, 84503, 134326).

Sample D: Three specimens 258-395 mm.; 2 from Bergen, Norway (17435), 1 from the North Sea (39732); no depth data available.

*Comparison.*—This species differs from all other western Atlantic scorpaenids as follows. The dorsal spines number 14-15. The scales are small, and it has numerous accessory scales. The gill rakers are more numerous. The count of all three characters is discontinuous as compared with the other species. It differs from its eastern Atlantic congener, *Sebastes viviparus*, in the more numerous scales, 87-110 instead of 76-82 in 4 specimens of *viviparus* examined. The latter also averages lower numbers of anal and pectoral rays, but these counts evidently overlap widely.

*Populations.*—While the samples examined indicate considerable differences between the local populations, the specimens are not numerous enough to draw taxonomic conclusions with anything approaching finality. These differences, as presented in tables 6-8, and the given measurements, are here briefly discussed.

Samples B and C from the western Atlantic show a significant difference in the number of dorsal rays as compared with the 3 eastern Atlantic specimens; 13 or 14 rays in 52 western Atlantic specimens as compared with 15 rays in the 3 eastern specimens. This might suggest a possible divergence of subspecies or even species magnitude. However, sample A, which was taken in deeper water off Long Island, is intermediate, having 14 or 15 dorsal rays.

The anal ray and scale counts average highest in sample A; those of the pectoral rays average lowest in sample B; those of the gill rakers on the lower limb average highest in sample C. However, the extents of divergence of these characters are evidently of low degree, below the subspecies level.



Differences in proportional measurements are contrasted above between the 3 European specimens examined and 6 American specimens of nearly comparable size. The 3 European specimens average a slenderer body, longer pectoral and snout, and smaller eye. The greatest divergence appears to be in the depth and eye measurements which were therefore determined for all available nearly comparable

TABLE 7.—*Frequency distribution of the number of dorsal spines and dorsal, anal, and pectoral rays in *Sebastes marinus*, segregated by population as delimited in the text*

Population	Dorsal spines		Dorsal rays			Anal rays				Pectoral rays		
	14	15	13	14	15	7	8	9	10	18	19	20
Sample A . . . . .	I	9	..	5	5	..	5	4	I	..	9	I
Sample B . . . . .	4	40	22	20	..	40	4	..	..	13	30	I
Sample C . . . . .	I	10	5	5	..	5	6	..	..	..	9	2
Sample D . . . . .	..	3	..	..	3	I	2	..	..	..	3	..

TABLE 8.—*Frequency distribution of the number of gill rakers on the first gill arch in *Sebastes marinus*, segregated by population*

Population	Upper limb			Lower limb					Total both limbs							
	9	10	11	23	24	25	26	27	32	33	34	35	36	37	38	
Sample A . . . . .	2	7	I	I	3	3	3	..	I	I	2	2	4	..	..	
Sample B . . . . .	4	24	13	3	12	16	7	3	..	4	11	9	11	6	..	
Sample C . . . . .	2	8	I	..	..	6	3	2	..	..	I	6	2	I	I	
Sample D . . . . .	..	2	I	I	..	I	I	..	..	I	..	I	..	I	..	

TABLE 9.—*Frequency distribution of the number of scales in *Sebastes marinus*, segregated by population, the classes grouped by intervals of three*

Population	Distribution								
	87	90	93	96	99	102	105	108	111
Sample A . . . . .	..	I	..	I	4	I	2	I	..
Sample B . . . . .	I	3	7	5	5	I	..	..	I
Sample C . . . . .	..	I	..	3	I	..	..	..	..
Sample D . . . . .	..	I	I	I	..	..	..	..	..

specimens with the following result: depth 33.6-34.5 and eye 10.1-11.8 percent of the standard length in 3 European specimens 258-395 mm., as compared with 35.2-39.4 and 11.7-13.3 percent, respectively, in 20 American specimens of all populations 200-361 mm. These differences might possibly form a basis for the subspecific or specific distinction of the American and European populations; but the specimens examined are too few to enable me to draw definite conclusions.

Genus **HELICOLENUS** Goode and Bean

*Helicolenus* GOODE and BEAN, Oceanic ichthyology, p. 248, 1895 (genotype *Scorpaena dactyloptera* De la Roche by original designation).

*Helicolenus* is in a way intermediate between *Sebastes* and *Scorpaena*, agreeing with either genus in some characters and differing in others. It agrees with *Sebastes* in having the first preopercular spine shorter than the second, in having ctenoid scales, in the extent of scalation, and in lacking tentacles, and nearly agrees in the spinous armature of the head. *Helicolenus* lacks accessory scales which are present in *Sebastes*. The two genera differ further in the number of dorsal spines, anal rays, and gill rakers. The normal or usual number of dorsal spines is 12 in *Helicolenus* and 15 in *Sebastes*. The number of anal rays is almost constantly 5 in *Helicolenus*, while in *Sebastes* the number differs with the species and varies with the individual, the range being 6-10. The gill rakers are less numerous and not so well developed in *Helicolenus*. *Helicolenus* agrees with *Scorpaena* in normally having 12 dorsal spines and 5 anal rays, and differs from the latter in having the first preopercular spine shorter than the second, ctenoid scales, and an emarginate caudal. In general, the spinous armature of the head is not well developed in *Helicolenus* and the gill rakers better developed, as compared with *Scorpaena*. The degree of development and number of gill rakers in *Helicolenus* are rather intermediate between *Sebastes* and *Scorpaena*. *Helicolenus* differs from both genera in the shape and structure of its pectoral fin. The generic characters are included below in the description of the one species here treated.

**HELICOLENUS DACTYLOPTERUS** (De la Roche), *sensu lato*

D.(XI) XII (XIII) (10) 11-13. A.III (4) 5. P.17-20. Sc.60-79. GR.7-9+16-19.

*Description*.—Eye larger than snout. Interorbital width approximately a third to a half the eye diameter. Maxillary ending approximately under anterior margin of pupil. Palatine teeth present. No slit on inner side of fourth gill arch. Gill rakers comparatively rather slender, of moderate length at angle, rather gradually decreasing in size both ways, those at both ends short, sometimes one or two at either end very short, tubercle-like; total number of gill rakers and tubercles 7-9+16-19, 23-27 in combined number. Occiput flat, without a pit. Parietal ridge divided into two unequal parts, the anterior

part long, both parts ending in spinous points; frontal spine placed laterad of parietal ridge, in a line with postocular; upper and lower posttemporal spines rather closely approximated; sphenotic and pterotic spines placed rather low, approximately on a lengthwise line through upper margin of pupil; sphenotic spine short and blunt or represented by a mere bony knob or absent; pterotic rather narrow and pointed or absent; postorbital absent; preorbital without definite spinous points, two slight or moderate blunt knobs instead; suborbital ridge with one slight or moderate point, or smooth; cleithrum without a spinous point or projection. Second preopercular spine longest, reaching about halfway to opercular margin or a little farther; first spine distinctly shorter than second, subequal to or slightly longer than third, without a supplementary spine; fourth and fifth spines moderate. Upper outer corner of interopercle often ending in a blunt angle or spinous point. Without tentacles or tabs. Scales ctenoid, 60-79; nape, opercle, and cheek virtually all scaled; interopercle partly scaled; interorbital scaled for a short distance posteriorly, its greater part scaleless; snout scaleless; maxillary partly scaled, infrequently the scales few and nearly embedded (such variants appearing scaleless on superficial examination). Dorsal typically with 12 spines; penultimate spine about four-fifths as long as last spine or slightly longer; longest dorsal spine subequal to postorbital part of head. Ventral having its outer angle a little behind lower pectoral angle, about reaching anus, varying slightly both ways. Pectoral usually having upper 2 rays unbranched, next 8-10 branched, lower 7-9 unbranched, total number of rays 17-20; the lower unbranched rays notably thickened, their distal ends detached from one another for nearly half their length; posterior margin of upper half of fin a nearly straight, slightly inclined line; the fin reaching backward approximately to a vertical through end of ventral. Caudal very moderately emarginate.

Ground color yellowish or golden; upper part of body, for a variable distance, with dark, irregular, partly anastomosing or confluent markings, the dark pigment mostly confined to margin of scales; these dark markings or shadings absent in most specimens examined (probably disappearing in preservative); posterior and greater part of mouth cavity and inner face of gill cover black or dusky, dark color especially marked on roof of cavity, sometimes the dark color hardly appreciable in specimens long in preservative. In recently preserved specimens the color in the mouth cavity is a deep bluish black.

The smaller specimens of *maderensis* have a dorsal spot as de-

scribed under that subspecies. Smaller specimens of the other two subspecies are not available for comparison.

*Subspecies.*—The samples of this species examined are divisible into three major allopatric populations according to the following geographic regions: (1) eastern Atlantic and Mediterranean, (2) western north Atlantic, (3) Atlantic coast of South America; and are hereafter treated as subspecies, *dactylopterus*, *maderensis*, and *lahillei*, respectively. The subspecies differ in the relative frequency of occurrence of a spine on the suborbital ridge, in the scale count, and in some proportional measurements as stated and discussed under their accounts. In some proportional measurements *dactylopterus* and *lahillei* represent the extremes while *maderensis* is intermediate. The interorbital has the greatest average width in *lahillei* and the narrowest in *dactylopterus*. The proportional numerical value of the ventral, pectoral, depth, head, maxillary, and eye measurements average highest in *dactylopterus* and lowest in *lahillei*.

#### HELICOLENUS DACTYLOPTERUS DACTYLOPTERUS (De la Roche)

*Scorpaena dactyloptera* DE LA ROCHE, Ann. Mus. Hist. Nat. Paris, vol. 13, pl. 22, fig. 2, 1809 (Barcelona).

*Helicolenus dactylopterus* NORMAN, *Discovery Reports*, vol. 12, p. 24, 1935 (summarizes distribution; compares with the American *maderensis* and other species).

D.XII 12. A.III 5. P.19-20. Sc.66-73. GR.7-8+16-18.

*Description.*—Spine on suborbital ridge usually absent, sometimes present (on one side in 1 out of 7 specimens). Scales 66-73 (in 5).

Measurements of 6 specimens 197-325 mm.: caudal 25.5-28.0, ventral 22-26, pectoral 30.5-33.0, depth 33.0-36.5, head 40-45, maxillary 21.5-22.5, snout 9.0-11.0, eye 13.5-14.2, interorbital 4.4-4.7; snout 1.2-1.5 and interorbital 2.9-3.2 times in eye.

*Specimens examined.*—Bergen, Norway (17434). Azores (23302, 94491). Bay of Naples (48329). Genoa (29783, 124422). Received from Paris Museum, without a definite locality (42086). Total examined, 7 specimens 192-395 mm., the largest from Norway.

*Comparison.*—This subspecies differs from the other two here treated in usually lacking a spine on the suborbital ridge. It possibly averages a longer head, maxillary, pectoral and ventral, larger eye, narrower interorbital, fewer gill rakers, and more pectoral rays. The scale count is rather intermediate between *maderensis* and *lahillei*.

**HELICOLENUS DACTYLOPTERUS MADERENSIS** Goode and Bean

*Helicolenus maderensis* GOODE and BEAN (in part), Oceanic ichthyology, p. 250, pl. 68, fig. 244, 1895 (plate labeled *dactylopterus*, but legend to plate, on page 15\*, labeled *maderensis*; for restriction of name see below).—NORMAN, *Discovery Reports*, vol. 12, p. 25, 1935 (off Long Island, N. Y.).—LONGLEY and HILDEBRAND, Carnegie Inst. Washington Publ. 535, p. 165, 1941 (Tortugas, Fla.).

*Helicolenus thelmae* FOWLER, Proc. Acad. Nat. Sci. Philadelphia, vol. 89, p. 300, fig. 5, 1937 (near Gulf Stream off Cape May, N. J.).

D.(XI)XII(XIII) (10) 11-13. A.III (4) 5. P.(17) 18-20. Sc.60-71. GR.7-9+16-18.

*Description*.—Spine on suborbital ridge usually present, often absent (see below for frequencies). Scales 60-71 (counted in 38 specimens; scalation incomplete in most specimens examined and number of scales not definitely determinable in such specimens).

Measurements of 12 Atlantic specimens 185-278 mm., including the lectotype, and 2 specimens 152-162 mm., the holotype and paratype of *H. thelmae*: caudal 25.5-27.5 (25.5-26.5), ventral 21-24 (23-24.5), pectoral 25.5-31.0 (28.5), depth 32-37 (35-36), head 38.5-43.5 (39.5), maxillary 20-22 (20), snout 9.6-11.1 (8.9-9.5), eye 11.7-13.7 (13.0-13.2), interorbital 4.6-5.7 (4.6-4.7); snout 1.1-1.3 (1.4-1.5) and interorbital 2.1-2.7 (2.8) times in eye. The same measurements of 5 Gulf of Mexico specimens 195-238 mm. fall within the range of the above large specimens, except as follows: pectoral 28.0-31.5, maxillary 21.0-22.5, eye 13.4-14.7, interorbital 4.2-5.3; snout 1.4 and interorbital 2.6-3.4 times in eye.

Small specimens with a dark spot on dorsal between seventh or eighth and eleventh spines; the spot beginning to disappear at about 100 mm., often well marked in specimens up to 150 mm., and a more diffuse spot sometimes persisting up to 200 mm.

*Specimens examined*.—In the U. S. National Museum, 177 specimens in 54 constituent samples. The great majority were taken by the *Albatross* and the *Fish Hawk* at a number of stations. The geographic range of these specimens is from off Cape Cod, Mass. (41° 49' N., 65° 49' 30" W.; 143291) to off Tortugas, Fla.; and off Egmont Key and Cape San Blas, Fla., and the Mississippi Delta in the Gulf of Mexico. Besides the preceding large sample the following 4 specimens were examined. About 70 miles southeast of Cape May, N. J. (A.N.S.P. 68261 and 68262, the holotype and paratype, respectively, of *H. thelmae*). Off Massachusetts Bay (U.M.M.Z. 157066; lat. 42° N., long. 68° W., 85-95 fathoms, fishing boat *Mary and Josephine*; U.M.M.Z. 157067; lat. 42° 20' N., long. 68° 50' W., 106

fathoms, fish boat *Bonaventure*). The last specimen constitutes the northernmost record. The recorded vertical range is 70-373 fathoms. Total examined, 181 specimens 29-444 mm., the largest from off Long Island, N. Y. (21824).

*Populations.*—According to the measurements given above, the Gulf population of this subspecies differs from that of the Atlantic in averaging a larger eye and narrower interorbital. The frequency of occurrence of a spinous point on the suborbital ridge in the Gulf population, judged by the 5 specimens examined, seems to be not much different than in the Atlantic population.

*Lectotype.*—In the original account of *maderensis* only western Atlantic localities are enumerated for the specimens examined. However, the authors state that the same species occurs in Madeira, and they cite the account of *Sebastes imperialis* of Lowe as referring to their *maderensis*. Their account, consequently, is a composite one, referring to more than one subspecies, and it becomes necessary to restrict the use of the name *maderensis*. Therefore, U.S.N.M. No. 26627 is hereby designated as the lectotype. It is one of Goode and Bean's original specimens, apparently the one figured, and its data are as follows: *Fish Hawk* station 897, lat.  $37^{\circ} 25' N.$ , long.  $74^{\circ} 18' W.$ , off Hog Island, Va., 158 fathoms, 200 mm. As restricted, the name *maderensis* is inappropriate for a common fish living off the east coast of the United States; but all the original specimens came from this region.

*Comparison.*—Norman and also Longley (cited above) treat the western Atlantic *maderensis* as of specific rank. Norman states that *maderensis* differs from *dactylopterus* in having a smaller eye, in constantly having a spine on the suborbital ridge, in the less deeply concave interorbital, and possibly in having a little larger scales. Longley distinguishes *maderensis* from *dactylopterus* by its smaller eye and by its having a spine on the suborbital ridge. However, an examination of more extensive samples than those available to the above authors lead to the following conclusions.

The depth of the interorbital concavity is largely a matter of individual variability and can hardly be used as a specific character. The difference in the size of the eye does seem to have some value, 13.5-14.2 in 6 European specimens, and 11.7-13.7 in 12 specimens of comparable size from the Atlantic coast of the United States. However, when the measurements of the eye of the 17 specimens are arranged in order of magnitude, 3 European and 2 American Atlantic specimens intergrade, which indicates a degree of divergence of less than

subspecies magnitude. Moreover, in 5 comparable specimens from the Gulf of Mexico the eye measurement is 13.4-14.7, very nearly the same as in the European specimens. It is evident that the size of the eye differs with the minor population and cannot be used even in subspecific division. The scales in 5 European specimens number 66-73, while in 38 American fish the range is 60-71, and this difference also is obviously below the subspecies level.

The difference showing the greatest divergence apparently refers to the spinous point on the suborbital ridge, but this character also intergrades considerably. Of 181 specimens examined from the western Atlantic, 124 have a spinous point on both sides, 41 have the spine on one side only, and 16 lack a spine on both sides. The percentages of these three categories of specimens in the entire composite sample are: 69, 23, and 9, respectively. Of 7 European specimens examined only one has a spinous point on one side only. In the absence of an adequate sample from Europe, to express the extent of divergence in numerical terms, the number of observations, which is twice the number of specimens, may be used as a base. Of 362 observations on western Atlantic specimens, 73, or 20.17 percent, are zero and 289 are 1; while the corresponding observations on European specimens are 13 and 1, respectively, that is, the intergrading observation is 7.14 percent of the sample. The index of intergradation then is 14, and concomitantly the index of divergence is 86 (Ginsburg, 1938), which is not more than of subspecies magnitude, and the populations are so treated here.

*Synonymy.*—The 2 types of *thelmae* were examined and their data included in this account. The holotype has a blunt projection in the normal position of the spinous point on the suborbital ridge. It is included in the above enumeration with the specimens having a spine, as the development of this spine shows all degrees of difference from a sharp point to a blunt projection. In the paratype the interorbital ridge is smooth on both sides as in 15 other individual variants of *maderensis*. The two types seemingly lack scales on the maxillary, while *dactylopterus*, sensu lato, including *maderensis*, normally has such scales. However, the scales in *maderensis* and the two other subspecies are more or less deciduous. Other specimens of *maderensis* examined seemingly lack scales on the maxillary. Besides, the holotype of *thelmae* shows faint traces on the right maxillary of scales having been present. In measurements, counts, the presence of a diffuse dorsal spot, and other characters, the two types of *thelmae* agree with the common *maderensis* and there is no question that they belong to this subspecies.

**HELICOLENUS DACTYLOPTERUS LAHILLEI Norman**

*Helicolenus lahillei* NORMAN, *Discovery Reports*, vol. 16, p. 124, fig. 68, 1937 (coasts of Uruguay and northern Argentina).

*Helicolenus uruguayensis* FOWLER, *Proc. Acad. Nat. Sci. Philadelphia*, vol. 95, p. 326, figs. 18, 19, 1943 (off Uruguay).

D.XII-XIII 11-13. A.III 5. P.18-19. Sc.68-79. GR.7-8+17-19.

*Description*.—Spinous point on suborbital ridge usually present, sometimes absent (of 9 specimens examined, 7 have a spine on both sides and 2 lack it on one side only). Scales 68-79 (in 4).

Measurement of 9 specimens 208-290 mm.: caudal 25-29, ventral 20-23, pectoral 27.0-30.5, depth 32.0-35.5, head 37.0-41.5, maxillary 18.5-20.5, snout 8.5-10.0, eye 11.4-13.0, interorbital 4.6-6.2; snout 1.2-1.5 and interorbital 1.9-2.7 times in eye.

The shadings on the body, as described under the account of *dactylopterus*, *sensu lato*, is usually somewhat better developed in *lahillei* than in the other two subspecies in the preserved specimens examined.

*Specimens examined*.—Off Río de la Plata, lat. 36° S., long. 54° W., 50 meters, F. Filippone (85509, 290 mm.). Five specimens 208-252 mm. obtained in Uruguay during 1921-22, probably in the Montevideo market, by Hugh M. Smith (86696-86700, inclusive). Uruguay (A.N.S.P. 70325, the holotype 286 mm., and A.N.S.P. 70326-7, two paratypes 227-229 mm., of *uruguayensis*).

*Comparison*.—This subspecies, like *maderensis*, usually has a spine on the suborbital ridge. It differs in having a higher scale count, 68-79 instead of 60-71. While the specimens with a fairly complete scalation examined are not enough to determine the precise degree of divergence, it is apparently not greater than subspecies magnitude. This subspecies differs from the other two in proportional measurements also, as stated under the account of the species and as may be gathered by comparing the measurements here given for the three subspecies. In measurements also *lahillei* is nearest *maderensis*.

*Nomenclature and synonymy*.—The three types of *uruguayensis* were examined and their data are included in this account, but the types of *lahillei* were not examined. Fowler, in describing his *uruguayensis*, calls attention to some discrepancies in Norman's account of *lahillei*, based mainly on a comparison of his specimens with Norman's published figure. However, allowing for imperfections that nearly always are found in pen-and-ink drawings of fish, and taking Norman's account of *lahillei* in its entirety, it is evident that it refers to the subspecies here described, which seems to be common on the coast of Uruguay.



Genus **SCORPAENODES** Bleeker

*Scorpaenodes* BLEEKER, Nat. Tijdschr. Ned. Ind., vol. 13, p. 371, 1857 (genotype *Scorpaenodes polylepis* (Bleeker) = *Scorpaena polylepis* Bleeker by monotypy; name merely listed, no description).

*Definition.*—Eye moderately larger than snout. Interorbital one-half the eye diameter or moderately narrower. Maxillary ending under middle or posterior margin of eye. Palatine teeth absent (the only one of the present genera lacking palatine teeth). Small slit behind fourth gill arch present or absent. Gill rakers moderate at angle becoming very short, tubercle-like at ends of first gill arch; tubercles well separated and individually countable in the few specimens examined; gill rakers and tubercles combined 4-8+10-13, or 15-20 in total number. Occiput flat, without a pit. Interorbital with two bilaterally placed ridges, one on both sides of midline, slightly or well developed, ending in a spinous point, or the point virtually absent; parietal ridge divided into subequal parts, both ending in spinous points; frontal spine nearly alined with postocular, placed laterad of parietal ridge; lower posttemporal present, upper one present or absent; sphenotic and postorbital spines inconspicuous, in form of a group of a few slight spinules, asperities, or tuberosities; pterotic large or small; pterotic, lower posttemporal and supracleithral spines almost on same lengthwise line; preorbital with two broad, lobelike projections, without spinous points; suborbital ridge well developed, its spinous points differing widely with the species; supracleithral spinous point notably long, tapering, and sharp; cleithrum with a moderate tapering projection, sharply pointed or rather blunt. Preopercle having first spine longest, supplemental spine varying with the individual, present or absent (sometimes varying on both sides of same specimen); second spine placed near first spine; third spine in form of a rather broad projection without a sharp point; fourth and fifth spines virtually absent or slightly developed. Tentacles and other appendages comparatively few. Scales 40-42, ctenoid on body, occiput, opercle, and cheek; mostly cycloid on chest and fleshy pectoral base; opercle, and cheek to about under middle of eye nearly all scaled; interorbital, snout, and maxillary scaled or nearly scaleless; interopercle scaleless. Dorsal spines 13; emargination between spinous and soft parts rather well developed, penultimate spine two-fifths to seven-tenths as long as last spine; longest dorsal spine shorter than postorbital part of head. Second anal spine longer than third. Ventral reaching anus or a little short, its outer angle placed under lower pectoral angle. Pectoral nearly wedge-shaped, the longest rays near

its middle, reaching a vertical through beginning of anal or a little short; with 17-19 rays, upper 5-7, except uppermost 1 or 2, branched. Caudal rounded.

*Pectoral rays and gill rakers.*—As the number of available western Atlantic specimens belonging to *Scorpaenodes* are very few, the pectoral rays and the gill rakers, being of importance in distinguishing the species, have been counted on both sides of every specimen and all the counts entered in the tables and in the accounts of the species. The gill-raker count differs rather widely on both sides of the type of *russelli*, 10 on the lower limb of the right side, 13 on the left.

*Comparison.*—*Scorpaenodes* differs from all other known western Atlantic scorpaenid genera in lacking palatine teeth and normally having 13 dorsal spines.

*Speciation.*—Five western Atlantic species of *Scorpaenodes*, namely, *tridecimspinosus*, *caribbaeus*, *russelli*, *triacanthus*, and *floridae*, have been successively described from time to time by different authors. In most instances the successive new species were established on the basis of published accounts, rather than by direct comparison of specimens. I examined and compared directly a cotype of *tridecimspinosus*, the holotype and a paratype of *floridae*, and the holotypes of the other three species. This study has shown that *caribbaeus*, *russelli*, and *triacanthus* are based on specimens of the same species which is different from *tridecimspinosus*; while the two types of *floridae* are doubtfully different specifically from *tridecimspinosus*. That is, based on a direct comparison of the types, not more than three species of *Scorpaenodes* are now known from the western Atlantic, one of which is doubtfully distinct. The species are compared below in some detail under their accounts.

#### SCORPAENODES CARIBBAEUS Meek and Hildebrand

*Scorpaenodes caribbaeus* MEEK and HILDEBRAND, Publ. Field Mus. Nat. Hist., zool. ser., vol. 15, pt. 3, p. 847, pl. 82, September 1928 (Toro Point, Canal Zone).

*Scorpaenodes russelli* BEEBE and TEE-VAN, Zoologica, vol. 10, No. 1, p. 189, fig., December 1928 (Port au Prince, Haiti).

*Scorpaenodes triacanthus* PARR, Bull. Bingham Oceanogr. Coll., vol. 3, art. 4, p. 115, fig. 30, 1930 (Cat Island, Bahamas).

D.XIII 9. A.III 5. P.18-19. Sc.41-42. GR.6-8+10-13.

*Description.*—Eye a little larger than snout. Interorbital about two-fifths the eye. Maxillary ending under middle of eye. Small slit behind fourth gill arch present. Most spines on head, including the interorbital ridges and spinous points, well developed; lower post-

temporal well developed, upper one small or absent; an extra spinous point about midway between posterior parietal and lower posttemporal ridges (latter spine bifid on right side of type of *caribbaeus* and absent on left side of type of *triacanthus*; an extra small spinous point a little way below posterior parietal ridge on right side of type of *caribbaeus*); pterotic spine notably well developed; suborbital ridge with 4 or 5 spinous points; 2-4 other points on a line parallel to main ridge and at a very short distance below it, placed under anterior part of eye (on right side of type of *caribbaeus* an extra spinous point over main ridge slightly behind a vertical through posterior margin of eye). Small tentacles or tabs placed at some of the spines on the head, including the supraocular spine, and along the course of the lateral line. Interorbital, snout, and cheek under anterior part of eye with very small nonimbricate scales; maxillary for a moderate extent along its upper part with similar small scales present or absent. Penultimate dorsal spine about two-thirds as long as last spine. Ventral reaching anus or falling slightly short. Pectoral reaching a vertical through base of first anal spine or falling slightly short; its upper 2 rays unbranched, next 6-7 rays branched, lower 9-11 rays unbranched.

Measurements of 2 specimens 63.5-68.7 mm. in standard length, the caudals damaged, and 1 specimen 48 mm. or 36.5 mm. in standard length: caudal (32.5), ventral 26 (31), pectoral 31.5 (35.5), depth 37.5-39.0 (39.5), head 44-45 (47.5), maxillary 21-23 (24.5), snout 11.8-13.2 (12.3), eye 13.8-14.2 (14.8), interorbital 5.5-5.8 (7.4); snout 1.1-1.2 (1.2) and interorbital 2.4-2.6 (2.0) times in eye.

Rather dark brownish above, somewhat lighter below; dorsal dark, the pigment somewhat more concentrated between eighth and ninth and twelfth spines, without a definite spot; pectoral, soft dorsal, and caudal with small spots; no other distinctive color marks.

*Development.*—The preceding account is based in large part on two specimens 63.5-68.7 mm. in standard length (the holotypes of *caribbaeus* and *russelli*, respectively). A considerably smaller specimen, 36.5 mm. in standard length (the holotype of *triacanthus*), differs from the two larger specimens as follows. The very small scales on the snout and interorbital are as yet undeveloped, but some tiny papillae are present, which are seemingly destined to become scales. The maxillary about reaches to under posterior margin of eye. The suborbital and pterotic spinous points are not as well developed. The caudal peduncle is abruptly lighter. The pectoral and, to a lesser extent, the soft dorsal, anal, and caudal have a dark area near their base, and the small spots on the fins are much fewer. Differences in some proportional measurements are indicated above. All these differ-

ences are readily ascribable to growth changes. There are no well-marked specific differences such as distinguish scorpaenid species. It is therefore concluded that the holotype of *triacanthus* is a small specimen of *caribbaeus*, although a complete series is not available to trace growth changes more definitely.

*Specimens examined*.—Toro Point, Canal Zone (81619, holotype of *caribbaeus*, 63.5 mm. in standard length). Port au Prince Bay, Haiti (N.Y.Z.S. 7207, holotype of *russelli*, 68.7 mm. in standard length). Cat Island, Bahamas (B.O.C. 2533, holotype of *triacanthus*, 48 mm.). The type of *caribbaeus* is an abnormal specimen having the soft fins malformed, apparently a result of either an injury at some past time in life or a derangement during development. Therefore, its soft dorsal and anal counts and the ventral measurement is not included in the account of the species. But the dorsal and anal spines, the scalation, the shape of the body and head, and the spinous armature of the latter are evidently normal.

*Comparison*.—This species differs from *tridecimspinosus* in a number of characters, as follows. Some spinous points are present under the anterior main part of the suborbital ridge. The interorbital ridges are better developed and they end in well-developed spinous points. The pectoral rays and the gill rakers on the upper limb are more numerous. The minute scalation on the snout and interorbital is better developed. It has a small slit behind the fourth gill arch.

*Synonymy*.—A direct comparison of the types of *russelli* and *caribbaeus* shows without a doubt that both specimens belong to the same species. Its presumed specific differences given in the original description of *russelli*, based on a comparison with rather inadequate accounts of previously established species, do not hold, or the differences are based on individual variation.

*S. triacanthus* was established chiefly because it was supposed that it has 3 opercular spines. However, an examination of the type shows that it has only 2 spines in the opercle, like the other species of its family. Apparently the supracleithral spine was assumed to be a third opercular spine. The type of *triacanthus* is evidently a half-grown specimen of *caribbaeus* as discussed above.

#### SCORPAENODES TRIDECIMSPINOSUS (Metzlaar)

*Scorpaena tridecimspinosus* METZLAAR, Rapp. Vissch. Kol. Curaçao, edited by J. Boeke, vol. 2, pt. 1, p. 146, fig. 44, 1919 (Aruba and Bonaire Islands, D.W.I.).

D.XIII 9. A.III 5. P.17. Sc.4I. GR.5+10.

*Description*.—Eye rather large, moderately larger than snout. Interorbital slightly less than half the eye. Maxillary ending under poste-

rior margin of eye. No slit behind fourth gill arch. Interorbital ridges slight, not ending in definite spinous points; upper posttemporal absent; pterotic small; suborbital ridge with three moderate spinous points. A foliar tentacle at base of supraocular spine, much expanded for its distal and greater part, digitated; a similar narrower tentacle at lower posterior corner of preorbital bone; a moderate elongate tentacle at postocular spine; a foliar sessile tentacle on eyeball nearly over anterior margin of pupil; a similar larger tentacle attached to posterior rim of anterior nostril; small tentacles at other spines on head. Anterior and greater part of interorbital, snout, and cheek under anterior part of eye with numerous papillae, some of them in form of tiny scalelike structures; no scales on maxillary. Penultimate dorsal spine about half as long as last spine. Ventral falling a little short of anus. Pectoral a little short of a vertical through first anal spine; its upper ray unbranched, next 6 or 7 rays (differs on both sides of same specimen) branched, lower 9 or 10 rays unbranched, notably thickened.

Measurements of one specimen 42.8 mm. in standard length, the caudal damaged: ventral 27.5, pectoral 30, depth 36, head 44.5, maxillary 25.5, snout 12.6, eye 1.4, interorbital 6.8; snout 1.1 and interorbital 2.1 times in eye.

Brownish, nearly uniform, slightly and irregularly shaded; a broad transverse whitish area under pupil to maxillary; dark pigment somewhat more concentrated at posterior part of spinous dorsal; pectoral and soft dorsal with small, rather faint brownish spots. The figure of the species published by Metzlaar shows rather sharply contrasting light and dark shades with 2 dark, broad cross areas on posterior part of body and caudal peduncle.

*Specimen examined*.—Bonaire Island, D.W.I. (160660, cotype of *tridecimspinosus*).

*Comparison*.—This species is compared with *caribbaeus* and *floridae* under their accounts.

#### SCORPAENODES FLORIDAE Hildebrand

*Scorpaenodes floridae* HILDEBRAND, Carnegie Inst. Washington Publ. 517, p. 251, fig. 14, 1940 (Tortugas, Fla.).

D.XIII 8-9. A.III 5. P.17. Sc. about 40-41. GR.4-5+11.

*Description*.—Eye rather large, snout about four-fifths the eye diameter. Interorbital width equaling one-half the eye or a little narrower. Maxillary ending under posterior margin of eye. No slit behind fourth gill arch. Interorbital ridges slight or moderate, their

spinous points moderate or virtually absent; lower posttemporal moderate, upper one absent; pterotic spine very moderate; suborbital ridge with one moderate spinous point, at its posterior end. A moderate, elongate tentacle at base of supraocular spine; a similar smaller tentacle at posterior lower angle of preorbital; a foliar sessile tentacle on eyeball nearly over anterior margin of pupil; tentacle at anterior nostril moderately expanded distally; very small tentacles or tabs at preocular and some other spines on the head. Anterior and greater part of interorbital, snout, and cheek under anterior part of eye with very small, nonimbricate, widely spaced scales and some papillae; no scales on maxillary. Penultimate dorsal spine about two-fifths as long as last spine. Ventral about reaching anus. Pectoral reaching to over base of first or second anal spine; its upper 1 or 2 rays unbranched, next 5-7 rays branched, lower 9-10 rays unbranched.

Measurements of 2 specimens 51-58 mm.: caudal 28-29, ventral 27-30, pectoral 34.5, depth 38.0-39.5, head 44-45, maxillary 25, snout 10.9-11.2, eye 13.1-14.2, interorbital 6.6; snout 1.2-1.3 and interorbital 2.0-2.2 times in eye.

The two specimens examined almost uniformly yellowish, apparently faded; a trace of brown pigment between the eighth or ninth and eleventh dorsal spines suggesting the possible normal presence of a spot in that position.

*Specimens examined*.—South of Tortugas, Fla., 45 fathoms (108875, the holotype; 108876, the paratype).

*Comparison*.—It is doubtful whether *floridae* represents a valid species, distinct from *tridecimspinosus*. The two type specimens of *floridae* differ from the paratype of *tridecimspinosus* examined as follows. The suborbital ridge has only 1 spinous point, instead of 3. The interorbital ridges and spines are somewhat better developed. The tentacles on the head, especially those at the supraocular spine, the preorbital bone, and the anterior nostril, are not as well developed. However, judged by intraspecific variability of some other scorpaeiid species, it seems possible that an examination of an adequate sample of *tridecimspinosus* will show that the differences outlined above are nothing more than differences between individuals of the same species.

#### Genus PONTINUS Poey

*Pontinus* POEY, *Memorias sobre la historia natural de la Isla de Cuba*, vol. 2, p. 172, 1860 (genotype *Pontinus castor* Poey by monotypy, the only other species, *pollux*, included in original account being a *species inquirendae*).—JORDAN and GILBERT, *U. S. Nat. Mus. Bull.* 16, p. 673, 1883 (*Pontinus castor* Poey designated genotype).

*Definition.*—Eye subequal to snout or smaller, except in *macrolepis* varying to larger than snout. Interorbital about a third to half the eye. Maxillary ending under middle to under posterior margin of eye. Palatine teeth present. A small slit behind fourth gill arch, either open altogether or bridged over its outer side by a thin, easily torn membrane. Upper limb with 3-6 end gill rakers short, tubercle-like, but individually readily distinguishable and countable; lower limb with 3-6 tubercles at end, some of them only slightly raised above surface of arch or much expanded lengthwise along arch, sometimes difficult to distinguish individually; combined number of gill rakers and tubercles 5-8+12-15, or 18-22 altogether. Occipital region flat, without a pit. Nasal spine small or well developed. Parietal ridge divided into two parts, both ending in spines, the anterior part somewhat longer; frontal spine in a line with postocular, placed a little laterad of parietal ridge; upper posttemporal very small or absent, lower posttemporal well developed; sphenotic in form of 2 parallel, transverse rows of small spinous points, growing smaller downward, 1 to 6 points in a row; pterotic ridge and spine well developed; a ridge between sphenotic and frontal spine fairly developed or slight; postorbital in form of a group of slight asperities, or very slight tubercle-like projections, or absent; preorbital with 2 free spinous points, the posterior better developed than anterior and directed backward, smaller anterior spine directed downward or backward depending on the species; suborbital ridge well developed, typically with 3 or 4 spinous points; spinous point on cleithrum moderate or rather well developed. First preopercular spine longest, supplemental spine usually present, sometimes absent as an individual variation; second spine smaller than third or absent, distance between first and third spines characteristically a nearly straight transverse line, the third spine marking a comparatively sharp turn in direction of preopercular margin downward and forward; fifth spine variable, well developed or absent. Tentacles sparsely developed. Scales ctenoid, 42-54; opercle and nape all scaled; cheek nearly all scaled posteriorly, naked or incompletely scaled under anterior part of eye; interorbital scaled posteriorly, scaled or naked for its larger part anteriorly; snout more or less scaled or scaleless; interopercle with a few scales posteriorly; maxillary scaleless. Dorsal typically with 12 spines; with 9 or 10 rays, depending on the species; penultimate spine about two-thirds to five-sixths as long as last spine; shape of spinous dorsal differing with the species. Second anal spine notably longer than third, except moderately so in *castor*. Ventral reaching anus or falling slightly short, its outer angle

under lower pectoral angle or slightly more forward. Pectoral irregularly wedge-shaped, the longest rays near its middle, usually falling short of a vertical through base of first anal spine, often about reaching this vertical; usually with 17 or 16 rays, depending on the species, all unbranched. Caudal truncate, slightly rounded, or very moderately emarginate.

*Comparison.*—This genus differs from the other western Atlantic scorpaenid genera in having all pectoral rays unbranched. It is most nearly related to *Neomerinthe*, as discussed under that genus.

*Western Atlantic species.*—Four western Atlantic species of *Pontinus* are here treated. A fifth species has been described, namely, *Pontinus corallinus* Miranda Ribeiro (1915, p. 4, photo); but no specimens are available for study. The general aspect of the published photograph of *P. corallinus* rather agrees with *Pontinus macrolepis*; but Miranda Ribeiro ascribes to his fish 6 gill rakers and 4 rudiments on the lower limb, and 2 and 4, respectively, on the upper limb. The combined number of gill rakers and rudiments on the lower limb and the total combined number on both limbs is less than in the four species of *Pontinus* here treated (compare with tables 4 and 5).

#### PONTINUS MACROLEPIS Goode and Bean

*Pontinus macrolepis* GOODE and BEAN, Oceanic ichthyology, p. 257, pl. 69, fig. 247 (off Yucatan).—EVERMANN and MARSH, Bull. U. S. Fish. Comm., vol. 20, pt. 1, p. 280, col. pl. 43, (1899) 1902 (Mayagüez Harbor, Puerto Rico).

D.XII 9. A.III 5. P.15-16. Sc.45. GR.7-8+12-13.

*Description.*—Eye a little larger than snout or subequal to it. Interorbital less than a third the eye diameter. Maxillary ending under posterior margin of pupil or a little behind. Nasal spine well developed; upper posttemporal spine small, sometimes absent; preorbital spines well developed, the anterior one directed backward; suborbital ridge usually with 3 spinous points, sometimes 4. Second preopercular spine present, placed nearer first than third spine; fifth spine very moderate or absent. A tentacle at supraocular spine usually present, slender or moderately thick, short or long; a short tentacle at preocular and posterior preorbital spine present or absent. Scales on cheek mostly ctenoid, those on anterior part of chest and pectoral base mostly cycloid; snout and greater part of interorbital scaleless. Third dorsal spine longest, subequal to postorbital part of head, moderately longer than fourth, thence gradually decreasing; penultimate spine about five-sixths as long as last spine. (Caudal damaged in the 4



specimens examined, its shape not definitely determinable.) Preserved specimens examined about uniformly yellowish, without color marks.

Measurements of 4 specimens 51-137 mm.: caudal 25-27, ventral 25.5-27.5, pectoral 27.5-30.5, depth 32.5-35.5, head 45-47, maxillary 22-24, snout 12.9-13.2, eye 12.9-15.4, interorbital 4.0-4.7; snout 1.0-1.2 and interorbital 3.1-3.6 times in eye.

*Specimens examined*.—Off Cozumel Island, Mexico (39324, the type). Off Havana, Cuba (100381). Off Anegada Island, Virgin Islands (117879). Mayagüez Harbor, Puerto Rico (126131). Total examined, 4 specimens 51-137 mm., taken in 122-224 fathoms.

*Comparison*.—This species has 15-16 pectoral rays instead of 17-18 in its three congeners (rarely 16 in *longispinis*, see table 1). The eye averages larger than in the three other species. It nearly agrees with *rathbuni* and *longispinis* and differs from *castor* in having the snout a little shorter than or subequal to the eye. Like *castor* it has 3 spinous points on the suborbital ridge, while *rathbuni* and *longispinis* usually have 4.

#### PONTINUS LONGISPINIS Goode and Bean

*Pontinus longispinus* GOODE and BEAN, Oceanic ichthyology, p. 258, pl. 68, fig. 246, 1895 (off Cape San Blas, Fla.).

D.XII 9 (10). A.III 5. P.(16) 17 (18). Sc.47-51. GR.6-7+12-15.

*Description*.—Eye a little smaller than or subequal to snout. Interorbital about a half to a third the eye diameter. Maxillary ending under middle of eye or posterior margin of pupil. Nasal spine small; upper posttemporal spine usually present, small, pointed or blunt, sometimes absent; preorbital spines well developed, the anterior one usually directed downward or slightly forward; suborbital ridge usually with 4 spinous points, the anterior one sometimes absent. Second preopercular spine in the larger specimens (see below) usually very small, often absent on one or both sides; fifth preopercular spine small but sharp. Tentacle at supraocular spine very slender and small or absent, of moderate length and slender in small specimens (skin partly destroyed in most specimens examined and this statement based on fragmentary data). Scales on cheek, chest, pectoral base, interorbital, and snout mostly ctenoid; interorbital and snout incompletely scaled for their greater part, scales on anterior part of snout minute. First dorsal spine about two-thirds as long as second. Third spine prolonged in specimens over 90-110 mm.; becoming notably long in large specimens, longer than postorbital part of head, nearly twice as long as second spine, reaching base of eighth to tenth spine when depressed.

Fourth spine a little longer than second; gradually decreasing in length from fourth backward; penultimate spine about three-quarters as long as last spine; in small specimens about 100 mm. or smaller, third spine only a little longer than fourth, the spines gradually decreasing in length from third to penultimate spine. Caudal very moderately emarginate with the upper rays slightly longer than lower.

Measurements of 5 specimens 123-178 mm.: caudal 25.5-28.5, ventral 23-25, pectoral 27-29, depth 31.5-33.0, head 41-45, maxillary 19.5-21.5, snout 12.6-13.1, eye 11.8-13.6, interorbital 4.3-5.0; eye 0.9-1.1 times in snout, and interorbital 2.4-3.1 times in eye. Two specimens 215-220 mm.: pectoral 29.5-30.0, depth 28.0-31.5, head 40.5-42.5, eye 11.5-12.1, snout 13.4; eye 1.0-1.3 times in snout, interorbital 2.1-2.7 times in eye; other measurements falling within range of variation of smaller specimens.

Ground color light yellowish; upper two-thirds of body with irregularly scattered small brownish spots, their number very variable, sometimes rather profuse, sometimes nearly confined to a row along course of lateral line or nearly absent; small, rather diffuse spots on caudal and dorsal, also variable in number. Small specimens, about 45 mm. or less, with a large dark blotch between sixth or seventh and ninth or tenth dorsal spines; otherwise not spotted.

*Development.*—In very small specimens, 24-30 mm., the upper 3 preopercular spines are in general approximately equal. With growth, the second and third spines become shorter in relation to the first. With further growth, the second spine decreases in length; it becomes smaller than the third at about 60 mm.; and is very small or altogether absent on one or both sides in larger specimens. (The development of the third anal spine is discussed above under the family account.)

*Specimens examined.*—Off the following localities: Bull Island, S. C. (151867). Savannah, Ga. (91403). Melbourne (155299), Tortugas (117144-5 and 117149-50), Cape San Blas (U.S.N.M. Nos. 39322-3, types; 46094, 155296, 155298, 157539), Pensacola (155295, 155297), and Santa Rosa Island (157540-1), Fla. Mississippi Delta (155287-90, inclusive) and Point au Fer (155291), La. Padre Island, Tex. (155292-4, inclusive; 157542). Total examined, 79 specimens 24-220 mm., the largest from off Tortugas. Available depth records range 40-142 fathoms. This is apparently a rather common species offshore. The majority of the specimens examined were collected by the *Pelican* and the *Oregon*.

*Comparison.*—This species differs from its three western Atlantic congeners in having the third dorsal spine notably prolonged, generally

in specimens over 100 mm. It is structurally nearest *rathbuni* with which it is compared under the account of the latter.

**PONTINUS RATHBUNI** Goode and Bean

*Pontinus rathbuni* GOODE and BEAN, Oceanic ichthyology, p. 255, pl. 68, fig. 245, 1895 (off Cape Hatteras, N. C.).

D.(XI) XII 9 (10). A.III 5. P.17 (18). Sc.43-48. GR.5-8+12-14.

*Description.*—Body averaging deep. Eye a little smaller than or subequal to snout. Interorbital equaling one-third the eye diameter or a little broader, sometimes slightly narrower. Maxillary ending nearly under posterior margin of eye or a little short. Nasal spine well developed; upper posttemporal spine absent or slightly developed; preorbital spines well developed, the anterior one usually directed sharply backward; suborbital ridge with 4 spinous points (a fifth point observed in one specimen). Second preopercular spine present; fourth and fifth spines directed downward or slightly backward; the fifth smaller than fourth, sometimes obsolescent. A thick, broad, moderately long tentacle at supraocular spine, sometimes forked distally and ending in two expanded lobes; shorter, slenderer tentacles at preocular, preorbital, and preopercular spines present or absent. Scales on cheek, chest, pectoral base, interorbital and snout mostly ctenoid; interorbital and snout scaled for their greater part, but scalation not continuous, more or less interrupted, leaving irregular, variable, bare spaces. Third dorsal spine longest, subequal to postorbital part of head; fourth slightly shorter or subequal to third, thence rather rapidly graduated, growing smaller backward; penultimate spine about three-fifths as long as last spine. Caudal truncate.

Measurements of 5 specimens 120-180 mm.: caudal 24.5-27.0, ventral 24.5-27.5, pectoral 27.0-29.5, depth 33.5-39.0, head 43-45, maxillary 22-23, snout 12.8-14.4, eye 11.0-13.2, interorbital 3.9-4.9; eye 1.0-1.3 times in snout and interorbital 2.3-3.2 times in eye.

Specimens of comparatively recent preservation having body irregularly shaded with dusky, especially on its upper part, against a yellowish background; some small dusky spots irregularly spaced along course of lateral line; caudal with some small, faintly dusky spots, sometimes well marked along edge of fin. Specimens long in preservative plain yellowish without shadings or spots. Small specimens, about 40 mm. or less, with a dusky smudge between sixth and ninth dorsal spines; pectoral with an irregular, elongate, dusky, smudged area at its middle and near its base, persisting up to about 60 mm., and as a slight trace up to about 125 mm.

*Development.*—The small specimens examined, although most of them not in good condition, suggest that the development of the spines on the preopercle is similar to that described above for *longispinis*.

*Specimens examined.*—From off the following localities: Cape Charles (157567; lat. 37° 07' 40" N., long. 74° 35' 40" W.) and Cape Henry (120995), Va. Cape Hatteras (39325, the holotype; 84521, 101522, 143055) and Cape Lookout (144573), N. C. Bull Island, S. C. (151866). Palm Beach (153124), Vaca Key (153125), Key West (72985, 73257, 143123), and Ten Thousand Islands (C.N.H.M. 46216), Fla. Dauphin Island, Ala. (47643). Total examined, 28 specimens 19-180 mm., the largest from off Bull Island. Recorded depths range 49-122 fathoms. While not rare offshore this species evidently is not as common as *longispinis*, especially in the Gulf whence only 2 small specimens 58-72 mm. were examined.

TABLE 10.—Frequency distribution of the body depth in *Pontinus longispinis* and *P. rathbuni*, expressed as a percentage of the standard length and segregated into size groups

Species	Standard length in mm.	Distribution											
		28	29	30	31	32	33	34	35	36	37	38	39
<i>longispinis</i> .....	148-174	1	1	3	2	4	..	1	..	..	..	..	..
<i>longispinis</i> .....	95-146	..	1	8	13	12	7	..	..	..	..	..	..
<i>rathbuni</i> .....	96-145	..	..	..	..	..	1	1	2	2	3	..	1
<i>longispinis</i> .....	51- 93	..	1	3	1	2	7	1	..	..	..	..	..
<i>rathbuni</i> .....	55- 83	..	..	..	..	..	..	1	3	1	..	..	..
<i>longispinis</i> .....	21- 36	..	..	..	..	..	3	2	1	..	..	..	..
<i>rathbuni</i> .....	18- 37	..	..	..	..	..	..	3	3	3	1	1	..

*Comparison.*—This species is nearest *longispinis* structurally. The larger specimens, those over 110 mm. or so, are readily separable by the length of the third dorsal spine which is conspicuously prolonged in *longispinis*. This species has a deeper body than *longispinis* (table 10), which is useful in separating specimens over 65 mm., but the two species intergrade somewhat in this character, and it becomes of only slight value in specimens under 50 mm. The direction of the first preorbital spine is of some specific value; it is directed backward in *rathbuni* and typically downward or slightly forward in *longispinis*. The tentacle at the supraocular spine which is usually conspicuously longer and stouter in *rathbuni* than in *longispinis*, is a moderately useful character for separating small as well as large specimens.

The scale count appears to be lower in *rathbuni*, and the caudal is approximately truncate, instead of moderately emarginate. However,

these two characters are not of much practical value, because of the state of preservation of most specimens. The scales are missing in large areas or over the greater extent of the body in the large majority of the specimens examined and their number not ascertainable with precision (that is why so few specimens of these two species are entered in table 6). Also, the caudal is frayed in many of the specimens examined and its normal shape not definitely determinable.

Differences in proportional measurements between the two species may be gathered by comparing their accounts giving measurements of five specimens of each in about the same size range. The greatest divergence is shown by the body depth and this measurement is further analyzed in table 10.

Small specimens do not have their specific characters developed to a sufficient extent to be distinguished as readily as large specimens. The most striking distinguishing character, the relative length of the third dorsal spine, does not develop until the fish reach a length of about 100 mm., more or less. The distinguishing specific characters are even less marked in specimens under 50 mm. The latter specimens are distinguishable by the presence of a dusky smudge on the pectoral of *rathbuni*, and the shape of the tentacle at the supraocular spine which is usually longer and broader in *rathbuni*. The anterior spinous point on the suborbital ridge develops at a somewhat smaller size in *rathbuni*. When placed side by side small specimens of *rathbuni* appear deeper-bodied, although this difference does not show well in measurements.

#### PONTINUS CASTOR Poey

*Pontinus castor* POEY, Memorias sobre la historia natural de la Isla de Cuba, vol. 2, p. 173, July 1860 (Cuba).

*Sebastes nematophthalmus* GUNTHER, Catalogue of fishes in the British Museum, vol. 2, p. 99, 1860 (West Indies, see discussion below; Gray's preface dated June 1, 1860, and volume very likely published after July).

*Pontinus microlepis* BEAN, Proc. Biol. Soc. Washington, vol. 25, p. 125, 1912 (Bermuda).

D.XII 10. A.III 5. P.17. Sc.50-54. GR.7-8+14-15.

*Description*.—Eye about two-thirds as long as snout. Interorbital about one-third the eye diameter. Maxillary ending approximately under posterior margin of pupil. Nasal spine small; upper post-temporal spine small or absent; preorbital spinous points poorly developed, the anterior one blunt or very slightly projecting; suborbital ridge with 3 stubby spinous points. Supplemental preopercular spine a blunt projection (absent on one side in one specimen); second preopercular spine absent, fifth slightly developed or virtually absent at the

surface. A variably long, slender tentacle at base of supraocular spine (absent on one side in two specimens, very long, about reaching dorsal origin on one side in one of these specimens); shorter, broader tentacles at preocular spine and lower preopercular spines present or absent. Scales on cheek, chest, anterior part of pectoral base, and interorbital mostly cycloid; snout and interorbital with small isolated groups of small cycloid scales, naked for their greater part. Fourth dorsal spine longest, thence gradually decreasing to penultimate, or fourth to sixth subequal; penultimate spine about three-fourths as long as last; longest dorsal spine a little shorter than snout and considerably shorter than postorbital part of head. Second anal spine moderately longer than third. (Caudal more or less damaged in the specimens examined, form of its posterior margin not definitely de-

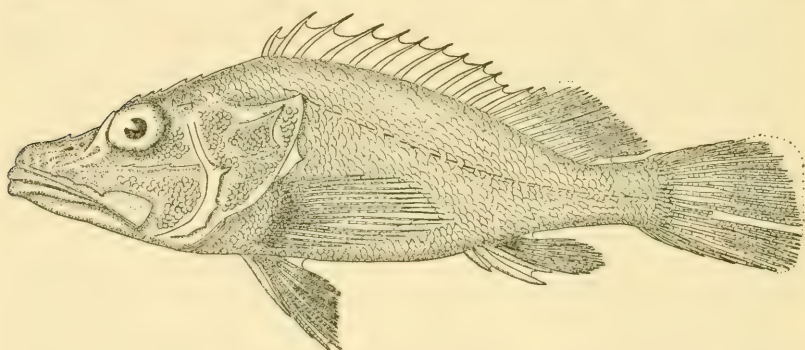


Fig. 5.—*Pontinus castor*, 228 mm., U.S.N.M. No. 74113, the holotype of *P. microlepis*, off Bermuda. Drawn by Mildred H. Carrington.

terminable.) Uniformly yellowish all over without color marks in preserved specimens.

The above description is drawn from 3 specimens 171-228 mm. in the U. S. National Museum. One specimen examined in the Chicago Natural History Museum, 324 mm., but not directly compared, has the eye relatively smaller in relation to the snout and interorbital and the suborbital ridge is nearly smooth, having one slightly raised tubercle-like projection.

Measurements of 1 specimen 324 mm. and 3 specimens 171-228 mm.: caudal about 24.5 (23.5-26.5), ventral 22.5 (24.5-25.0), pectoral 26.5 (29.0-31.5), depth 34 (31.5-34.0), head 51 (48-49), maxillary 23 (22.5-23.0), snout 17.2 (16.0-16.5), eye 9.7 (10.4-11.3), interorbital 4.2 (3.4-4.0); eye 1.8 (1.4-1.6) times in snout, interorbital 2.3 (2.7-3.1) times in eye.

*Specimens examined*.—Cuba (29554, 37566; transmitted by Poey). Bermuda (74113, holotype of *microlepis*, fig. 5; C.N.H.M. 48526,

324 mm.). Total examined, 4 specimens 171-324 mm. The specimen listed last was taken at 90 fathoms; no depth records are available for the others.

*Comparison.*—In general appearance *castor* differs markedly, by its long snout, from its three congeners here treated. It further differs from those three species in having 10 dorsal spines, instead of a normal count of 9, and a greater number of scales. The second preopercular spine is absent, while in the other three species it is present, except in individual variants of *longispinis*.

*Nomenclature and synonymy.*—Two of the three specimens examined in the National Museum were received from Poey and are entered in the catalog as *castor*. Consequently, the present identification of *castor* is evidently appropriate. The type of *microlepis* belongs to the same species and its data are included in this account.

Gunther's *S. nematophthalmus* is possibly a composite species. Two specimens are listed: a stuffed specimen, size not stated, the locality of which is given as Île de France with a question mark, and one specimen 6 inches 7 lines, about 167 mm., from the West Indies. The given description apparently refers to the latter specimen, in large part at least. As the two specimens might belong to two species, the name *S. nematophthalmus* is formally restricted to the West Indies specimen which is hereby designated as the lectotype. Gunther's description, as far as it goes, fairly agrees in general with the specimens of *castor* examined and *nematophthalmus* is very likely based on a specimen of this species. Judged by the description, the body depth of Gunther's specimen appears to be somewhat greater and the head moderately shorter than in the four specimens examined, but the differences do not appear to be significant and might be accounted for by differences in method. Besides, Gunther does not give the standard and caudal length of his specimen, and the above comparison of measurements is made by assuming that its caudal is 25 percent of the standard length. These differences may not hold when the standard length of Gunther's specimen is actually determined and the same methods of measurements are used as in this investigation.

#### Genus NEOMERINTHE Fowler

*Neomerinthe* FOWLER, Proc. Acad. Nat. Sci. Philadelphia, vol. 87, p. 41, 1935 (genotype *Neomerinthe hemingwayi* Fowler = *Pontinus pollux* Poey by original designation).

*Definition.*—Eye smaller than snout. Interorbital one-third to two-thirds the eye, depending on the species. Maxillary reaching approxi-

mately to under middle of eye. Palatine teeth present. A small slit behind last gill arch. Gill rakers moderate at angle; upper limb with 2-5 end gill rakers short, tubercle-like but individually readily distinguishable and countable; lower limb with 1-5 tubercles at end, some of them only slightly raised above surface of arch or much expanded lengthwise along arch, sometimes difficult to distinguish individually. Combined number of gill rakers and tubercles 6-7+9-12. Occipital region flat, without a pit. Parietal ridge divided into two subequal parts, each part ending in a spine; frontal spine directly behind postocular, the two placed on a line distinctly laterad of parietal ridge; upper posttemporal spine small or absent, lower posttemporal spine and ridge well developed; sphenotic spine very small, placed close to orbital rim; pterotic spine and ridge well developed; an extra ridge between frontal and sphenotic spines, and one or two ridges below parietal ridge not as well developed; postorbital spine absent; preorbital with 2 free spinous points, the posterior spine larger, broader and directed backward; suborbital ridge well developed with 3-5 spinous points (ridge becoming serrate in large specimens of *pollux*; see under its account); cleithral spine present. First preopercular spine longest, moderate in size but sharp, with a supplemental spine; second spine usually absent, when present in individual variants small in size. A rather broad tentacle at base of posterior preorbital spine, very variable in form, digitated or fimbriated, often divided into two or three main stems; smaller tentacles variably present at other spines on head; a fimbriated or entire tentacle at anterior nostril; no other tentacles. Scales ctenoid, except on pectoral base and chest ctenoid or cycloid; opercle and cheek almost all scaled; interopercle and maxillary partly scaled; interorbital and snout with or without scales. Dorsal typically with 12 spines; with 9 or 10 rays, depending on the species; penultimate spine about two-thirds to three-quarters as long as last. Second anal spine longer than third. Ventral reaching anus or falling short, its outer angle a little in front of lower pectoral angle. Pectoral irregularly wedge-shaped, the middle rays longest; with 5-8 branched rays; total number of rays constantly 17 in specimens examined. Caudal moderately rounded.

*Comparison.*—This genus agrees with *Scorpaena* in having palatine teeth, branched pectoral rays, the first preopercular spine longest, and 12 dorsal spines. It differs in having ctenoid scales; in the greater extent of scalation, the shape of the pectoral, and the position of the ventral. In the structure of the scales and their extent it about agrees with *Trachyscorpia*, and is compared with the latter under its ac-



count. It further differs from *Scorpaena*, *Trachyscorpia*, *Helicolenus*, and *Sebastes* in having a small and well-defined slit behind the last gill arch. On the whole, *Neomerinthe* is nearest *Pontinus*. The shape of the preopercle and its spinous armature is about the same in both genera. The second preopercular spine is small or absent in both. The two western Atlantic species with a prolonged third dorsal spine belong, one each, to these two genera, *Neomerinthe beanorum* and *Pontinus longispinis*. The pectoral shape and its number of rays and the nature and extent of scalation are nearly the same in both genera. They differ chiefly in that some of the pectoral rays are branched in *Neomerinthe* and all are unbranched in *Pontinus*.

#### NEOMERINTHE POLLUX (Poey)

*Pontinus pollux* POEY, Memorias sobre la historia natural de la Isla de Cuba, vol. 2, p. 174, 1860 (Cuba).

*Neomerinthe hemingwayi* FOWLER, Proc. Acad. Nat. Sci. Philadelphia, vol. 87, p. 41, fig., 1935 (about 70 miles southeast of Cape May, N. J.; deep water).

*Neomerinthe tortugae* HILDEBRAND, Carnegie Inst. Washington Publ. 517, p. 247, fig. 13, 1940 (Tortugas, Fla.).

D.XII 10. A.III 5. P.17. Sc.62-68. GR.6-7+9-12.

*Description*.—Snout long and eye comparatively small, eye about three-quarters the snout length in medium-sized specimens, about one-half the length in large fish. Interorbital rather wide, about two-thirds the eye diameter in the larger specimens. Upper posttemporal spine absent, except in the young (see below); suborbital spinous points usually 4, sometimes 3 or 5; in large specimens (3 specimens 420-465 mm.) suborbital spines becoming greatly reduced in size and the ridge becoming serrate, the gross effect being a moderately serrate ridge, the serration somewhat interrupted; cleithral spine comparatively sharp. Second preopercular spine absent except in the young; third and fourth spines rather broad, the third somewhat larger, fifth spine virtually absent at surface. Most scales on chest and pectoral base ctenoid, rather weakly so; area on occiput limited by posterior part of parietal ridge and frontal spine with very small ctenoid scales, similar scales extending on interorbital, snout, anterior part of cheek, and partly on maxillary and premaxillary (small scales often absent in irregular patches in preserved specimens, probably deciduous); interopercle partly scaled. Penultimate dorsal spine about two-thirds as long as last spine; longest dorsal spine subequal to snout, shorter than postorbital part of head. Ventral about reaching anus in the smaller specimens, falling considerably short in large fish. Pectoral falling more or less short of a vertical through base of first anal spine;

uppermost 1 or 2 rays unbranched, next 6-7 rays branched, lower 8-9 unbranched.

Measurements of 3 specimens 250-420 mm., including the holotypes of *hemingwayi* and *tortugae*, and 2 specimens 136-152 mm.: caudal 23.5-24.5 (25.5), ventral 21.5-24.0 (26.0-26.5), pectoral 23.5-26.0 (28.0-28.5), depth 29.5-31.0 (34), head 45-46 (44-45), maxillary 20.5-21.5 (in all 5), snout 13.7-16.0 (13.2-14.8), eye 7.7-9.0 (10.3-10.8), interorbital 5.3-5.7 (5.6-5.9), eye 1.6-1.9 (1.3-1.4) in snout, interorbital 1.5-1.6 (1.8-1.9) in eye.

Ground color straw yellow to brownish with a somewhat reddish tinge; irregularly marked with large diffuse blotches and small spots; 1 blotch above and in juxtaposition to the lateral line under base of sixth to eighth dorsal spines, 1 or 2 blotches behind it but placed below lateral line and touching it; a series of diffuse smaller blotches at dorsal base; a somewhat curved bar directly in front of dorsal; small dark spots irregularly and variably scattered on body, head and fins including underside of pectoral and its fleshy base, except ventral plain yellowish. Intensity of markings described variable, often faint, sometimes hardly perceptible.

*Development.*—A small specimen, 53 mm., has the pectoral rays unbranched (some of the rays damaged), and it shows slightly the second preopercular and upper posttemporal spines.

*Specimens examined.*—Off the following localities: about 70 miles southeast of Cape May, N. J. (A.N.S.P. 63482, holotype of *hemingwayi*, 322 mm.). Cape Lookout, N. C. (152084). Bull Island, S. C. (151884). Tortugas (108871 and 108872, the holotype and 2 paratypes, respectively, of *tortugae*), Cape San Blas (144575, *Albatross*; 155336, *Pelican*; C.N.H.M. 46218, *Oregon*), St. Joseph Point (157557, *Oregon*), and Santa Rosa Island (157558, *Oregon*), Fla. Mississippi Delta, La. (155334-5, *Pelican*; C.N.H.M. 46217, *Oregon*). Gulf of Mexico (125716, no definite locality). Total examined, 16 specimens 53-465 mm., the largest from off Bull Island. Available depth records for 10 of the 14 constituent samples range 26-112 fathoms. Evidently this species is not uncommon offshore.

The spinous part of the dorsal in the type specimen of *hemingwayi* is evidently abnormal, having the second and third spines missing. It has the stump of a spine on the midback placed over the supracleithral spine. After some interval, the rest of the spinous dorsal consists of 9 spines the relative lengths of which are about the same as in normal specimens of this species. The first of the normally formed spines is placed over the posterior upper corner of the opercle.

Although the interval on the midback between the stump and the first fully formed spine is partly scaled over with imbricated scales, it is evident from the positions and relative lengths of the spines that this condition is a malformation probably due to an injury earlier in life in which the second and third spines were lost. In other characters and color this specimen agrees with the normal specimens of this species. A similar abnormality in a specimen of *Scorpaena agassizi* is described under that species.

*Comparison.*—This species is readily distinguishable from the other western Atlantic scorpaenids by the combination of its fin ray, scale, and gill-raker counts and its other generic and specific characters. It is compared with its congener, *beanorum*, under the account of that species. It agrees with *Pontinus castor* in having 10 dorsal rays, and nearly agrees in the spinous armature of the preopercle and the rather long snout.

*Nomenclature and synonymy.*—The types of *Neomerinthe hemingwayi* and *N. tortugae* have been examined. They belong to the same species and the data derived from the types are included in this account.

The type of *Pontinus pollux* Poey does not seem to be in existence now. Judged by the circumstances and known facts, it seems reasonably safe to conclude that Poey's specimen also belonged to the species here treated. According to the findings here reported only two species normally have 10 dorsal rays, this species and *Pontinus castor*, and Poey gives this count in the original descriptions of his *P. castor* and *P. pollux*. That Poey used the same method of counting the rays as employed in this paper, that is, counting the last 2 approximated rays as one, is proved by the count of *P. castor* in which Poey's count agrees with that here determined for 4 fish that included 2 specimens which were presumably identified by him. The number of pectoral rays, 17, as determined for 14 specimens examined of this species also agrees with that given by Poey. Also, in his description of *P. pollux* Poey compares it largely with *P. castor* stating that it is very near that species in shape. This is significant. There really is a striking resemblance between our species and *P. castor* in the shape of the body, head, and snout, and any student having specimens of both species before him would naturally be led to compare them at length. Furthermore, Poey's description of the differences between *P. castor* and his *P. pollux* in the suborbital and preorbital spinous points agrees fairly well with that between this species and *P. castor*. There are some minor discrepancies. Poey fails to mention the dark or dusky

spots or shadings shown by this species; but the color is highly variable, some specimens examined having very faint shadings. Also, according to his description Poey's *P. pollux* had a narrower interorbital than our specimens, and the maxillary did not extend so far backward. However, such discrepancies are found in other descriptions by Poey and they do not seem of much significance. All in all, the probability is high that the not uncommon species here described is the same as Poey's *P. pollux* and it is here designated accordingly.

#### NEOMERINTHE BEANORUM (Evermann and Marsh)

*Pontinus beanorum* EVERMANN and MARSH, Bull. U. S. Fish Comm., vol. 20, pt. 1, p. 279, fig. 85 (1899) 1902 (San Juan Harbor, Puerto Rico).

D.XII 9. A.III 5. P.17. Sc.41-46. GR.6+9-10.

*Description*.—Eye moderately smaller than snout. Interorbital rather narrow, one-third the eye diameter or slightly wider. Upper posttemporal spine very small; ridge between frontal and sphenotic spines well developed, projecting, forming with side of head an inverted troughlike recess; a similar and smaller trough directly below parietal ridge; suborbital spines 3 or 4; cleithral spinous projection rather short and blunt. Second preopercular spine usually absent or a slight trace present, sometimes fairly shown; lower 3 spines narrow and sharp, the third directed downward and slightly backward or forward, fourth and fifth more or less antrorse. Most scales on chest and pectoral base cycloid; occipital area limited by posterior part of parietal ridge and frontal spine with scales of moderate size; maxillary and interopercle with very few scales or none; interorbital and snout scaleless. Third dorsal spine in male prolonged, rising above normal distal outline of fin; subequal to postorbital part of head in male, to snout in female; penultimate dorsal spine about three-quarters as long as last spine. Ventral falling moderately short of anus. Pectoral about reaching a vertical through base of first anal spine; its upper 2 rays unbranched, next 5-8 rays branched, lower 7-10 rays unbranched.

Measurements of 6 specimens 118-163 mm.: caudal 27.0-30.5, ventral 22.5-24.5, pectoral 29.0-30.5, depth 29.0-32.5, head 44-47, maxillary 21.5-22.0, snout 13.7-14.6, eye 11.4-12.8, interorbital 3.9-4.5; eye 1.1-1.3 in snout, interorbital 2.6-3.1 in eye.

Ground color of preserved specimens reddish yellow or olivaceous, upper part of body and head shaded with dusky irregular areas; spinous dorsal with a lengthwise row of smoke-colored blotches placed on posterior interradiial membranes; soft dorsal, upper part of caudal, and upper posterior part of pectoral with small, diffuse, dark spots.

*Specimens examined.*—San Juan Harbor, Puerto Rico, 91 fathoms, *Fish Hawk* (49534, the holotype); off Puerto Rico, 80-180 fathoms, *Caroline Station 35* (117877). Total examined, 6 specimens 118-163 mm.

*Comparison.*—This species differs chiefly from *pollux*, its known western Atlantic congener, in having fewer scales and 9, instead of 10, dorsal rays. The gill rakers are fewer on the average. The scalation on the head is somewhat less extensive. The eye is larger, the snout shorter and the interorbital narrower than in *pollux*.

#### TRACHYSCORPIA, new genus

*Genotype.*—*Scorpaena cristulata* Goode and Bean.

*Definition.*—Eye subequal to snout or a little larger. Interorbital about half the eye or a little narrower. Maxillary ending under posterior margin of pupil or a little behind. Palatine teeth present. No slit behind fourth gill arch. Gill rakers short, those at ends of arch very short, tubercle-like but individually distinguishable and readily countable; in medium numbers, 5-6+13. Occipital region with a slight, broad depression, without a definite pit. Spines on head well developed; parietal ridge divided into two parts, both ending in a spine; frontal spine not alined with parietal ridge, nearly in a line with postocular spine; upper posttemporal spine absent, lower one rather well developed; sphenotic spine small, single, usually with 1 or a small group of spinules or asperities or slight tuberosities below it; pterotic ridge and spine well developed; postorbital in form of a slight tuberosity or a group of slight asperities or absent; preorbital with 2 free moderate points, sharp or rather blunt; suborbital ridge notably well developed, with 6-7 spinous points. First preopercular spine longest, with a supplemental spine; second spine subequal to or shorter than third, placed nearer to first spine; fifth spine slightly indicated or obsolescent. Tentacles and filaments sparsely developed. Scales ctenoid, 57-67: except those on chest, fleshy pectoral base, and interorbital weakly ctenoid or cycloid, partly embedded; on dorsal aspect scales extending to opposite postocular spine; posterior and smaller part of interorbital scaled, its anterior and greater portion partly scaled or nearly scaleless; opercle nearly all scaled; check largely scaled to a variable point opposite pupil, except narrow area directly above and below suborbital ridge scaleless; maxillary and interopercle scantily scaled or naked; snout virtually scaleless; fins moderately or well scaled on a variable proximal area, except spinous dorsal and ventral. Dorsal normally with 12 spines; with 8-9 rays (see also below, counts

recorded in the literature for *echinata*); rather deeply emarginate, penultimate spine about one-half to two-thirds as long as last spine; longest dorsal spine subequal to snout or a little longer. Anal with 3 spines and 5 rays; second spine subequal to third or a little longer. Ventral falling considerably short of anus, its outer angle close to lower pectoral angle. Pectoral broad and rather short with 11-13 branched rays, or 20-24 altogether, about reaching a vertical through anus; upper rays, third to fifth or seventh rays subequal and longest, thence gradually decreasing in size; lower rays thickened and their ends free for a short distance. Caudal truncate or slightly rounded.

*Comparison.*—The two species, *crustulata* and *echinata*, comprising this genus form a group that differs markedly from the other species here placed in *Scorpaena* as follows. The scales are strongly ctenoid, the head is much more extensively scaled and the pectoral shape is different. The ventral is placed close to the pectoral, instead of at some distance behind it. Correlated with these differences, the gill raker, pectoral ray, and scale counts fall near the upper limits of the range of *Scorpaena*.

The two species agree with *Helicolenus* in having ctenoid scales and nearly agree in the extent of scalation on the head. They differ in having the first preopercular spine longest, in the position and length of the ventral, and the pectoral shape. The spinous armature on the head of *Helicolenus* is not as well developed, as it usually lacks the sphenotic and pterotic spines and the suborbital keel has only one weak spinous point or none.

*Trachyscorpia* agrees with *Neomerinthe* in having ctenoid scales and the extent of squamation, and the armature of the head in the two genera is not trenchantly different. It differs in the shape of the pectoral which also has more numerous rays, in the position of the ventral, and in lacking a slit behind the fourth gill arch.

On the whole, *Trachyscorpia* is perhaps nearest *Osorioia* Fowler (1938, p. 63), agreeing with it in having ctenoid scales and nearly agreeing in the pectoral shape and other characters. *Osorioia* differs in having a shallow occipital pit and in lacking scales on the head, occiput, chest, and pectoral base.

I am establishing this new scorpaenid genus with a measure of reluctance. Many scorpaenid genera have been proposed in scattered studies, and the task remains of correlating properly and determining the relationship between the proposed genera by a revision of the family on a world-wide basis. It would, therefore, seem imprudent to add still another generic name to the long list of genera that have been proposed in a number of papers and that still remain undigested.

Nevertheless, the two species studied form a related group that does not seem to fit in well with any of the genera that have been proposed so far, and no choice remains but to propose a distinct genus to include these two species.

#### TRACHYSCORPIA ECHINATA (Koehler)

*Scorpaena echinata* KOEHLER, Résultats scientifiques de la campagne du *Caudan* dans le Golfe de Gascogne, in Ann. Univ. Lyon, 1896, p. 478, pl. 27, figs. 4-6 (lat. 45° 57' N., long. 6° 21' W.; Bay of Biscay; 1,410 meters).—NORMAN, *Discovery Reports*, vol. 12, pt. 1, p. 32, 1935 ("southwest of Ireland and in the Bay of Biscay").

*Scorpaena cristulata* KOEHLER (not Goode and Bean), op. cit., p. 524 (states in footnote that *echinata* the same as *cristulata*; specimens apparently not compared).—HOLT and BYRNE, Fisheries of Ireland Scientific Investigations, 1906, No. 5, p. 20, pl. 2, 1908 (off southwest Ireland, 250-800 fathoms).

D.XII 8. A.III 5. P.20. Sc.60. GR.5+13.

*Description*.—Eye a little larger than snout. Interorbital width one-half the eye diameter. Occipital area enclosed by parietal ridges and frontal spines only slightly longer than wide; posterior part of parietal ridge somewhat better developed than anterior part; no spine or projection on posterior margin of cleithrum (in the large specimen examined). First preopercular spine moderate; next three spines rather short, the second more pointed than other two and nearer to first; fifth spine virtually absent at surface. A lengthwise row of short, slender filaments on upper part of eyeball; similar, still shorter filaments on upper part of head and opercle. Interorbital with a few scattered, largely nonimbricate scales, its greater part scaleless; maxillary and interopercle scaleless. Penultimate dorsal spine about three-fourths as long as last. Second anal spine a little longer than third. Ventral reaching about half the distance from its base to anal origin. Pectoral having its uppermost ray unbranched, next 13 rays branched, lower 6 rays unbranched.

Measurements of a specimen 433 mm.: caudal 22, ventral 15, pectoral 25.5, depth 32, head 43.5, maxillary 23.5, snout 10.6, eye 11.9, interorbital 5.8; snout 1.1 and interorbital 2 times in eye.

Ground color light yellowish, lower part somewhat lighter; upper part of head and body irregularly marked with dusky shades, a brown blotch between suborbital ridge and eye, placed under pupil, somewhat better marked than other shadings; a U-shaped mark at origin of spinous dorsal, at its base; spinous and soft dorsal with black or dusky blotches or areas on interradiial membranes; other fins unpigmented.

*Specimen examined*.—Lat.  $51^{\circ} 46'$  N., long.  $12^{\circ} 14'$  W., off southwest coast of Ireland, 550 fathoms, 433 mm. (61663). The above account is based on this one specimen. Other measurements and counts compiled from the literature on *echinata* are given below.

*Comparison*.—In accounts of the eastern Atlantic population, cited in the above synonymy, which has been named *echinata* and is closely related to the western *cristulata*, Koehler, in a footnote, and Holt and Byrne synonymize these two names. Norman tentatively treats *echinata* as a distinct species, but expresses doubt as to its distinctness. However, these authors evidently arrived at their conclusions by comparing their specimens with the account of *cristulata* rather than by a direct comparison of specimens. The specimen in the National Museum from the coast of Ireland, which forms the basis of the above description, makes possible a direct comparison of specimens from the eastern and western Atlantic.

Measurements of eastern Atlantic specimens were published by Koehler, 1 specimen 172 mm.; Holt and Byrne, 5 specimens 255-504 mm.; Norman, 6 specimens 330-510 mm. These measurements reduced to a percentage basis to correspond with the method here adopted, and divided into two size groups, 2 specimens 172-255 mm. and 10 specimens 358-510 mm. (Norman gives only part of the measurements), are as follows: ventral 14.5-16.5 (16.5-19.5), pectoral 23.5-24.5 (21.5-22.5), depth 31.5-35.5 (30.5-31.5), head 41-46 (41.5-44.0), snout 8.9-10.5 (8.8-10.7), eye 8.9-10.5 (10.5-13.5), interorbital 4.7-5.7 (4.7).

Comparing the preceding measurements with those given below for two similar size groups of *cristulata*, the eastern Atlantic specimens have a shorter head and ventral, a smaller snout and eye, a narrower interorbital, and the body not as deep. The eastern Atlantic specimen in the National Museum agrees in general with the previously published measurements of *echinata* as given above.

The eastern Atlantic specimen described above shows two noteworthy differences as compared with the extant description of *echinata*. It has 8 dorsal rays, and 20 pectoral rays (counted on both sides); whereas the given ranges in the published accounts of western Atlantic specimens are 9-10 dorsal and 21-22 pectoral rays. However, a spread of 3 in the frequency distribution of the dorsal and pectoral rays occurs also in other species (see table 1), although the variants from the predominating number of dorsal rays are generally few. At any rate the presence of only 8 dorsal rays in the specimen examined does not exclude it from being an example of *echinata*.

An adequate picture of the variability of these two counts in *echinata*



remains to be determined by a study of a satisfactory sample. Meanwhile, it may be confidently concluded that the eastern and western Atlantic populations differ considerably, at least on the average, in the pectoral count, 20-22 and 22-24, respectively.

Besides the variability in the number of dorsal rays as discussed above, Holt and Byrne in the 5 specimens tabulated by them record 3 as having 12 dorsal spines and 2 with 11 spines. Norman also records 11-12 dorsal spines. In view of the relative constancy of the number of dorsal spines in all species (table 1), this is a noteworthy variation. In all 13 specimens examined of the western Atlantic *cristulata* the dorsal count is constantly XII 9, except one which has 8 rays.

In the western Atlantic specimens, the slight nuchal depression, the area enclosed by the parietal ridges and frontal spine, is notably longer than wide, while in the eastern Atlantic specimen examined it is only moderately longer than wide. The European specimen also has one gill raker less than 13 American specimens examined, the gill-raker count being constant in the latter.

Considering all differences discussed above, especially the differences in proportional measurements and the number of pectoral rays, it may be concluded with assurance that the eastern and western Atlantic populations represent distinct species.

Holt and Byrne describe their specimens as being shaded or blotched with dark pigment, and this also holds for the specimen in the National Museum from the coast of Ireland. Specimens of *cris- tulata*, on the other hand, are nearly uniformly colored or moderately shaded, and the type of *echinata* is described as uniformly colored also. This color difference and the unusual variability in the number of dorsal spines and rays shown by the Irish specimens, as discussed above, point to the possibility that the Bay of Biscay and Ireland populations diverge to a degree which remains to be determined.

#### TRACHYSCORPIA CRISTULATA (Goode and Bean)

*Scorpaena cristulata* GOODE and BEAN, Oceanic ichthyology, p. 246, pl. 67, fig. 242, 1895 (off Georgia).

D.XII (8) 9. A.III 5. P.22-24. Sc.57-67. GR.6+13.

*Description.*—Eye subequal to snout in large specimens, moderately larger in medium-sized fish. Interorbital one-half to one-third the eye diameter. Occipital area limited by parietal ridges and frontal spines, notably longer than wide; usually anterior part of parietal ridge longer and lower than, and its spine not as well developed as that of posterior part; cleithrum with a rather well-developed spinous

projection in the smaller specimens, becoming reduced in large specimens. First preopercular spine extending more than half the distance across opercle in the smaller specimens, becoming relatively shorter with growth; supplemental spine well developed; second spine subequal to third or slightly smaller, placed nearer to first spine; lower 3 spines moderately developed, somewhat graduated. Short, slender filaments sparsely developed on upper part of eyeball and at some of the spines on the head. Interorbital scaled anteriorly, scaleless in large part at its middle portion; maxillary scantily scaled; interopercle with a few scales at its upper end or altogether scaleless. Penultimate dorsal spine about two-thirds as long as last spine in the smaller specimens, about half as long in larger fish. Second anal spine subequal to third or a little longer. Ventral reaching a little more than half the distance from its base to anal origin. Pectoral about reaching a vertical through anus, its uppermost ray unbranched, next 11-14 rays branched, lower 8-10 unbranched. In a large specimen, 400 mm., ventral reaching less than half the distance to anal origin, and pectoral falling a little short of a vertical through anus.

Measurements of 2 specimens 319-400 mm., 5 specimens 165-212 mm., and 3 specimens 100-142 mm. The following measurements are given in 3 groups in same order: caudal 20.5-22.0, 23.5-25.5, 24.5-26.5; ventral 17.5-18.0, 20.5-22.5, 21.5-24.0; pectoral 25, 24-27, 24.5-25.5; depth 34-36, 34.5-36.0, 33.0-34.5; head 47.5-48.0, 46.5-49.5, 46.0-47.5; maxillary 23-24, 23.0-24.5, 22.5-24.0; snout 12.2-13.5, 12.0-12.4, 11.4-11.9; eye 12.6-12.9, 13.5-14.8, 14.9-16.0; interorbital 5.4-6.8, 4.8-6.7, 4.5-5.5. Snout 1.0, 1.1-1.2, 1.3-1.4 and interorbital 1.9-2.4, 2-3, 2.9-3.3 times in eye.

Yellowish or golden nearly uniform without color marks in the preserved specimens examined; one specimen having occiput, interorbital, and a narrow lengthwise area above suborbital ridge, dusky in contrast with rest of uniform lighter coloration; some specimens having a dark irregular area on inner side of opercle, showing through on outer side as a dusky area.

*Specimens examined*.—From off the following localities: Nantucket Island, Mass. ( $41^{\circ} 49' N.$ ,  $65^{\circ} 49' 30'' W.$ , 84474 and 143932); Cape Hatteras, N. C. (44644); Charleston, S. C. (130962); Cumberland Island, Ga. (39362, the type); Key West (72979), Tortugas (92058), and Cape San Blas (50547), Fla. Total examined, 13 specimens 100-400 mm., the last one listed the largest. The vertical range is 72-440 fathoms.

*Comparison*.—This species is easily distinguished from other western Atlantic scorpaenids by the characters given in the key. It is

nearest *echinata* from the eastern Atlantic and the differences between them are discussed above. A noteworthy feature of this species is that in all 13 specimens examined the combined number of gill rakers and tubercles on the first arch is constantly 6+13.

#### Genus SCORPAENA Linnaeus

*Scorpaena* LINNAEUS, *Systema naturae*, vol. 1, p. 266, 1758 (genotype by later designation).—BLEEKER, *Versl. Akad. Amsterdam*, vol. 9, p. 295, 1876 (*Scorpaena porcus* Linnaeus designated as genotype).—JORDAN and GILBERT, *U. S. Nat. Mus. Bull.* 16, p. 678, 1882 (*porcus* designated as genotype).

*Definition.*—Relative size of eye varying widely with the species from considerably larger than snout in *agassizi* to considerably smaller than snout in extreme variants of *plumieri*, with varying gradations in between among the other species. Interorbital likewise differing widely with the species from subequal to eye in *plumieri* to one-third the eye in extreme variants of *calcarata* and *inermis*. Maxillary end differing from a point under posterior margin of pupil or slightly in advance to under posterior margin of eye. Palatine teeth present. No slit behind fourth gill arch. Gill rakers moderately developed at angle of arch; upper limb with 1-5 end gill rakers low, tubercle-like, but distinguishable individually and readily countable; lower limb with 1-5 tubercles anteriorly still lower, well or moderately projecting beyond surface of arch, rounded, nearly always fairly distinguishable and countable; combined number of gill rakers and tubercles 3-7+6-12 or 10-17 in total number. Occipital pit present except in *inermis* and *calcarata* (the only genus here treated having a pit); nasal spine moderate or rather well developed, except often low in *inermis*; parietal ridge divided into two parts, the anterior part somewhat longer in small specimens, the two parts about subequal in large fish except in *bergi*, both parts ending in spinous points; frontal spine present, except in the larger specimens of *grandicornis*, placed at anterior corner of occipital pit, nearly in a line with parietal ridge except in *inermis*, *calcarata*, and *microlepis*; lower posttemporal spine present; upper posttemporal spine present, except subject to individual variability in *brasilienis* and *microlepis*, present or absent; sphenotic spine rather small, usually double or bifid, often single, sometimes in form of a group of spinules or asperities; pterotic ridge well developed, ending in a spinous point; postorbital moderately or slightly developed or absent, when present often in form of a group of spinules or asperities; preorbital with 2 free spinous points, except 3 points in *dispar*, *plumieri*, and *microlepis*; suborbital ridge very moderate to well developed, with 1-4 spinous points depending on the species

and intraspecific variability, occasionally smooth in individual variants; cleithral spine present or absent. First preopercular spine longest, with a supplemental spine except in *inermis* and *calcarata*; the lower four spines moderate, sometimes the fifth hardly perceptible; second spine subequal to or shorter than third, sometimes virtually absent in individual variants of *calcarata*; upper outer angle of interopercle sometimes ending in a projecting blunt or sharp point. Development of tentacles differing with the species and varying greatly with the individual. Scales cycloid, 41-76, extending in front of dorsal to a transverse line through anterior parietal spine; chest and fleshy pectoral base scaled, the scales embedded in some species; flexible part of opercle on area between the two diverging spines scaled, anterior area on hard part of opercle between the two ridges naked, except for a few nonimbricate scales sometimes present in *plumieri*; a few scales near preopercular margin, in some species the scalation extending backward from preopercular margin to cover a substantial or greater part of opercle; a rather large, somewhat wedge-shaped patch of scales covering greater part of cheek posteriorly below suborbital ridge; area above ridge between eye and preopercular margin more or less scaled; scales at preopercular margin, on cheek, and behind eye well embedded in some species, hardly appreciable at the surface; nuchal pit, interorbital, snout, maxillary, interopercle, and mandible scaleless. Dorsal typically with 12 spines; modally with 9 rays, except 8 in *inermis*; total range 7-10; penultimate spine differing with the species, about seven-eighths to two-thirds as long as last. Outer ventral angle placed behind lower pectoral angle. Pectoral with 5-10 branched rays, except in small specimens, total number of rays 16-21; distal margin of its upper part, to about eighth ray, evenly and moderately rounded, thence the rays rapidly decreasing in length downward. Caudal slightly or moderately rounded.

*Development.*—Young fish differ from grown specimens in certain characters, some of them of importance in distinguishing the species and genera. The approximate size at which a given character changes from the juvenile to the adult condition is given under the separate accounts of the species. General statements of changes with growth in some taxonomic characters are discussed here.

In small specimens all pectoral rays are unbranched as in the adults of *Pontinus*. Ramification is a gradual process. The rays that are destined to become branched assume a finely grooved appearance in young fish, for a short distance at their tip, when examined with a moderate power of a binocular microscope. The end of the ray appears to have longitudinal, crowded, very fine, alternate grooves and

ridges. At first only one or two rays split at their tip. The number of forked rays and the length of the branches increase gradually. Usually the second ray is the last one to begin branching.

The relative development of the occipital pit differs with age. For instance, in *plumieri* a fairly well-developed pit is typically present, and *calcarata* has a slight occipital depression instead of a pit. But in young *plumieri* the pit is virtually absent, while in young *calcarata* the depression is somewhat better developed than in the adult.

The number of free preorbital spinous points is a specific character, 3 in *plumieri*, *dispar*, and *microlepis*, 2 in the other species. In *plumieri* the middle spine does not appear until the fish has reached some size. (Small specimens of *dispar* and *microlepis* are not available to determine this development.)

In the young the anterior portion of the parietal ridge is somewhat longer than the posterior part; while in grown specimens, except in *bergi*, the two parts are subequal.

The fleshy appendages, tentacles, filaments, and tabs, are better developed, in general, in the young than in grown specimens.

The edge of the scales in small specimens has a soft tumescent excrescence which is particularly noticeable in *plumieri*. It gives the fish a peculiar pimply appearance that is striking, but of no apparent taxonomic importance.

*Comparison.*—This genus differs from other western Atlantic scorpaenid genera, except *Setarches*, in having the scales cycloid instead of ctenoid. It differs from *Setarches* in its larger scales, and in having the first preopercular spine distinctly longer than the second and third. *Setarches* lacks a number of spines on the head that are present in *Scorpaena*.

#### SCORPAENA INERMIS Cuvier and Valenciennes

*Scorpaena inermis* CUVIER and VALENCIENNES, Histoire naturelle des poissons, vol. 4, p. 311, 1829 (Martinique).—LONGLEY and HILDEBRAND, Carnegie Inst. Washington Publ. 535, p. 162, 1941 (Tortugas, Fla.).

*Scorpaena occipitalis* POEY, Memorias sobre la historia natural de la Isla de Cuba, vol. 2, p. 171, 1860 (Cuba).

*Scorpaena luckei* FOWLER, Proc. Acad. Nat. Sci. Philadelphia, vol. 93, p. 87, figs. 1, 2, 1941 (Tortugas, Fla.).

D.XII 7-9. A.III 5. P.19-21. Sc.44-49. GR.3-5+6-8.

*Description.*—Eye a little larger than snout or subequal to it. Interorbital about 2.5 times in eye or a little narrower. Maxillary ending under posterior margin of pupil, varying a little both ways. Occiput between parietal ridges nearly flat, only slightly depressed, occipital pit virtually absent. Spines and ridges on head rather low; nasal spine

notably low, often a mere blunt protuberance; frontal spine placed slightly laterad of a line marking parietal ridge; preorbital with 2 very moderate spinous points, the posterior spine directed downward; suborbital ridge usually having 2 rather weak spines, under middle and a little behind eye, the anterior one often obsolescent, sometimes also posterior one; cleithrum without a spinous projection. First preopercular spine reaching about half the distance from its base to posterior margin of opercle, without a supplemental spine; second spine moderate or very short, subequal to or shorter than third. A moderate or rather well-developed tentacle at supraocular spine, sometimes slightly developed; other tentacles and tabs on head, body, and upper opaque part of eyeball rather numerous; those at the spines and along lateral line usually rather more prominent; a row of well-developed tentacles along line marking boundary between upper opaque and lower transparent part of eyeball; a curving row of rounded tabs at opercular margin usually present. Opercle largely scaleless; scales on chest partly embedded; scales on fleshy pectoral base and cheek embedded, hardly or not at all visible at surface. Penultimate dorsal spine about three-quarters as long as last spine; longest dorsal spine a little shorter than postorbital part of head. Second anal spine longer than third. Ventral about reaching anus and pectoral about reaching a vertical through base of third anal spine, both varying a little both ways; uppermost pectoral ray unbranched, next 5-6 rays branched, lower 12-15 rays unbranched.

Measurements of 5 specimens 71-89 mm. including the type of *luckei* and a cotype of *occipitalis* and 2 specimens 32-34 mm.: caudal 27-30 (30.5-31.0), ventral 24-26 (26.0-26.5), pectoral 33-36 (31.5-33.0), depth 33.5-40.0 (34.5-38.0), head 45.5-48.5 (49-50), maxillary 23.5-26.0 (25-26), snout 12.4-13.8 (12.7-13.4), eye 13.3-16.2 (16.3-17.8), interorbital 3.6-4.3 (5.3-5.8); snout 1.0-1.2 (1.2-1.4) and interorbital 2.6-4.4 (3.3) times in eye.

Opaque, usually whitish, rather narrow columns descending from the line marking the boundary between the upper opaque and the lower transparent parts of eye, the columns expanding in rounded areas at their lower ends, altogether producing effect of inverted mushroomlike figures on transparent part of eye (these marks often few or undeveloped in specimens 55 mm. or less). Upper and greater part of body irregularly mottled and shaded with brown against a lighter background, sometimes the pigment aggregated in places to give a faint suggestion of incomplete cross bands; ventral aspect light-colored or whitish. Many of the tentacles and tabs whitish. Caudal with two cross bands, one at its distal margin, the other at a moderate distance in front of it.

*Development.*—In 3 specimens 32-36 mm., all pectoral rays are unbranched. At 55 mm. the rays are branched virtually as in the adult.

*Specimens examined.*—Miami to Angelfish Creek (C.N.H.M. 46212), Florida Reefs just south of Biscayne Bay (C.N.H.M. 46213), and Tortugas (117135, fig. 6; A.N.S.P. 69716, type of *S. luckei*), Fla. Eleuthera Island, Bahamas (53212). Cuba (153576-7; cotypes of *S. occipitalis*). Ensenada de Santa Rosa (82553) and Ensenada de Cajón (82554), Cuba. Luispena Channel, Puerto Rico (117878). Curaçao (38595). The above-listed 11 lots comprise 18 specimens 32-89 mm., the largest one from Curaçao.

*Comparison.*—This species is nearest to *calcarata*, agreeing with it in the lack of a definite occipital pit, a supplemental preopercular

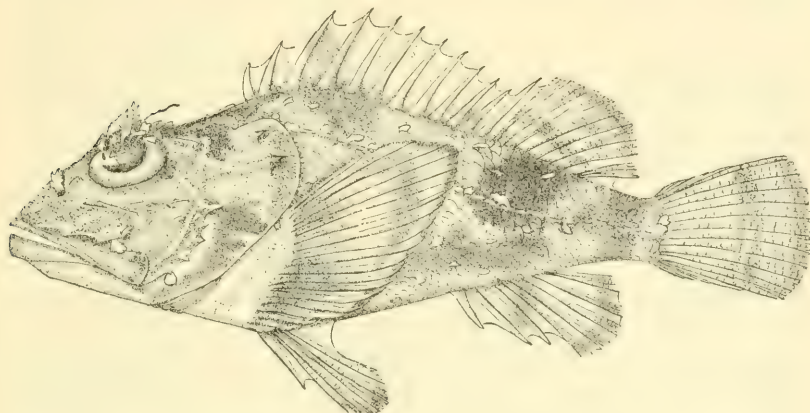


Fig. 6.—*Scorpaena inermis*, 82 mm., U.S.N.M. No. 117135; Tortugas, Fla. Drawn by Mildred H. Carrington.

spine, and other characters. The differences between them are indicated in the key and discussed under the account of *calcarata*.

*Synonymy.*—The type of *luckei* 67 mm. and 2 cotypes of *occipitalis* 46-71 mm. were examined and their data included in this account. All three specimens have 8 dorsal rays, the cross bands on the caudal are well developed, and they lack a spot behind the head. The type of *luckei* has the eyes dark, apparently caused by the preservative, but the inverted mushroom-shaped areas are discernible when viewed with a magnifying lens in the proper light. The 71-mm. cotype of *occipitalis* also has these areas. The three types also agree in other characters with the other specimens examined. They all belong to the same species which was identified by Longley with *inermis* after an examination of its type.

## SCORPAENA CALCARATA Goode and Bean

*Scorpaena calcarata* GOODE and BEAN, Proc. U. S. Nat. Mus., vol. 5, p. 422, 1882 (Clearwater Harbor, Fla.).—LONGLEY and HILDEBRAND, Carnegie Inst. Washington Publ. 535, p. 164, 1940 (Tortugas).

*Scorpaena russula atlantica* NICHOLS and BREUER, Proc. Biol. Sec. Washington, vol. 37, p. 21, pl. 7, 1924 (off Galveston, Tex.).

*Scorpaena mercatoris* DELSMAN, Mem. Mus. Roy. Hist. Nat. Belg., ser. 2, fasc. 21, p. 74, fig. 11, 1941 (Cay Sal Bank).

D.(XI)XII(XIII) 8-9 (10). A.III(4) 5(6). P.(18) 19-21. Sc.41-49. GR.(3)4-5+7-11.

*Description*.—Eye larger than snout. Interorbital 2-3 times in eye. Maxillary ending under posterior margin of pupil or a little behind. Occiput between parietal ridges with a very shallow depression, somewhat better marked in small specimens, without a definite pit. Frontal spine placed a little laterad of a line through low parietal ridge; upper posttemporal spine very moderate or slight, sometimes a mere bony angle rather than a spine; parietal ridge and upper posttemporal and supraclithral spines often alined in a curved or nearly straight line; sphenotic armature in form of a group of spinules or blunt asperities, 1-4 in number; preorbital with 2 free moderate spinous points, posterior spine usually directed downward or slightly forward (this spine doubled in one specimen observed); suborbital ridge usually with 2 moderate or slight spinous points, one under eye and one at posterior end of ridge, sometimes anterior one, less often also posterior one, absent or hardly perceptible, occasionally a third slight projection between the two usual points; cleithrum without a spine. First preopercular spine rather long, usually reaching more than half the distance from its base to opercular margin, without a supplemental spine; second spine notably small, smaller than third, occasionally absent; fifth spine usually in form of broad, blunt projection, sometimes minutely serrate; preopercular margin above first spine usually with sparse, slight, variable, and irregular serrations, sometimes with 1 or 2 comparatively prominent points. A small tentacle at base of supraocular spine sometimes present, usually absent (well developed in small specimens); a row of tentacles on eyeball marking boundary between upper opaque part and lower transparent part; some small elongate tabs along edge of preopercle often present: some broad, fimbriated tentacles often present along course of lateral line; smaller tentacles on head, body, and eyeball variable, few to many. Opercle largely scaleless; scales on chest, fleshy pectoral base, opercle, and cheek more or less embedded or fairly distinguishable at surface. Penultimate dorsal spine about two-thirds as long as last spine; longest



dorsal spine shorter than postorbital part of head. Second anal spine subequal to third varying a little both ways. Ventral reaching anus or a little behind. Pectoral about reaching a vertical through base of third anal spine, varying a little both ways; its uppermost ray unbranched, next 5-7 rays branched, lower 12-14 unbranched.

Measurements of 4 specimens 108-159 mm., 3 specimens 65-75 mm., and 2 specimens 31-36 mm., all from the coast of the United States, given in 3 groups in the same order: caudal 29-32, 30-31, 32.5-33.5; ventral 22.5-25.5, 25.5-27.5, 25.0-26.5; pectoral 32.5-35.5, 34.0-36.5, 33-37; depth 32.5-35.0, 35.0-37.5, 39.5-40.0; head 42.0-45.5, 44.0-44.5, 49.0-49.5; maxillary 21.5-23.5, 22-23, 25.5-26.5; snout 11.2-12.1, 10.9-11.8, 11.3-13.3; eye 12.4-15.3, 14.0-16.5, 17.2-17.8; interorbital 5.1-5.8, 5.5-6.5, 6.7-7.6. Snout 1.1-1.3, 1.2-1.5, 1.3-1.5 and interorbital 2.1-3.0, 2.3-2.6, 2.3-2.7 times in eye. (See also below, measurements of 2 Caribbean specimens.)

Short, elongate, oblong or broad, opaque, whitish areas extending on transparent part of eye at base of some of the tentacles in the horizontal row on the eyeball present or more often absent; when present not mushroom-shaped as in *inermis*. Upper part irregularly shaded, sometimes dusky, shading somewhat more marked in 4 transverse areas, giving very faint suggestion of a cross-banded pattern; a dusky blot a little behind head, at and below lateral line, faintly or moderately marked in most specimens, sometimes imperceptible; first dorsal often with 2 lengthwise rows of diffuse spots; second dorsal sometimes with oblique rows of diffuse smaller spots; caudal usually uniformly light-colored, sometimes with 2 transverse, rather faintly shaded cross areas near its middle and at its margin; ventral in the smaller specimens usually dusky to nearly black distally; body and fins often mottled with whitish, especially in the smaller specimens.

*Development.*—The pectoral rays begin to branch in fish between 35 and 40 mm. The nuchal depression is relatively better marked in small fish which also have a well-developed tentacle at the supra-ocular spine.

*Specimens examined.*—This is not an uncommon offshore species on the east coast of the United States whence 167 specimens 22-159 mm., in 69 constituent samples, were examined, ranging from off the mouth of Chesapeake Bay (102177) to Tortugas, Fla., to off Padre Island, Tex. (155310), including the type of *calcarata* (23556, Clearwater, Fla.) and the holotype of *russula atlantica* (86167, off Galveston, Tex.). Also, 4 specimens 94-145 mm. from off Cabo Catoche (101602, 148349) and 25 specimens 96-130 mm. from off Campeche (157543-4), Yucatan Peninsula; 1 specimen 68 mm., Flanagan Passage, Virgin

Islands (47642); 1 specimen 75 mm., off the Caribbean coast of Colombia (142881). The largest specimen, 159 mm., is from off South Carolina (151941). Depth records are available for most lots examined and range 7-50 fathoms.

*Comparison.*—This species is very close to *inermis* and the name *calcarata* had been placed in the synonymy of that species until Longley determined some of their differences. Other distinguishing characters have been elaborated during this investigation. The main differences between them are stated in the key, and they are not absolute. Besides these differences, *calcarata* usually has the upper posttemporal spine placed slightly higher up, almost directly behind the parietal ridge, the second preopercular spine is generally somewhat smaller, sometimes absent, and the nasal spine is somewhat better developed. The two species probably also differ in the averages of some proportional measurements, as may be gathered by comparing their accounts. While the two species do not differ sharply in any one character, they are satisfactorily distinguishable when all their differences are taken into consideration.

From the other species of its genus here treated, *calcarata* differs in lacking a supplemental preopercular spine and in the virtual absence of an occipital pit. Among those species it seems to be nearest to *agassizi*, with which it is compared below.

*Populations.*—The two Caribbean specimens examined are those entered in table 4 as having 41 rows of scales, while those from the coast of the United States and the Yucatan Peninsula have 42-49 scales. The measurements of these two specimens, 68-75 mm., are: caudal 30.5, ventral 23.5-24.0, pectoral 31, depth 37.5-38.5, head 44.5-47.0, maxillary 23-24, snout 10.6-10.7, eye 17.0-17.3, interorbital 4.6-5.0; snout 1.6 and interorbital 3.4-3.8 times in eye. Comparing these with the measurements of three specimens of similar size from the coast of the United States, given above, the tropical American specimens average a shorter ventral and pectoral, a deeper body, a longer head and maxillary, a shorter snout, a larger eye, and a narrower interorbital. While the precise extent of divergence of the tropical American population is, of course, indeterminable from only two specimens, it appears to be no greater than that of racial magnitude.

The 29 specimens from off the Yucatan Peninsula more frequently have 8 dorsal rays and 21 pectoral rays, the frequency distributions being as follows. Yucatan Peninsula: dorsal rays 8 (in 7 specimens) or 9 (in 22); pectoral rays 19 (1), 20 (19), 21 (9). All other constituent samples combined: dorsal rays 8 (16), 9 (159), 10 (3);

pectoral rays 18 (1), 19 (22), 20 (133), 21 (20). Approximately one-fourth of the Yucatan specimens have 8 dorsal rays and one-third have 21 pectoral rays.

*Synonymy*.—The holotype and paratype of *S. russula atlantica* have been examined and their data included in this account. Longley previously placed *atlantica* in the synonymy of *calcarata*.

The name *mercatoris* is here doubtfully placed in the synonymy of *calcarata*, as Delsman's brief description does not admit a positive identification of his specimen without its reexamination. His account agrees with *calcarata* in the main, and no essential character is given to show that *mercatoris* is different. The eye of *mercatoris* is said to measure 4 times in the head, whereas in 11 specimens of *calcarata* measured the eye varies 2.6-3.4 times in the head; but this slight difference may readily be ascribed to a difference in method. The figure of *mercatoris* shows a notably long snout; but the drawing is obviously rather crude and no special significance can be attached to this seeming difference. It seems highly probable that *mercatoris* is based on a specimen of the common *calcarata*. Another possibility is that *mercatoris* is a synonym of *inermis*.

#### SCORPAENA AGASSIZI Goode and Bean

*Scorpaena agassizi* GOODE and BEAN, Oceanic ichthyology, p. 247, pl. 67, fig. 243, 1895 (Blake station CCLIX).—LONGLEY and HILDEBRAND, Carnegie Inst. Washington Publ. 535, p. 159, 1941 (Tortugas).

D.XII (XIII) (8) 9. A.III (4) 5. P.19-21. Sc.43-53. GR.4-6+8-11.

*Description*.—Eye notably large, snout about two-thirds as long as eye. Interorbital about one-half the eye diameter. Maxillary ending under space between posterior margin of pupil and that of eye. Occipital pit moderate. Spines on head well developed; sphenotic usually bifid, sometimes single, sometimes 2 very blunt projections directly below sphenotic; preorbital with 2 spines, the posterior one usually notably long, directed backward, almost horizontal; suborbital ridge usually with 3 well-developed spines, the anterior one more widely spaced than posterior two, sometimes one or two of the spines hardly perceptible, sometimes a fourth small spine present in front; cleithrum without a spine. First preopercular spine moderate, reaching about half the distance from its base to opercular margin, with a supplemental spine; second spine smaller than third. Tentacle at supraocular spine short or absent; other tentacles or filaments usually rather sparse. Chest in the smaller specimens normally scaled and

with a smooth surface, with growth becoming much wrinkled in a somewhat cerebriform manner, without scales visible at the surface, with some deeply embedded, nonimbricate scales; scales on fleshy pectoral base and head partly embedded; opercle largely scaleless. Penultimate dorsal spine about three-quarters as long as last spine; longest dorsal spine subequal to postorbital part of head or very slightly shorter. Second anal spine subequal to or a little shorter than third. Ventral reaching anus or anal origin. Pectoral reaching a vertical approximately through end of anal base, varying a little both ways; its uppermost ray unbranched, next 6-8 rays branched, lower 11-13 unbranched.

Measurements of 5 specimens 116-172 mm. and 2 specimens 31-36 mm.: caudal 33.5-37.0 (32-33), ventral 23.5-28.5 (27.5-28.0), pectoral 44.0-48.5 (34.5-35.0), depth 32.5-39.5 (42), head 43.5-47.5 (48.5-49.0), maxillary 20.5-23.5 (24-25), snout 9.7-11.7 (9.3-11.6), eye 15.5-17.0 (17.3-20.3), interorbital 8.1-8.6 (9.4-10.5); snout 1.4-1.6 (1.5-2.2) and interorbital 1.9-2.0 (1.8-2.0) times in eye.

Upper part of body and head lightly and irregularly pigmented with dusky shades, one specimen with a few small dark points on nape extending to the area over opercle and a little behind head; the dusky pigment somewhat more concentrated in a small area behind head, giving very faint suggestion of a dusky blot; in addition to the general distribution of pigment as described, the pigment also more concentrated over central and greater part of area of each scale, surrounded by a lighter peripheral margin; distal edge of pectoral and ventral with a dark margin present or absent; the fish, including fins, otherwise notably light-colored. The above description drawn from three specimens after 2 years in preservative (152042). Specimens kept longer in preservative plain yellowish or grayish without distinctive markings; tabs sometimes whitish. Young specimens having distal part of ventral and often also that of pectoral dusky or blackish; soft dorsal and anal with dusky pigment separated by a clear area near middle; specimens in one lot of young fish, after many years of preservation, being suffused or mottled with a bright pink color, in some of these specimens the pink color incompletely separated into four broad areas, giving a faint suggestion of a cross-banded pattern, the bands extending partly on dorsal fins.

*Development.*—The pectoral rays begin to branch between 50 and 55 mm. The occipital pit is developed about as in the adult in specimens as small as 30 mm. Small specimens have the tentacles better developed. The tentacle at the supraocular spine is notably well de-

veloped and fimbriated and other rather well-developed tentacles are distributed on the head and body, being especially conspicuous along the course of the lateral line, at its anterior part.

The appearance of the chest in the larger specimens of *agassizi* is unique among the western Atlantic scorpaenids. In the smaller specimens the chest has a normally even and scaled surface as in the other species. With growth the chest becomes notably wrinkled and assumes somewhat of a cerebriiform appearance, while the scales become deeply embedded and nonimbricate.

*An unusual variant.*—One small specimen, 42 mm. in standard length, from Sand Key, Fla. (74093), not in good condition, fairly agrees in its characters with *agassizi*; but the dorsal fin has a peculiar structure. It has 2 spines united by membrane and detached from the rest of the fin by an intervening space of considerable extent. The posterior part of the dorsal consists of 8 spines and 9 rays. Although the midback in the intervening space is scaled over and the specimen seems normal, it agrees so nearly with *S. agassizi* that it is safe to assume that this peculiar structure is caused by an early injury involving two of the dorsal spines. The type of *Neomerinthe hemingwayi* Fowler shows a similar development (see p. 54).

*Specimens examined.*—From off the following localities. Mid-Atlantic: Blake station 259, lat.  $23^{\circ} 10' N.$ , long.  $39^{\circ} 10' W.$  (153583; one specimen 148 mm. taken at same station as holotype, but not mentioned in original description). Coast of North Carolina (152042). Cape Lookout (101545) and Cape Fear (91430), N. C. Palm Beach (153219), Cape Florida (72980), Sand Key (74093), Key West (101600, 131612, 132197, 134160), Tortugas (117126-8, inclusive; 144570), Cape St. George (157548), Cape San Blas (133999, 157549), and Santa Rosa Island (157550), Fla. Total examined, 106 specimens 20-176 mm., the largest from off Cape St. George. Available depth records range 37-116 fathoms. This is evidently not an uncommon species offshore.

*Comparison.*—This species has the longest pectoral and largest eye of any species of *Scorpaena* here treated. *S. calcarata* approaches it in these two characters, and both are sometimes taken together in the same trawl drags. It differs from *calcarata* in having a supplemental preopercular spine and a fairly developed nuchal pit. The comparatively long posterior preorbital spine of *agassizi*, the structure of its chest, and its nearly plain color are diagnostic of most of the larger specimens.

## SCORPAENA BRASILIENSIS Cuvier and Valenciennes

- Scorpaena brasiliensis* CUVIER and VALENCIENNES, Histoire naturelle des poissons, vol. 4, p. 305, 1829 (Brazil).
- Scorpaena stearnsi* GOODE and BEAN, Proc. U. S. Nat. Mus., vol. 5, p. 421, 1882 (Pensacola, Fla.).
- Scorpaena colesi* NICHOLS, Bull. Amer. Mus. Nat. Hist., vol. 33, p. 537, fig. 1, 1941 (Cape Lookout, N. C.).
- Scorpaena isthmensis* BEEBE and TEE-VAN (not Meek and Hildebrand, which is a synonym of *bergi*), Zoologica, vol. 10, No. 1, p. 188, fig., 1928 (Port au Prince, Haiti; specimen reexamined).

D.XII (XIII) (7-8) 9. A.III (4) 5 (6). P.(17) 18-20. Sc.50-62. GR.4-5+8-10.

*Description*.—Eye moderate, snout subequal to eye, varying a little both ways. Interorbital nearly one-half to about two-thirds the eye diameter. Maxillary ending under posterior margin of eye or slightly more forward. Occipital pit well developed. Upper posttemporal spine absent or small; preorbital spines 2, well developed, posterior one directed downward or nearly so; suborbital ridge usually with 3 moderate spinous projections, often one or two of them very slight or imperceptible; cleithrum with a slight spinous projection disappearing in large specimens. First preopercular spine extending about half the distance across opercle or a little more; supplemental spine very small or moderate, virtually absent in infrequent variants; second spine subequal to third or smaller; fifth spine rudimentary or absent. Tentacle at supraocular spine very variable, short to moderately long; other tentacles, tabs, or filaments on head, body, and eye also very variable from sparse to profuse. Opercle moderately scaled, anterior area above upper spine scaled, a variable patch of scales below lower spine; scales on fleshy pectoral base, chest, and head partly embedded. Penultimate dorsal spine about two-thirds as long as last spine; longest dorsal spine subequal to postorbital part of head in the smaller specimens, shorter in larger fish. Second anal spine more or less shorter than third. Ventral reaching anus or anal origin. Pectoral reaching a vertical through base of first to third anal spine; its first ray unbranched, the following 7-10 branched, the lower 8-11 unbranched.

Measurements of 6 specimens 118-293 mm. including the types of *stearnsi* and *colesi*, and 2 specimens 46-48 mm., all from the coast of the United States: caudal 30.5-35.5 (33-34), ventral 23-26 (26-28), pectoral 33.0-38.5 (32.5-34.0), depth 34.0-37.5 (40.0-40.5), head 41.0-43.5 (43.0-45.5), maxillary 20.0-22.5 (23.5), snout 10.8-12.1 (11.5-12.4), eye 10.5-12.4 (14.6-15.2), interorbital 5.8-7.7 (8.0-8.9);

snout 0.9-1.1 (1.2-1.3) and interorbital 1.6-2.1 (1.7-1.8) times in eye. The measurements of one specimen 135 mm. from Brazil fall within the above given ranges of variation.

Two rather large spots on a horizontal line through second opercular spine, the first directly behind head, the second at a moderate distance behind in juxtaposition to lateral line, the two spots usually sharply or moderately marked, sometimes rather faint; sometimes a spot over space between preceding two spots, sometimes a third faint spot in a row with and behind the two; lower part of body with many irregularly scattered small spots of variable intensity, extending to pectoral base and usually on anterior part of inner side of fin, number of such small spots very variable from profuse to nearly or quite absent; sometimes similar spots but averaging fewer in number, also on head, pectoral base, and upper part of body; sometimes two irregular, diffuse, incomplete cross bands on posterior part of body and caudal peduncle, rather faintly indicated; sometimes rather dark or marbled or suffused with a whitish shade in part or nearly all over; often with two or three very diffuse spots at dorsal base; oblique bands on dorsal and anal poorly marked; caudal with a broad brownish transverse band at its margin and one near its middle; two or three similar but less well-marked bands at base, margin, and middle of pectoral; sometimes body and fins almost uniformly light-colored or variably shaded.

*Development.*—The pectoral rays begin to branch when the fish reach approximately a length of 50-55 mm. The occipital pit is relatively shallow at 31 mm. and becomes about as deep as in the adult at 45 or 50 mm.

*Specimens examined.*—Atlantic coast of the United States, ranging from off Cape Henry, Va. (127411), to off Tortugas, Fla., including the type of *colesi* (A.M.N.H. 4689); 66 specimens in 44 constituent samples. Gulf coast of Florida, ranging from off Cape Sable to Pensacola, including the type of *stearnsi* (30169); 47 specimens in 28 constituent samples. One specimen obtained by the *Grampus* off Galveston, Tex. (148137, 95 mm.). Also, off or at the following localities: Cabo Catoche (91431, 144574; altogether 5 specimens 182-213 mm.) and Campeche (157546-7, 2 specimens 187-201 mm.), Yucatan Peninsula, Mexico. Jamaica (32084, 2 specimens 171-204 mm.). Port au Prince, Haiti (N.Y.Z.S. 7381, 211 mm.). St. Thomas, Virgin Islands (9325, 38651; 2 specimens 32-174 mm.). Rio de Janeiro (83177, 182 mm.) and Bahia (43276, 135 mm.), Brazil. Total ex-

amined in detail, 128 specimens 31-293 mm. Besides the above, 74 specimens 42-256 mm. in 28 constituent samples were rapidly examined in the Chicago Natural History Museum and the University of Michigan Museum of Zoology after the manuscript of this account was drawn up, to verify the conclusions arrived at. The largest specimen is from off Savannah (155324). Available depth records range 1-56 fathoms. This is evidently a fairly common offshore species obtained by trawling and is also taken inshore by seining. On the Gulf coast of the United States all specimens examined were collected on the west coast of Florida, except one small specimen from Texas. Gunter (1948, p. 159) also records only two small specimens from Texas of those examined by him. Apparently this species is rather common on the west coast of Florida and comparatively uncommon on the northern Gulf coast westward of Florida.

*Comparison.*—This species is distinguishable from its western Atlantic congeners by its relatively high scale count and its distinctive color pattern, especially the presence of two dark spots behind the head and the small black spots in the pectoral axil, although the divergence is not pronounced. The lower extreme of its scale-count distribution approaches the other species closely and overlaps with *agassizi*, and the distinctive color pattern is not evident in all specimens. The absence or small size of the upper posttemporal is of some help in distinguishing *brasiliensis*, as well as the frequency distribution of its pectoral and gill-raker counts, its proportional measurements, and the relative length of the second and third anal spines. On the whole, it is not a difficult species to distinguish.

*Synonymy.*—The types of both *stearnsi* and *colesi* which are here placed in the synonymy of *brasiliensis* have been examined and their data included in this account of the species. The name *stearnsi* generally and correctly has been placed by authors in the synonymy of *brasiliensis*.

Nichols, in describing his *colesi*, compares its type with *brasiliensis* and points out some differences. However, an examination of a rather large composite sample of *brasiliensis* proves that these differences have their basis in intraspecific individual variability. The structural characters of the type of *colesi* easily fall within this range of variability. Nichols in his account of *colesi* describes the three or two large lateral blotches and the small dark axillary spots that are characteristic of *brasiliensis*. These color marks are now largely faded, but their traces may still be discerned.



## SCORPAENA GRANDICORNIS Cuvier and Valenciennes

*Scorpaena grandicornis* CUVIER and VALENCIENNES, Histoire naturelle des poissons, vol. 4, p. 309, 1829 (Martinique; Puerto Rico).—JORDAN and EVERMANN, U. S. Nat. Mus. Bull. 47, p. 1850, pl. 273, fig. 672, 1898 ("Florida Keys to Brazil").

D.XII (XIII) (8) 9 (10). A.III (4) 5. P.17-19. Sc.44-49. GR.4-6(7) + (7)8-10.

*Description*.—Eye slightly or moderately larger than snout. Interorbital about two-thirds eye diameter. Maxillary ending under posterior margin of pupil or a little behind. Occipital pit notably well developed. Spines on dorsal aspect of head notably well developed, their bases broad, somewhat shelflike; frontal spine absent in the larger specimens, very moderate or small in small specimens; upper posttemporal subequal to lower; preorbital with 2 free spinous points, the anterior one very moderate; spines on suborbital ridge very variable, 1-3, sometimes none, the one at end of ridge usually present, sometimes absent; cleithrum with a moderate spinous point in the smaller specimens tending to disappear with growth. First preopercular spine extending less than half the distance across opercle; second spine subequal to third or longer; fourth and fifth spines very slightly developed or imperceptible. Tentacle at supraocular spine notably well developed, long, broad, and branched or fimbriated, usually reaching dorsal origin; other well-developed tentacles along course of lateral line, on head and eyeball; smaller tentacles or tabs irregularly scattered on body and head. Opercle moderately scaled, anterior area over upper ridge scaled, a variable patch of scales below lower ridge at preopercular margin and sometimes a few scattered, nonimbricate scales on rest of opercular extent below lower ridge. Penultimate dorsal spine four-fifths to nine-tenths as long as last spine; longest dorsal spine subequal to postorbital part of head in the smaller specimens, moderately shorter in large fish. Second anal spine longer than third. In the larger specimens ventral reaching to anus, and pectoral over base of first anal spine or shorter; in the smaller specimens ventral about reaching anal origin and pectoral to over base of first to third anal spine; pectoral having the first ray unbranched, the following 7-9 branched, the lower 7-10 unbranched.

Measurements of 5 specimens 113-181 mm. and 2 specimens 32-47 mm., from Key West, Cuba, Puerto Rico, Guadalupe Island, Panama, and Brazil: caudal 29.0-33.5 (34.5), ventral 25.5-29.5 (27.5-28.5), pectoral 33.5-37.0 (33), depth 40.5-42.5 (43.5-45.0), head 41-43 (44.5-45.5), maxillary 19.5-20.5 (22.5), snout 9.8-10.7 (11.2-12.1),

eye 10.7-12.2 (14.6-15.1), interorbital 6.8-8.3 (7.9-8.4); snout 1.0-1.2 (1.2-1.3) and interorbital 1.5-1.7 (1.8-1.9) times in eye.

An area at upper pectoral angle, extending partly on the side of the body and partly on inner surface of fin, with many very small, crowded, whitish, rounded spots, often ringed with dark pigment. Strongly pigmented with dark color on head, body, and fins; often prevailing dark all over except ventral aspect; often with 2 broad, dark cross areas on posterior lower part of body, one under soft dorsal, the other on caudal peduncle, abruptly separated by a lighter area; caudal with 2 broad cross bands, at its middle and at the margin; soft dorsal, anal, and pectoral usually with oblique or transverse, more or less irregular, lighter areas separating the dark color; ventral often nearly black distally, lighter proximally; sometimes with a transverse black area at some distance from its end; head and body with many very small white dots, similar to dots in pectoral axil but smaller, usually well marked in the lighter-colored specimens, imperceptible in dark fish.

*Development.*—The pectoral rays begin to branch at about 60 mm. The occipital pit is well developed in the smallest specimen examined, 32 mm.

The frontal spine is very small in young fish and disappears with growth, the size at disappearance varying greatly with the individual. The smallest specimen examined lacking the frontal spine is 59 mm., and the largest having it is 110 mm. Nine specimens 32-58 mm. all have a small frontal spine; 23 specimens 113-181 mm. lack this spine; of 35 specimens 59-110 mm., 15 have the spine, at least a trace of it, some of them on one side only, and 20 lack it.

*Specimens examined.*—Key West (35101, 67655), Boca Chica (148130), and Tortugas (117139), Fla. Castle Harbor, Bermuda (50949). Cuba (4689, 9830, 13040, 24944). Port au Prince, Haiti (133728). Puerto Plata, Dominican Republic (22134). Puerto Rico (50181, 63050, 126445.) Guadeloupe (25285). St. Lucía (142833). Fort Randolph (148675), Porto Bello (80969, 81595, 81601), and Fox Bay (80968, 81596-7, 81602-4), Panama. Río Atrato, Colombia (1681). Brazil (6944). Total examined, 67 specimens 32-181 mm., the largest from Cuba (13040).

This species does not seem to range north of southern Florida. No specimens from north of Key West were examined. Records in the literature ascribing *grandicornis* to Cape Cod probably originated in a misidentification, as one lot in the National Museum (58876) from Katama Bay, Marthas Vineyard, containing four specimens 37-53 mm. and labeled *grandicornis*, proved to be the young of *plumieri*.

While no definite depth records are available, *grandicornis* seems to be an inshore, shallow-water species.

*Comparison.*—The characteristic small white spots at the pectoral angle, together with the absence of the frontal spine permit the ready identification of this species. The frontal spine is present in small specimens, but it is smaller than in specimens of related species of similar size. The tentacle at the base of the supraocular spine is longer and thicker than in the other species, but individual variants of *brasiliensis* and *plumieri* have this tentacle developed nearly as well. On the whole, taking all its characters into consideration as outlined above, this species is not difficult to distinguish.

#### SCORPAENA BERGI Evermann and Marsh

*Scorpaena bergii* EVERMANN and MARSH, Bull. U. S. Fish Comm., vol. 20, pt. 1, p. 276, fig. 83, 1902 (Mayagüez, Puerto Rico).—LONGLEY and HILDEBRAND, Carnegie Inst. Washington Publ. 535, p. 161, 1941 (Tortugas).  
*Scorpaena isthmensis* MEEK and HILDEBRAND, Publ. Field Mus. Nat. Hist. Chicago, zool. ser., vol. 15, pt. 3, p. 842, pl. 80, 1928 (Porto Bello, Panama).

D.(XI) XII (8) 9. A.III 5. P.16-18. Sc.42-48. GR.3-4+7-10.

*Description.*—Snout subequal to eye, varying moderately both ways. Interorbital width about one-half eye diameter or moderately less. Maxillary reaching to under posterior margin of eye or that of pupil. Occipital pit and spines on dorsal aspect of head well developed. Anterior portion of parietal ridge usually somewhat better developed than posterior part; upper and lower posttemporal spines subequal; preorbital with 2 free spinous points, the anterior directed forward, the posterior downward; suborbital ridge moderate, usually ending posteriorly in a slight or moderate point, sometimes the point inappreciable; cleithral spine moderate or well developed. First preopercular and its supplemental spine moderate; second spine longer than third and somewhat nearer to first; fifth spine slightly developed or hardly appreciable at surface. Interopercle with a slight or moderate spinous point at its outer upper corner. Development of tentacles very variable in size and number; tentacle at supraocular spine usually well developed, broad, digitated or fimbriated, sometimes small or notably large nearly reaching spinous dorsal, other tentacles and tabs at spines on head, body, and upper part of eyeball varying from moderate to very profuse. Opercle largely scaleless; scales on cheek deeply embedded, hardly appreciable at the surface. Penultimate dorsal spine usually about four-fifths as long as last spine; longest dorsal spine only a little shorter than postorbital part of head. Second anal spine longer than third. Ventral reaching anus or a little behind. Pectoral

about reaching a vertical through base of first anal spine, varying a little both ways; in the larger specimens usually 1 upper ray unbranched, sometimes upper 2 unbranched, next 4-5 rays branched, lower 10-12 rays unbranched.

Measurements of 30 specimens 49-87 mm. and 3 specimens 33-47 mm., all from southern Florida: caudal 26.5-32.0 (28.5-32.0), depth 35.0-40.5 (35.5-41.0), head 42.5-46.5 (46.5-48.0), eye 11.4-14.2 (14.1-15.2). One specimen from Long Island 36 mm.: caudal 29, depth 40.5, head 42, eye 12.4. One specimen from Cozumel Island 59 mm.: caudal 26.5, depth 38, head 44, eye 14.3. Two specimens from Puerto Rico 57-76 mm. (types of *bergi*): caudal 27.5-28.0, depth 40.0-41.5, head 46.0-47.5, eye 15.1-16.1. One specimen from Panama (type of *isthmensis*): caudal 32, depth 38, head 42.5, eye 12.2. Five specimens 59-92 mm. and 3 specimens 33-43 mm. from the entire range of the species: ventral 25-30 (26-30), pectoral 29.5-34.0 (28.0-33.5), maxillary 20.5-24.5 (21.0-23.5), snout 11.1-13.0 (13.8-15.2), interorbital 5.3-6.3 (6.4-7.6); snout 0.9-1.3 (0.9-1.0) and interorbital 2.1-2.6 (2.4-2.8) times in eye.

Rather irregularly pigmented with brown shades against a somewhat lighter background; the pigment somewhat more concentrated on posterior part of body, at end of dorsal and anal fins, forming an irregular, not sharply defined, broad cross band; another band, more irregular and not as marked, at caudal base; the area between the two bands rather abruptly lighter (distribution of pigment in region of caudal peduncle resembling that of *plumieri*); caudal with 3 somewhat irregular, broad, cross bands at base, at distal margin and in between; spinous part of dorsal rather irregularly pigmented, the pigment especially concentrated on an area between third, fourth, or fifth to seventh or eighth dorsal spines, forming a spot only slightly distinguishable from surrounding pigment in dark specimens, well marked in light-colored or faded specimens; anal, pectoral, and soft dorsal with irregular alternate light and dark areas; ventral light-colored or moderately pigmented on its distal part.

*Development.*—The third and fourth pectoral rays are forked for a short distance in the smallest specimen examined, 33 mm. In a 36-mm. specimen all rays are still unbranched. In the next size examined, 43 mm., the second to the fifth rays are rather well branched. The nuchal pit is rather shallow in the 33-mm. specimen. It is developed nearly as in the adult at about 50 mm.

*Specimens examined.*—Porto Bello, Panama (81617, holotype of *isthmensis*, 92 mm.). Mayagüez, Puerto Rico (49533, holotype of *bergi*, 76 mm.). Culebra Island, Puerto Rico (126190, paratype of

*bergi*). Cozumel Island, Mexico (37103). Tortugas (one specimen 55 mm. in 117138; 117137, 29 specimens 43-87 mm., all other lots consisting of one specimen each), Key West (119119), Palm Beach (153128), and Miami (C.N.H.M. 46214), Fla. Fire Island Inlet, Long Island, N. Y. (108656, 36 mm.). Total examined, 38 specimens 33-92 mm. This appears to be a shallow-water species, although adequate habitat data are unavailable.

*Population.*—As may be gathered from the measurements given above, the Puerto Rico population seems to average a comparatively deep body, long head, and large eye. The Panama population might be found to average a high pectoral count, and the relative length of the second and third anal spines might differ with the population as discussed below.

*Extreme variants and other possible population differences.*—The two holotypes examined are both extreme variants in relation to the composite sample examined.

The holotype of *bergi* has 11 dorsal spines, while all other 37 specimens have 12 spines.

The type of *isthmensis* is an extreme variant in four characters: (1) It has 18 pectoral rays, while the other 37 specimens have 17 or 16 rays. (2) It lacks a spine on the suborbital ridge. In the other specimens, 32 have a spine on both sides in various stages of development from well marked to slight, 3 lack the spine on one side and 1 lacks it on both sides. (3) The end of the third anal spine is broken off in the type specimen; but judged by the larger part left and its persistent sheath of skin, it was probably not much shorter than the second spine, the relative length of the two spines in the living fish probably was as in the variant from Long Island discussed below. (4) It is very dark-colored and the spot on the spinous dorsal not sharply marked.

The long caudal of the type of *isthmensis* by which, in the original description, it is said to differ from *bergi*, does not hold, as five of the other specimens examined have the caudal about as long.

The small specimen, 36 mm., taken on Long Island, shows three differences as compared with the other specimens: (1) The head measurement, 42 percent, is unusually low for its size, not only as compared with the other specimens of *bergi* of similar size, but also with other western Atlantic species of *Scorpaena* examined. (2) In the other specimens of *bergi* the tip of the second anal spine reaches beyond that of the third when both are depressed, while in this specimen the tips of the two spines are about coterminous when depressed. (3) The distribution of the pigment on the caudal is somewhat differ-

ent. Its posterior half is rather diffusely and almost uniformly pigmented, except for a narrow, almost clear marginal area; the base is deeply pigmented transversely; the two pigmented areas are separated by a broad, transverse, nearly clear area.

The relative shortness of the head of the Long Island specimen might be explained by presuming that the specimen is precocious in this respect, having assumed the adult head length at a small size. The difference in the relative length of the second and third anal spines might be a population difference. At any rate, in the absence of conclusive evidence, a shade of doubt exists in the identification of this specimen with *bergi*.

*Comparison.*—This species averages the lowest pectoral count of all its congeners. The gill rakers average lower than in most species. It is a small species and its pectoral rays are branched at a comparatively small size. In this respect it is near to *albifimbria*. In most characters *bergi* is nearest *grandicornis* and *albifimbria*. It differs from both in usually having a fairly well-marked spot on the spinous dorsal. It further differs from *grandicornis* in having the frontal spine well developed, and in averaging a slenderer body and fewer pectoral rays and gill rakers, the extent of intergradation in the latter three characters being considerable. From *albifimbria* it differs in having a slenderer body and fewer pectoral rays and gill rakers. As only the type of *albifimbria* and one uncertain specimen are available the extent of divergence between it and *bergi* could not be determined adequately.

*Synonymy.*—As discussed above, the type specimen of *isthmensis* differs somewhat from the norm of the composite sample of *bergi* examined. However, it about agrees in the color pattern and in the important structural characters with the types and other specimens of *bergi*. There are no well-marked specific differences such as distinguish other scorpaenid species, or species of fishes in general. Evidently, the differences noted are either individual differences or they might prove to be minor population differences on examination of adequate samples. The name *isthmensis* is therefore placed in the synonymy of *bergi*.

#### SCORPAENA ALBIFIMBRIA Evermann and Marsh

*Scorpaena albifimbria* EVERMANN and MARSH, Bull. U. S. Fish Comm., vol. 20, pt. 1, p. 275, fig. 82, 1902 (off Culebra Island, Puerto Rico).

D.XII 9. A.III 5. P.19. Sc.42. GR.5+10.

*Description.*—Eye larger than snout. Interorbital about two and a half times in eye diameter. Maxillary ending under posterior mar-

gin of pupil. Occipital pit moderate. Anterior part of parietal ridge somewhat longer than posterior part; upper and lower posttemporal spines subequal, well developed; preorbital with 2 well-developed free spinous points; suborbital with 3 spinous points; cleithrum with a blunt projection. First preopercular spine well developed, supplemental spine moderate; second spine about as long as and more slender than third, somewhat nearer to first; lower 3 spines rather broad and blunt, gradually decreasing in size downward. Upper outer corner of interopercle ending in a blunt point. A long tentacle at base of preocular and supraocular spines, rather broad and somewhat fimbriated proximally, slender distally; other tentacles and tabs in very moderate numbers; head and upper part of eyeball with many papillae. Scallation at preopercular margin rather well expanded backward, but greater part of opercle scaleless; scales on cheek and behind eye well embedded. (Spinous dorsal damaged and relative length of spines indeterminable; see below relative length of spines in uncertain variant examined.) Second anal spine longer than third. Ventral falling a little short of base of first anal spine. Pectoral reaching a vertical through base of second anal spine; its first ray unbranched, next 5 rays branched, lower 13 rays unbranched.

Measurements of a specimen 43 mm.: caudal 31.5, ventral 29.5, pectoral 30.5, depth 43.5, head 49, maxillary 27, snout 13.3, eye 17.2, interorbital 7.2; snout 1.3 and interorbital 2.4 times in eye.

Pale yellowish, washed with whitish in places; pectoral with small white spots, and moderately dusky distally; other fins plain; no distinctive color marks. Published figure of specimen examined, made when recently preserved, shows a dark area behind head over lateral line, and soft dorsal and anal with spots and a band respectively.

*Specimen examined.*—Off Culebra Island, Puerto Rico, 15 fathoms, 43 mm. (49532, the holotype).

*An uncertain variant.*—A specimen having the following data possibly belongs to this species: Off Palm Beach, Fla., 40 fathoms, Thompson and McGinty, February 1950 (153127), length 44 mm., caudal 32, ventral 31.5, pectoral 33, depth 46.5, head 50.5, maxillary 25, snout 13.3, eye 17.2, interorbital 6.3; snout 1.3 and interorbital 2.7 in eye.

D.XII 9. A.III 5. P.17. Sc.46. GR.5+11.

The counts and measurements of this specimen agree rather well with those of the type given above, except that it has 17 instead of 19 pectoral rays. It further agrees in having the second to the sixth pectoral rays branched, in its almost uniformly pale color, in general appearance, and in the other characters given above, with the follow-

ing exceptions, besides the difference in the number of pectoral rays. The suborbital ridge ends in 1 moderate spinous point at the end, instead of having 3 spinous points. The second preopercular spine is smaller than the third, instead of being subequal to it. The tips of the second and third anal spines end at the same point when depressed, while in the type the tip of the second spine extends beyond that of the third. The cleithral spine is better developed than in the type. The tentacle at the supraocular spine is broader, and the one at the preocular spine much shorter, than in the type specimen.

Judged by intraspecific variability in other species of *Scorpaena* the differences outlined might well fall within the range of variation of the same species; but this conclusion needs to be confirmed by the study of an adequate sample. Meanwhile, the type and the other specimen concerned are described separately to call attention to the differences, and the counts of the type only are entered in the tables.

The twelfth dorsal spine is damaged in the type. In the variant the penultimate spine is approximately one-half as long as the last.

*Comparison.*—This is evidently a small species. The pectoral rays are branched at a size at which they are still unbranched in the other species of *Scorpaena*, except *bergi*. It is compared with *bergi* under its account. In general appearance, especially in body shape, the type specimen of *albifimbria* examined somewhat resembles small specimens of *plumieri*; but in specimens of *plumieri* of comparable size all pectoral rays are unbranched, the interorbital is much wider, the cleithral spine much better developed and they are deeply pigmented with a specific color pattern.

#### SCORPAENA DISPAR Longley and Hildebrand

*Scorpaena dispar* LONGLEY and HILDEBRAND, Carnegie Inst. Washington Publ. 517, p. 24, fig. 12, 1940 (Tortugas, Fla.).

*Scorpaena similis* GUNTER, Copeia, 1948, pt. 3, p. 161 (off the Mississippi Delta, La.).

D.(XI) XII 8-9. A.III 5. P.17-19. Sc.42-48. GR.5+10-12.

*Description.*—Eye moderate, usually a little smaller than snout, sometimes subequal to it. Interorbital about one-half the eye. Maxillary ending under space between posterior margin of pupil and that of eye. Occipital pit and spines on head well developed. Lower post-temporal spine larger than upper; preorbital with 3 free spines, the middle one close to and usually smaller than anterior spine; suborbital ridge usually with 3 spines, sometimes middle spine absent; cleithrum with a moderate spinous projection. Preopercular spines moderate, supplemental spine large in comparison, first spine extending less than



half the distance across opercle, next three spines subequal or slightly graduated, fifth spine slight or obsolescent. Upper posterior corner of interopercle forming a blunt projection or ending in a spinous point. Tentacle at supraocular spine very variable, broad, and long to short; other tentacles, tabs, or filaments on body, head, and eyeball variable, usually rather sparse. Scallation on opercle very variable, area below lower ridge scaled or naked in greater part, or covered with partly nonimbricate scales in profusion or in sparse numbers; scales on cheek and opercle moderately or well embedded. Penultimate dorsal spine about two-thirds as long as last spine; longest dorsal spine subequal to postorbital part of head or slightly shorter. Ventral reaching anal origin or a little short. Pectoral about reaching a vertical through base of first anal spine, varying slightly both ways; its first ray unbranched, next 6-8 rays branched, lower 9-11 unbranched.

Measurements of 4 specimens 167-192 mm. and 2 specimens 106-111 mm.: caudal 29.5-31.5 (30.0-30.5), ventral 25.0-26.5 (26-27), pectoral 32.0-35.5 (29.5-33.5), depth 35.0-38.5 (35.0-36.5), head 45-48 (45.0-45.5), maxillary 22-25 (21.0-21.5), snout 13.5-15.6 (12.5-13.9), eye 11.3-12.7 (12.2-12.7), interorbital 5.8-6.1 (5.1-6.0); eye 1.1-1.3 (1.0-1.1) times in snout, interorbital 1.9-2.1 (2.0-2.5) times in eye.

Plain-colored without well-defined color marks; caudal rather faintly marked in two transverse areas, near the middle and near its distal margin, with diffuse small spots; similar spots on pectoral and, to a lesser extent, on soft dorsal and anal still fainter. One specimen has a faint blotch, directly over lateral line at some distance behind head, and a faint elongate blotch directly below lateral line a little farther behind. The above color description is drawn from specimens on the coast of the United States; those from off Cabo Catoche differ somewhat in color as follows. The caudal has elongate, rounded, rather clear-cut brown spots which are generally situated on the interradiial membrane, and a few such spots are often present also on the pectoral, dorsal, and anal; while the much fainter spots on the United States specimens are generally situated partly on the rays.

*Development.*—Two specimens 50-60 mm. already have some of the pectoral rays branched, but the extent of branching is less and the number of branched rays is fewer than in the larger specimens. The same two specimens have the occipital pit and the middle preorbital spine nearly as in the large specimens.

*Specimens examined.*—Cape Florida (124304) and Tortugas (108-867, holotype of *dispar*), Fla.; off Mississippi Delta (124332, holotype of *similis*, and 155332, both collected by the *Pelican*); off Cabo

Catoche, Yucatan Peninsula, Mexico (101537, 119768, 134220). Total examined, 4 specimens 60-195 mm. from the coast of the United States and 12 specimens 50-207 mm. from off Cabo Catoche. Available depth records range 21-95 fathoms.

*Comparison.*—This species and *plumieri* differ from their other congeners, except *Microlepis*, in having 3 free spinous points on the distal margin of the preorbital and their distinguishing characters are, therefore, contrasted in the key. However, in general appearance these two species are rather unlike, and it is doubtful whether they are closely related.

*Populations.*—As noted above, the specimens examined from off Cabo Catoche differ moderately in color as compared with those from the coast of the United States. In the few specimens examined, those from Cabo Catoche average fewer pectoral rays. Counting the rays on both sides, the frequency distribution is as follows, the figures inside the parentheses giving the number of pectorals on which a stated count is based: United States 17 (2), 19 (6); Cabo Catoche 17 (5), 18 (17), 19 (1). Also, both variants having 8 dorsal rays, as shown in table 1, are from Cabo Catoche. The differences indicated point to the need of further research in regard to the precise differences between the two populations, but the specimens examined are altogether too few to form the basis for definite conclusions.

**SCORPAENA PLUMIERI** Cuvier and Valenciennes, sensu lato

D.XII (8) 9. A.III (4) 5 (6). P.18-21. Sc.42-49. GR.4-6+8-12.

*Description.*—Eye about two-thirds as large as snout. Interorbital subequal to eye, varying a little both ways. Maxillary ending approximately under posterior margin of eye. Occipital pit rather well developed or moderate; a pit under anterior margin of eye, above suborbital ridge (the only species having a definite pit in this position). Spines on head rather coarse, broadened below apex; lower post-temporal ridge somewhat better developed than upper; preorbital with 3 free spinous points, middle spine small and placed near anterior spine (occasionally absent on one side); suborbital ridge usually with 3 spinous points, sometimes a fourth small point in front; cleithral spine moderate or well developed in the smaller specimens, becoming blunt with growth; in large specimens cleithrum markedly projecting upward and somewhat backward, the two distal corners of the projecting part forming tapering, sharp or rather blunt angles with a well-developed emargination between them, the lower outer angle representing the cleithral spine of the smaller specimens; upper outer angle of interopercle blunt or moderately sharp. Preopercular spines rather short, first spine not extending halfway across opercle; supplemental

spine moderate or well developed, usually placed on upper surface of first spine; second spine slightly longer and sharper than third; fourth spine moderately sharp or blunt; fifth spine blunt or obsolescent. Tentacle at supraocular spine very variable from short to long; other tentacles, tabs, and filaments very variable in number and development. Greater part of opercle scaled, but extent of scalation on part below lower ridge very variable, often the scales nonimbricate in part, hard part of opercle between the two diverging ridges usually scaleless as in its congeners, often some nonimbricate scales present; scales on cheek, opercle, and sometimes also on chest more or less embedded. Penultimate dorsal spine averaging about seven-eighths as long as last; longest dorsal spine considerably shorter than postorbital part of head. Second anal spine more or less longer than third. Ventral reaching anus, but more often a little behind. Pectoral usually falling a little short of a vertical through base of first anal spine, sometimes reaching there; its uppermost ray unbranched, next 5-10 rays branched, lower 9-14 rays unbranched.

Body with two variably dark areas, one directly behind head, the other under soft dorsal, separated by a variable lighter area; the three areas very variable in extent and intensity of pigmentation, without clear-cut boundaries, not uniformly pigmented, mottled with lighter and darker shades; caudal peduncle light, usually almost uniformly and strikingly so; a slightly curved cross band at caudal base; an oblique band forking from middle of latter band, downward and forward to underside of peduncle, leaving a light triangular area, bounded by the two bands, at lower part of peduncle; inner surface of pectoral with a black area at its base, spotted with white, usually this pattern extending for some distance on side; caudal with two broad, dark, mottled, transverse areas, one at middle, one at margin; pectoral with three similar transverse areas, not as well marked; soft dorsal and anal mottled before and behind, separated by a nearly clear area in middle; greater distal part of ventral mottled; spinous dorsal often with a black or brown spot, or a row of spots, saliently outstanding from rest of pigmentation; often prettily marbled with white all over the light and dark areas on head, body, and fins.

Growth changes in the color pattern and structural characters are described below under the account of the subspecies *plumieri*, of which a fair sample in a graded size range is available for examination. Small specimens of the subspecies *mystes* are not available for study.

*Comparison.*—This species has a distinctive color feature which is of much value in distinguishing it from other species of its genus, namely, the inner region at the pectoral base is black with small white

spots, sometimes partly confluent, the distinctively colored area extending partly on the side and partly on the surface of the fin. The caudal peduncle stands out from the rest of the body as lighter-colored, uniformly so or more or less shaded. The distinctive combination of structural characters is as follows: 18-21 pectoral rays; 42-49 cycloid scales; total number of gill rakers and tubercles on both limbs 12-17; occipital pit moderate to well developed; 3 preorbital spines. It has a comparatively wider interorbital and smaller eye than its other western Atlantic congeners. The fairly marked pit between the suborbital ridge and eye, under its anterior margin, is unique for this species.

The larger specimens of this species are readily distinguished by the combination of their distinctive color and the structural characters given above and in the key. Small specimens have their distinctive color and the same structural characters, except that the occipital and suborbital pit and the middle preorbital spine are as yet undeveloped (see below under the subspecies *plumieri*).

This species is doubtfully divisible into two subspecies, *plumieri* in the Atlantic and *mystes* in the Pacific. As discussed below under *mystes*, the difference between the two possible subspecies is slight, and it is a question whether they should be so treated. Evidently *plumieri*, sensu lato, is one of those comparatively few species of fish, the Atlantic and Pacific populations of which have diverged but little since their long isolation.

#### SCORPAENA PLUMIERI PLUMIERI Bloch

*Scorpaena plumieri* BLOCH, Nya Handl. Stockholm, pt. 10, p. 234, 1789 (Martinique).

*Scorpaena bufo* CUVIER and VALENCIENNES, Histoire naturelle des poissons, vol. 4, p. 306, 1829 (Martinique).

*Scorpaena scrofina* CUVIER and VALENCIENNES, *ibid.*, vol. 9, p. 465, 1833 (Brazil).

*Scorpaena rascacio* POEY, Memorias sobre la historia natural de la Isla de Cuba, vol. 2, p. 169, 1860 (Cuba).

*Scorpaena albofasciata* METZLAAR, Rapp. Vissch. Kol. Curaçao, edited by J. Boeke, vol. 2, pt. 1, p. 145, fig. 43, 1919 (Curaçao).

*Scorpaena nuttingi* EVERMANN and SEALE, Stud. Nat. Hist. Univ. Iowa, vol. 10, p. 39, pl. 1, 1924 (Carlisle Bay, Barbados).

*Scorpaena colonensis* MEEK and HILDEBRAND, Publ. Field Mus. Nat. Hist. Chicago, vol. 15, p. 844, pl. 81, fig. 1, 1928 (Colón, Panama).

*Scorpaena ginsburgi* GUNTER, Copeia, 1942, p. 105 (Texas).

D.XII (8) 9. A.III 5 (6). P.18-21. Sc.42-49. GR.4-6+8-12.

*Description*.—Measurements of 14 specimens 206-306 mm. and 3 specimens 33-43 mm.: ventral 27.5-30.5 (29-31), pectoral 33.0-36.5

(29.5-31.0), maxillary 20.5-24.0 (23.0-24.5), snout 12.6-15.0 (12.3-13.2), eye 7.6-9.4 (11.9-13.2), antedorsal distance 35.5-38.5 (41.5-44.0), depth of peduncle 10.6-12.2 (11.2-12.0); eye 1.4-1.9 (1.0-1.1) in snout, interorbital 0.8-1.2 (1.0-1.2) in eye. Measurements of caudal, depth, head, and interorbital given in table 12.

Within the limits of the specific color pattern as described above, many specimens of this subspecies show the following minor characteristics: Variegated dark and light or white markings on body and fins very notable; black area at pectoral axil very deeply pigmented, the white spots in the area very sharply contrasted, comparatively rather large, and usually extend also on side of body; light area on caudal peduncle sharply contrasted with the dark pigment before and behind; small spots on lower part of sides few and diffuse or absent. However, color markings vary much with the individual and one or all of the preceding color characteristics are not present in many of the specimens examined.

*Development.*—Small specimens, under 50 mm., have a characteristic and distinctive color pattern as follows: Head and body almost uniformly very dark, in sharp contrast the caudal peduncle abruptly very light, without melanophores, except the characteristic forking band described above under the species; posterior part of dorsal and anal likewise clear; a vertical nearly straight line marking anterior boundary of clear part of peduncle and dorsal and anal fins; rest of dorsal and anal, and ventral and pectoral almost uniformly very dark except that pectoral has a narrow whitish margin; color of caudal nearly as in grown specimens. The change from the juvenile to the adult color pattern occurs early and rather rapidly. The adult color pattern is not radically different; it is merely a modification of the juvenile pattern. The characteristic white spots against a black background in the pectoral axil begin to appear at about 40 mm.

At 30 mm. the occipital pit is virtually absent, the area occupied by the pit in the adult being only slightly depressed, almost flat for its greater part. It reaches its full development at about 90 mm. In the largest specimens it becomes again rather shallow, and also comparatively broader.

The suborbital pit begins to appear between 60 and 70 mm., and a trace of the middle preorbital spinous point somewhat later, between 65 and 75 mm. The pectoral rays begin to branch at about the time the suborbital pit begins to develop.

*Specimens examined.*—Katama Bay, Marthas Vineyard, Mass. (49677, 58876, 58901-2; altogether 7 specimens 30-53 mm.). Beaufort, N. C. (53407, 111509, 126501; altogether 3 specimens 64-87

mm.). Biscayne Bay (61704) and Tortugas (6777, 41839, 117136, 117140), Fla. Corpus Christi (148135), Harbor Island (148134, 148136), Aransas Pass (119016, holotype *ginsburgi*), Mustang Island (119015, 119017-8), and Freeport (157559), Tex. Abaco, Bahamas (38387-8). Cuba (4688; 10126; 12543; 35096; 153578, cotype *rascacio*). Jamaica (30005, 30087, 35120, 38565). Haiti (122640, 133727). Puerto Rico (50149). Dominica (29854). St. Lucia (41333). Old Providence Island (38631). Fort Randolph (128702), Colón (81606, holotype *colonensis*), Fox Bay (80978-80, 81591-2), and Porto Bello (80973-4, 81593-4), Panama. Cabo San Román (123197) and Gulf of Venezuela (123196), Venezuela. São Paulo market (100875) and Santos market (100876), Brazil. Total examined 69 specimens 30-323 mm., the largest from Cuba.

This subspecies is the most widespread of all scorpænids here

TABLE II.—Frequency distribution of the number of pectoral rays, scales, and gill rakers in some populations of the subspecies *plumieri*.

	Pectoral rays				Scales								Gill rakers, total					
	18	19	20	21	42	43	44	45	46	47	48	49	12	13	14	15	16	17
Massachusetts . . . . .			7	..	..	2	1	1	1	2	..	..	..	..	1	3	3	..
Texas . . . . .	..	12	2	..	..	..	2	1	3	2	3	2	..	1	3	8	2	..
Cuba . . . . .	..	1	5	..	1	2	..	2	1	..	..	..	..	..	..	1	4	1
Jamaica . . . . .	..	5	..	..	..	..	..	2	1	2	..	..	..	..	3	2	..	..
Panama . . . . .	2	9	1	1	1	..	3	6	2	1	..	..	1	1	1	5	4	..

treated, ranging from Massachusetts to Brazil, and it is fairly common. The northern specimens examined are all small. It lives inshore and also ranges offshore.

*Comparison.*—This subspecies is compared with *mystes* under the account of the latter.

*Populations.*—Table II shows population differences in the frequency distribution of the number of pectoral rays, scales, and gill rakers. The gill-raker count gives the total number on the outer arch, including the gill rakers and tubercles on both limbs. While the samples are too small to serve as a basis for definitive conclusions, they at least give an indication of some of these differences.

The predominant number of pectoral rays is either 19 or 20, depending on the population. In the subspecies *mystes*, in 12 specimens representing a wide geographic range, the number is constantly 20. However, in *plumieri* the differences in the number of pectoral rays evidently cannot be correlated with geographic distribution or with other structural differences. Besides, the count within the range of

a given population is not absolutely constant. Consequently, this count cannot serve as a basis for subspecific distinction.

The scale count is low on the average in the Cuba and Panama populations and highest in that of Texas. The gill-raker count is low in the Jamaica and Panama populations and high in that of Cuba.

The caudal in small Texas specimens is appreciably longer as compared with similar specimens from Katama Bay. In 5 Texas specimens 30-52 mm. the caudal length ranges 32.4-34.1; while in 7 Katama Bay specimens 30-53 mm. the range is 28.3-30.9. Larger specimens from Katama Bay are not available for comparison. Texas specimens both large and small, when compared with combined samples of similar specimens from the West Indies and Central America do not show any striking differences in the caudal length.

On the whole, judged by the small samples examined, these minor population differences are not sufficiently divergent to serve as a basis for subspecies distinction.

*Synonymy.*—The names *bufo* and *rascacio* generally have been synonymized by authors with *plumieri*. One of Poey's cotypes of *rascacio* has been examined and its data included in this account. The original description of *bufo* is recognizable and it was evidently based on specimens of this species. The reasons for placing the other five names in the synonymy are as follows.

In the brief description of *S. scrofina*, it is said to have large white drops ("gouttes") on the pectoral axil, which is a characteristic color mark of *plumieri* and of no other known species. There is nothing in the description of *scrofina* to indicate that the specimen described is different from *plumieri*. It seems safe to conclude that it is an individual variant of this common species.

Metzlaar does not compare his *S. albofasciata* with any other species, nor does he state the reason for establishing a new species. Presumably, he based it on the striking color pattern of his specimens, which is well indicated in his published figure. This color pattern is characteristic of the young of *plumieri* as stated above. Three small specimens, 30 mm., of *plumieri* examined, about the same size as Metzlaar's specimens, are nearly exact replicas of his figure. Although I did not examine the type of *albofasciata*, there is hardly any question that it represents young specimens of *plumieri*.

The type of *colonensis*, 43 mm., which was reexamined, likewise represents a young *plumieri*. According to the character used in their key, *colonensis* was based by the original authors on the near absence of an occipital pit, which is a character of the young. In the type of *colonensis* the state of development of the occipital pit is like that

in specimens of *plumieri* of similar size, and its other specific characters agree with this species.

The single type specimen of *nuttingi* is said to differ from *plumieri* in having 5 branched pectoral rays (8 such rays shown on the figure) instead of 1. This is an error, *plumieri* normally having 5-10 such rays, except in the young. The other differences mentioned in the original description of *nuttingi* are largely governed by individual variability. The published figure of *nuttingi* is well executed and it is so typical of *plumieri* in color and general appearance that there seems no doubt that it represents a specimen of that species.

Gunter gives a number of characters which are said to distinguish *ginsburgi* from *plumieri*. However, examination of a larger series of specimens than that available to Gunter shows that those characters are subject to a great deal of individual variation. Any slight average differences that might exist evidently are no more than the slight differences that are usually found between the local populations of the same species. Some of the minor population differences are discussed above. Most any species of fish could be split up into a number of taxonomic units by using such minor population differences. To recognize such minor differences by the formal bestowal of scientific names would make nomenclature too burdensome, and in the present state of ichthyology would serve no useful purpose.

#### SCORPAENA PLUMIERI MYSTES Jordan and Starks

- Scorpaena mystes* JORDAN and STARKS, Proc. California Acad. Sci. (ser. 2) vol. 5, p. 491, pl. 52, 1895 (Mazatlán, Mexico).  
*Scorpaena tierrae* HILDEBRAND, U. S. Nat. Mus. Bull. 189, p. 441, fig. 84, 1946 (Peru; Chile).

D.XII 9. A.III (4) 5. P.20. Sc.44-47. GR.4-5+9-11.

*Description*.—Measurements of 5 specimens 199-279 mm.: ventral 27.5-29.5, pectoral 34.0-35.5, maxillary 21.0-24.5, snout 11.5-14.1, eye 8.3-9.7, antedorsal 35-39.5, depth of peduncle 10.8-11.7; eye 1.4-1.6 in snout and interorbital 1.0-1.2 in eye.

The majority of specimens differ in color characteristics from the subspecies *plumieri*, described above, as follows: Variegated dark and white markings on body and fins not as well marked; black area at pectoral axil not as strongly pigmented, and the white spots generally smaller, fewer, not as sharply marked, and usually confined to underside of pectoral fin; light area on the caudal peduncle generally somewhat suffused with a dusky tint, and not as markedly outstanding; small dark spots on lower part of side often well marked. However, there is much individual variation in the relative development of pig-



TABLE 12.—Range of depth, head, interorbital, and caudal measurements of *Scorpaena plumieri plumieri* and *S. p. mystes*, segregated into size groups, expressed as a percentage of the standard length.

Subspecies	Length of specimens	Number of specimens	Depth		Head		Interorbital		Caudal	
			Range	Average	Range	Average	Range	Average	Range	Average
<i>plumieri</i> .....	30-53	15	40.1-47.7	44.1	45.1-50.0	47.4	11.1-13.6	12.1	28.3-34.1	31.2
<i>plumieri</i> .....	58-110	14	37.5-43.7	40.9	44.4-47.6	45.9	9.1-11.0	9.9	29.0-33.9	31.4
<i>mystes</i> .....	80-108	2	33.7-35.0	34.4	46.0-46.7	46.4	7.4-7.5	7.5	29.1-30.8	30.0
<i>plumieri</i> .....	141-189	12	34.7-41.6	38.6	38.6-46.6	44.2	8.1-9.9	9.2	27.4-32.2	30.0
<i>mystes</i> .....	130-192	3	33.9-36.6	35.6	42.5-45.8	43.9	6.9-8.7	8.1	28.0-30.2	29.1
<i>plumieri</i> .....	205-280	23	33.3-40.1	35.9	39.2-46.0	43.7	7.6-9.4	8.5	27.0-31.5	29.3
<i>mystes</i> .....	199-279	5	29.8-35.2	33.4	42.5-46.7	45.1	7.7-8.9	8.3	25.0-29.9	28.0
<i>plumieri</i> .....	287-323	4	31.3-38.9	35.2	43.4-46.6	44.6	8.4-8.6	8.5	27.3-30.6	28.9
<i>mystes</i> .....	356	1	.....	29.8	.....	47.0	.....	9.8	.....	25.7
<i>mystes</i> .....	437	1	.....	33.6	.....	50.2	.....	9.2	.....	23.6

ments in both subspecies, and color differences do not distinguish them satisfactorily.

*Specimens examined*.—Bay of Guaymas (43257), Mazatlán (47450, cotype of *mystes*), and Acapulco (65657), Mexico. Taboguilla Island (128730), Taboga Island (80970, 12871), Naos Island (80971), Panama City tide pools (81599), Panama. Lobos de Tierra, Peru (128128, holotype, and 128129, paratype, of *tierrae*). Juan Fernández Island, Chile (88775, paratype of *tierrae*, 437 mm.). Total examined, 12 specimens 80-437 mm.

*Comparison*.—This Pacific population does not differ much from the corresponding Atlantic population. It differs somewhat on the average in some proportional measurements, as may be gathered by comparing the data given in table 12 and under the accounts of the subspecies, the greatest apparent degree of divergence referring to the body depth. As the depth changes with growth, an adequate appraisal of the precise degree of divergence of this measurement cannot be made with the available specimens. When the scant data included in table 12, in the size groups 130-192 and 199-280 mm., are arranged in the form of a frequency distribution, the apparent degree of divergence shown is less than that of subspecies magnitude.

A direct comparison of specimens shows that, in general, the occipital pit in the Pacific population is shallower. However, in both populations the degree of development of the pit varies with the individual, and changes markedly with growth as described above under the subspecies *plumieri*. It is very difficult to determine the precise degree of divergence of this character as it can hardly be expressed in terms of exact figures. But the difference is evidently not pronounced and individual specimens cannot be identified by its use as a criterion without a knowledge of the locality of capture. The degree of divergence of this character also appears to be less than that of subspecies magnitude.

The two populations also show, in bulk, some differences in color characteristics as described under their accounts; but individually the specimens are indistinguishable by color. This is another character that can hardly be expressed numerically.

On the whole, judged by the samples examined, the degree of divergence between the two populations seems to be of the order of race, rather than subspecies, or the border line between these two categories. But in the absence of conclusive data and considering their long isolation in point of time, it seems best to treat them, at least tentatively, as distinct subspecies, since they have been treated heretofore as distinct taxonomic entities and both have been formally named.

The relative depth of the occipital pit and the interorbital width constitute the two chief characters that have heretofore been used to distinguish the Atlantic and Pacific populations as distinct species. The very limited value of the occipital pit as a taxonomic character in separating these two populations is discussed above. Measurements of the interorbital width are given in table 12. It differs greatly with the size of the fish. When specimens of like size are compared there is a moderate difference in the smaller specimens, but hardly any difference in the size group 199-280 mm.

*Synonymy*.—The holotype of *tierrae* has the head unnaturally thrown out of shape. Evidently, the fish had the opercles spread outward when rigor mortis set in. This gives the head a broad, flat appearance; but when the opercles are pressed to their approximately normal position, the specimen does not differ materially from others of *plumieri*, sensu lato. Besides the head shape, other differences mentioned in the original description vary with the individual and the state of growth.

A statement used in the original description of *tierrae*, and also in the accompanying key, needs to be emended from the viewpoint of homology and also because it has a bearing on one of the main characters here used to separate the genera and species. The statement is made that *tierrae* has 6 preopercular spines. However, 5 preopercular spines is the typical basic number for all the species here treated, as discussed above, with the first spine having a supplementary spine or spur at its base in most species. In *plumieri*, sensu lato, the supplementary spine usually arises from the upper outer surface of the first preopercular spine, and in individual specimens, especially large ones, it sometimes becomes rather prominent. It might then mistakenly be included in the count of the preopercular spines, which would result in a total count of 6. However, though prominent, it is still the supplementary spine homologically and should not be taken for the first preopercular spine.

#### SCORPAENA MICROLEPIS Gunter

*Scorpaena microlepis* GUNTER, Copeia, 1948, No. 3, p. 162, plate 2 (off Englewood, Fla.).

D.XII 9. A.III 5. P.16-18. Sc.76. GR.5+11.

*Description*.—Eye subequal to snout. Interorbital approximately 2 times in eye. Maxillary ending on a vertical a little in front of posterior margin of eye. Occipital pit rather small and shallow. Anterior part of parietal ridge somewhat higher than posterior part;

frontal spine in a line with postocular placed laterad of parietal ridge; upper posttemporal slightly indicated (on right side of single specimen examined) or absent (on left); lower posttemporal ridge and spinous point moderate; sphenotic doubled; pterotic ridge and spinous point well developed; postorbital in form of very slight tuberosities; preorbital with 3 free spinous points; suborbital ridge with 2 very slight spinous points, 1 under eye, 1 at its posterior end (the anterior point missing on left side, the posterior absent on right side); cleithral spine well developed (on left) or very slight (on right). First preopercular spine reaching about halfway across opercle; supplemental spine slight; lower 4 spines graduated, the second longer than third, fifth slightly developed. Tentacles at supraocular spine moderate, other tentacles sparse (skin on head broken in places). Scales notably small, 76; fleshy pectoral base largely scaled, an area on its posterior lower part naked; scales on chest and pectoral base not embedded; opercle partly scaled over upper ridge (opercle below lower ridge having scalation seemingly incompletely preserved and skin partly destroyed, its greater part probably scaleless); scales in patch on cheek below suborbital ridge embedded and larger than any other. Penultimate dorsal spine about two-thirds as long as last; longest dorsal spine subequal to postorbital part of head. Second anal spine a little longer than third. Ventral nearly reaching anal origin. Pectoral reaching to over base of first anal spine; upper ray unbranched, next 6-8 rays branched (differs on both sides of specimen examined, both counts entered independently in table 2).

Measurement of one specimen 121 mm.: caudal 33.5, ventral 30, pectoral 33, depth 33, head 42, maxillary 19, snout 11.5, eye 10.9, interorbital 5.5; eye 1.1 times in snout, interorbital 2 times in eye.

Head and body a nearly uniform brown; soft dorsal and anal with irregular alternating areas of light and dark shades, similar areas on pectoral slightly perceptible; caudal with a dark transverse area at its base, followed by lighter area, its posterior and greater part diffusely dusky; ventral slightly pigmented.

*Specimen examined.*—Off Englewood, Fla., Bass Biological Laboratory, January 7, 1936 (U.M.M.Z. 110161, the holotype and only known specimen).

*Comparison.*—This is a strongly marked species. It is distinguishable from its western Atlantic congeners at a glance by its notably small scales. The occipital pit is small and rather shallow, being somewhat intermediate in this respect between *calcarata* or *inermis* and the other species of *Scorpaena*. The frontal spine is in a line with the postocular, laterad of the parietal ridge as in the above-named two

species. In having 3 preorbital spinous points it agrees with *plumieri* and *dispar* and differs from all others.

#### Genus SETARCHES Johnson

*Setarches* JOHNSON, Proc. Zool. Soc. London, 1862, p. 177 (genotype *Setarches guntheri* Johnson, by monotypy).

This genus has a combination of specialized and generalized characters. The unusual structure of the lateral line and the cavernous bones of the skull are evidently specialized features, while the poor development of a number of spines on the head more nearly approaches the generalized fish morphology than other scorpaenid genera. On the whole, considering all the characters, it seems to be a highly specialized genus. The generic characters are included under the account of the single species here treated where its relationship to the other western Atlantic scorpaenids is further discussed.

#### SETARCHES PARMATUS Goode

*Setarches parmatus* GOODE, Proc. U. S. Nat. Mus., vol. 3, p. 480, 1881 (*Fish Hawk* station 867, off Long Island, N. Y., 39° 57' N., 70° 56' W., 120 fathoms).—GOODE and BEAN, Oceanic ichthyology, p. 264, pl. 70, fig. 249, 1895 (the figure from the type specimen having a mutilated dorsal).

D.XII; 9-10. A.III (4) 5. P.22-24. Sc.88-103. GR.6-7+10-15.

*Description*.—Skull with large external cavities formed by configuration of skeletal elements, with ridges more or less developed between cavities, externally bridged over by a rather thin membranous skin. Eye smaller than snout. Interorbital comparatively broad, only a little less than eye diameter. Maxillary ending approximately under posterior margin of eye. Palatine teeth present. A small slit on inner side of fourth gill arch. Gill rakers at the angle of the arch rather long and slender, gradually decreasing in length both ways; difference between gill rakers and the tubercle-like outgrowths at ends of arch rather abrupt, the two kinds readily distinguishable; gill rakers on upper limb 3 (in 24) or 4 (17), infrequently 5 (1); gill rakers on lower limb 10 (25) or 11 (15), infrequently 9 (1) or 12 (1); tubercles on upper limb low but their number readily determinable, nearly always 3 or 4, infrequently 2 (in 1 out of 42 specimens); tubercles on lower limb not as well marked, their number difficult to determine with precision (see discussion below), varying 0-5. Occipital region flat, without a pit. Nasal and preocular spines small but sharp; supraocular and postocular absent, except indicated as blunt protuberances in small specimens (the only species here treated lacking

these spines); parietal ridge entire, long, low, ending in a single spinous point posteriorly; frontal spine absent; upper posttemporal short or moderate, sharp or rather blunt; lower posttemporal short, blunt, or nearly absent; sphenotic absent, except moderate in young; pterotic ridge and spine moderate; no postorbital spine or tuberosity; preorbital with 3 free spinous points well developed; suborbital ridge smooth, without spinous points; cleithrum with a moderate, blunt projection. The 5 preopercular spines well developed; upper 3 notably long in comparison, subequal, or second spine slightly longer than other two, sometimes first or third slightly longer; supplemental preopercular spine absent; fifth spine directed downward. Tentacles, filaments, and tabs absent. Lateral line a continuous channel, in form of very shallow ditchlike depression covered over by membranous vaulted roof; two rows of very thin, notably elongate, membranous scales forming part of roof, one row arranged in a horizontal series at lower part of roof, the ends of the scales moderately separated or almost touching, another row at upper part of roof containing narrower and flimsier scales somewhat more widely separated and rather obliquely placed (the rooflike structure more or less damaged in nearly all preserved specimens; the modified lateral line present in only this species of those examined). Scales small, cycloid, roundedly oblong, rather moderately imbricated, 88-103 (in four specimens, scales missing in large patches in other specimens); scalation on antedorsal area extending to parietal spines; opercle with a patch of scales above upper ridge, and its thin membranous marginal area more or less scaled, its greater part scaleless; a patch of scales on posterior part of cheek below suborbital ridge; area above suborbital ridge between eye and preopercular margin scaled; rest of head and occiput scaleless. Emargination between spinous and soft parts of dorsal notably developed, virtually forming two separate fins, eleventh spine about one-third as long as twelfth; longest dorsal spine subequal to snout length. Second anal spine shorter than third. Ventral falling considerably short of anus, its outer angle under lower pectoral angle. Pectoral irregularly wedge-shaped, the longest rays near its middle, but lower outline notably more curved than upper; fin reaching to over base of second anal spine or a little shorter, its upper 2 or 3 rays unbranched, next 12-16 rays branched, lower 5-9 rays unbranched. Caudal slightly emarginate or truncate.

Measurements of 3 specimens 115-167 mm.: caudal 24.5-27.5, ventral 19-21, pectoral 33.5-34.5, depth 32.0-35.5, head 40.0-43.5, maxillary 22.0-24.5, snout 12.3-13.6, eye 9.5-10.8, interorbital 8.4-9.2; eye 1.2-1.3 times in snout, interorbital 1.1-1.2 times in eye.

Recently preserved specimens having the head, body, and inner face of opercle suffused somewhat irregularly with a dusky shade; upper part above lateral line often with very small dusky or dark spots of a deeper shade than ground color; fins mostly yellowish, very moderately suffused with dusky; palate black; no distinctive markings; specimens long in preservative almost uniformly plain yellowish.

*Development.*—Although this is a small species the pectoral rays begin to branch comparatively late, at about 80 mm. Rudiments of supraocular, postocular, and sphenotic spines are evident in five specimens 49-58 mm. as blunt protuberances. Slighter traces of these spines persist up to 70 mm. and generally disappear at 80 mm.

*Gill rakers.*—The tubercles on the upper limb are low but easily distinguishable and their number varies only moderately with the individual. However, the precise enumeration of the tubercles on the anterior part of the lower limb is attended with some difficulties. They are often only slightly developed, especially in small specimens, and not easily observed. Sometimes they apparently coalesce and are not distinguishable individually. It seems also that supernumerary tubercles that are hardly distinguishable from the regular tubercles sometimes appear with growth. Some evidence points to the possibility of their being absent or few in the young and appearing after some growth has been attained. On top of this, the number of tubercles appears to vary widely with the individual. As a consequence, the number of tubercles on the lower limb constitutes an unstable and unsatisfactory specific character, and of course this also applies when the number of these tubercles is combined with the gill rakers into a single figure. On the other hand, in this species, unlike the condition in other scorpaenids here treated, the gill rakers are distinguishable readily from the tubercles, they vary within narrow limits, and their number given separately constitutes a well-marked, comparatively stable specific character. Therefore, under the above description the frequency distribution of the number of gill rakers only is stated separately; while in tables 3-5 and in the formula at the head of the species account the combined number of gill rakers and tubercles is given for the purpose of comparison with the other species, but these numbers are not as valuable taxonomically as the gill-raker numbers alone.

*Specimens examined.*—Off the following localities: Long Island, N. Y. (26084, the holotype). Cape Charles, Va. (46074). Cape Lookout, N. C. (57817). Savannah, Ga. (155333). Tortugas (92059, 117146), Egmont Key (157553, 157556), and Cape San Blas (44672, 46081), Fla. Horn Island, Miss. (157554). Isle Derniere, La.

(157555). Padre Island, Tex. (157568). Barbadoes (47644). Total examined, 42 specimens 49-167 mm., the largest from off Cape San Blas. Depth records, available for 11 of 13 constituent samples examined, range 93-280 fathoms.

*Comparison.*—This species differs from all other western Atlantic scorpaenids in having very small cycloid scales, in the peculiar structure of the lateral line, in having the upper 3 preopercular spines long, slender, and subequal or nearly so, in lacking the supraocular and postocular spines, and in the virtual presence of 2 dorsal fins. It has notably well-developed cavities at the surface of the head skeleton that are bridged over by the thin membranous skin. It is apparently the most specialized species as compared with the others here treated.

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SMITHSONIAN MISCELLANEOUS COLLECTIONS  
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FROM WESTERN MARYLAND

(WITH 1 PLATE)

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ARTHUR L. BOWSER

Division of Invertebrate Paleontology and Paleobotany  
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*Division of Invertebrate Paleontology and Paleobotany  
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(WITH 1 PLATE)

Specimens of lecanocrinids are fairly abundant in middle and upper Silurian rocks of many parts of the world. On the other hand, only three species and few specimens of lecanocrinids are known from Devonian rocks. Of these three species, *Lecanocrinus magniradialis* (Weller) from the Helderbergian of New Jersey, *L. soyei* Oehlert from the lower Devonian of France, and *Geroldicrinus roemeri* (Schultze) from the "Stringocephalen-kalk" of Germany, two are known from incomplete specimens consisting of dorsal cup and a few IBrr, while the third species is known from seven specimens, including one complete crown. The specimen from western Maryland is of special interest because it is an almost complete crown, the first from the Devonian of North America. From this specimen it is possible to determine the character of the rays and to study the lateral union of the rays by close sutures above the level of the RR. The specimen furnishes valuable information concerning the relations between the Silurian and Devonian lecanocrinids.

This important Devonian crinoid was collected by A. G. Perdeu, of Cumberland, Md., from the New Scotland formation, 2 miles east of Cumberland.

SYSTEMATIC DESCRIPTIONS

Family LECANOCRINIDAE Springer, 1913

Crown short, rotund; IBB erect or confined to basal concavity; rays in contact except at anal side, arms almost straight or coiled tightly upon themselves at distal ends. Silurian-Permian.

LECANOCRININAE Bowsher, new subfamily

Crown short, rotund; 3 IBB erect or confined to basal concavity; rays in contact except at anal side; RA and anal X; arms incurving at tips. Silurian-Devonian.

*Remarks.*—It is beyond the scope of this paper to review the classification of the numerous flexible crinoids formerly referred to the Lecanocrinidae. Jaekel (1918, p. 80) proposed the families Mespilocrinidae, Nipterocrinidae, and Calpiocrinidae to include some genera of flexible crinoids formerly referred to the family. Other genera are properly referred to Homalocrinidae Angelin, 1878, and Palaeoholopidae Wanner, 1916.

Springer (1920) placed much stress on whether IBB are erect, subhorizontal or confined to the basal concavity. He made these structural features of fundamental importance in classification. *Lecanocrinus* (s.s.) has erect IBB but *Miracrinus*, which is certainly a lecanocrinid, has the IBB confined to the basal concavity. The IBB of *Geroldicrinus* are also confined largely to the basal concavity. Because of obvious relations between *Lecanocrinus* (s.s.) and *Miracrinus* they are referred to the same subfamily.

As defined, the subfamily Lecanocrininae includes only the genus *Lecanocrinus* and the three subgenera, *Lecanocrinus* (s.s.), *Geroldicrinus* Jaekel, and *Miracrinus*, new subgenus.

#### Genus **LECANOCRINUS** Hall, 1852

A flexible crinoid and truncate bowl-shaped to conical cup which has 3 with IBB, rhombic RA lying obliquely below the left of the rpR and an anal X which is not followed by visible perisome. The IBB may be visible from the side or confined to the basal concavity. The crown is stout, rotund, and the arms may or may not be coiled at the distal ends. The arms may be free above the RR or suturally united for some distance above the cup. There are no iRR plates.

*Type species.*—*Lecanocrinus macropetalus* Hall, 1852.

*Range.*—Silurian and Devonian.

#### Subgenus **LECANOCRINUS** (*sensu stricto*) Hall, 1852

Lecanocrinids with the RA and X well developed, IBB erect and visible from the sides. The arms are free above the IBrr, are relatively long, not tightly coiled upon themselves at distal ends, and tend to dichotomize unequally.

*Type species.*—Same as for the genus *Lecanocrinus*.

*Range.*—Silurian.

#### Subgenus **GEROLDICRINUS** Jaekel, 1918

Lecanocrinids with the anal X well developed but RA much reduced by resorption, IBB subhorizontal and nearly confined to the

basal concavity. The arms are short, not coiled upon themselves at distal ends, and divide only twice isotomously.

*Type species.*—*Lecanocrinus* (*Geroldicrinus*) *roemeri* (Schultze).

*Range.*—Middle Devonian.

#### MIRACRINUS Bowsher, new subgenus

*Diagnosis.*—A lecanocrinid with a bowl-shaped cup, IBB hidden in basal concavity by the column, with the arms suturally united laterally

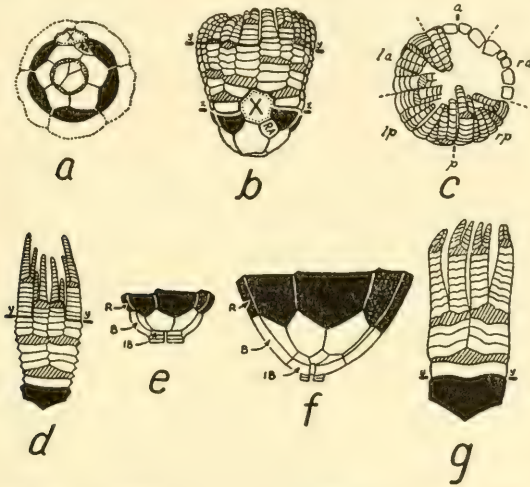


Fig. 1.—Diagrams showing the typical structures of *Lecanocrinus* (s.s.) and *Lecanocrinus* (*Miracrinus*) Bowsher, new subgenus.

*a*, Diagram of the cup of *Miracrinus* showing the IBB, BB, RR (solid black), RA, and anal X, X 1. *b*, Diagram showing the posterior interradius of the holotype of *Lecanocrinus* (*Miracrinus*) *perdevi*, the type species of the subgenus *Miracrinus* (U.S.N.M. No. 118033), X 1. *x* is at the level of the R-IBr suture, top of the cup, and *y* is at the top level of sutural union of the brachials of the posterior rays, X 1. *c*, Top view of *Lecanocrinus* (*Miracrinus*) *perdevi* showing the structure of the distal parts of the rays, X 1. *d*, Reconstruction of the left anterior ray of *Lecanocrinus* (*Miracrinus*) *perdevi*, X 1. *y* is at the top level of sutural union in the crown. *e*, Reconstruction of the dorsal cup of *Lecanocrinus* (*Miracrinus*) *perdevi* showing the IBB hidden in the basal cavity, X 1. *f*, Reconstruction of the dorsal cup of *Lecanocrinus* (*Lecanocrinus*) *macropetalus* Hall for comparison with that of *Miracrinus*, X 1. *g*, Reconstruction of the anterior ray of *Lecanocrinus* (*Lecanocrinus*) *macropetalus* (from specimens in Springer Collection, U.S.N.M. No. S1593) for comparison with that of *Miracrinus*, X 1. *y* marks the top of the cup and in general the upper level of sutural union of ossicles of the crown.

for nearly half their length, arms long, with considerably reduced IIIIBrr series in the inner part of each ray, and arms tightly coiled upon themselves at distal ends.

*Description.*—*Miracrinus* has a slightly flattened bowl-shaped cup which is about twice as wide as high (text fig. 1e). The plates of the

cup are massive. The IBB are hidden in a basal concavity into which the proximal columnal of the stem fits. The structure of the cup is typically lecanocrinid with a rhombic RA lying obliquely below the left of the rpR and a strong polygonal anal plate which extends for half its length above the level of the RR (text fig. 1b). The Brr of the arms are rigidly united within the ray and to those of adjacent rays to a level approximately twice the height of the dorsal cup (text fig. 1b). This in effect extends the level of the rigid cup to nearly half the length of the stout arms. Above this level the arms coil tightly upon themselves and the distal ends are hidden from view. The general pattern of the arms is lecanocrinid. The ambulacral tracts of this crinoid bifurcate three times giving eight terminal tracts to each ray. The ray

TABLE I.—Formula of the la ray of the type species of *Miracrinus*

$$\begin{array}{l}
 \left. \begin{array}{l} \text{I } 1 + 2 \dots \end{array} \right\} \begin{array}{l} \left. \begin{array}{l} \text{II } 1 - 3 + 4 \dots \end{array} \right\} \begin{array}{l} \text{III } 1 - 3, \bar{4} - \bar{10} + \bar{11} \dots \left\{ \begin{array}{l} \bar{\text{IV}} \bar{1} - \bar{12} + \bar{13} \\ \bar{\text{IV}} \bar{1} - \bar{6} + \bar{7} \end{array} \right. \\ \text{III } 1 - 5 + \bar{6} \dots \dots \dots \left\{ \begin{array}{l} \bar{\text{IV}} \bar{1} - \bar{7} + \bar{8} \\ \bar{\text{IV}} \bar{1} - \bar{10} + \bar{11} \end{array} \right. \\ \left. \begin{array}{l} \text{II } 1 - 3 + 4 \dots \end{array} \right\} \begin{array}{l} \text{III } 1 - 5 + \bar{6} \dots \dots \dots \left\{ \begin{array}{l} \bar{\text{IV}} \bar{1} - \bar{10} + \bar{11} \\ \bar{\text{IV}} \bar{1} - \bar{5} + \bar{6} \end{array} \right. \\ \text{III } 1 - 2, \bar{3} - \bar{9} + \bar{10} \dots \dots \dots \left\{ \begin{array}{l} \bar{\text{IV}} \bar{1} - \bar{7} + \bar{8} \\ \bar{\text{IV}} \bar{1} - \bar{12} + \bar{13} \end{array} \right. \end{array}
 \end{array}$$

This arm division is considered typical for *Miracrinus*. The posterior rays of the crown differ slightly from normal because of effect of the large anal plate. Bars over the numbers in the table indicate Brr of the free arms.

divides isotomously to the level of the IIAXx but dichotomies above this level are unequal. The anterior ray on the only known representative of the type species is incomplete, so the formula of the la ray is presented as typical of the genus (table I, text fig. 1d, and pl. 1, figs. 2 and 9). The inner arms of the rays are short, having only 6 IIIBrr, whereas the outer arms are much longer, having from 10 to 11 IIIBrr. The terminal arms are of unequal size. The inside arms of each half ray have fewer IVBrr, from 6 to 8, than the outside arms which have from 11 to 13 IVBrr. It is believed that the unequal dichotomies are a result of the tight coiling of the arms (text fig. 1c).

*Remarks.*—*Miracrinus* differs from *Lecanocrinus* (s.s.) in having the IBB confined to the basal concavity and rays suturally united part way up the arms. *Miracrinus* differs from *Geroldicrinus* in having a



truncate bowl-shaped cup, larger RA, arms suturally united to the level of the IIIAxx, unequal dichotomy of the arms and longer arms.

*Type species.*—*Lecanocrinus (Miracrinus) perdewi* Bowsher, new species.

*Occurrence.*—Lower Devonian of Maryland and New Jersey.

**LECANOCRINUS (MIRACRINUS) PERDEWI** Bowsher, new species

*Diagnosis.*—Truncate bowl-shaped dorsal cup of medium height, small subhorizontal IBB almost completely hidden in the basal concavity which is filled by the proximal columnal, moderately bulbous BB and RR, Brr of the ray rigidly united within the ray and to adjacent rays up to approximately the level of the IIIBrr<sub>3-4</sub> in the anterior rays and distal parts of the free arms sharply coiled upon themselves.

*Description.*—Parts of the last two proximal or part of the proximal columnal remains on the holotype and only known specimen. It is not possible to determine accurately the depth of the IBB concavity which is filled by these columnal fragments (text fig. 1e). The character of the columnal or columnals is not preserved: only crenulae are visible on the holotype (pl. 1, fig. 7.).

A portion of the small rp IB may be present just beneath the BB but silicification of the specimen does not permit accurate determination of sutures in this part of the cup. It is my opinion that the sutures between the BB disappear beneath the proximal columnal and that the 3 IBB are almost, if not completely, hidden in the basal concavity (pl. 1, figs. 3 and 7, and text fig. 1, a, b, and e). These same figures show the coarse silicification which has obliterated any trace of surface ornamentation.

Only the slightly bulbous nature of the BB and RR is of particular significance: the BB and RR are otherwise as in most lecanocrinids (pl. 1, figs. 2 and 9, and text fig. 1, b and e).

The position and character of the anal and RA is typical of most lecanocrinids. These plates of the posterior interradius are also slightly bulbous (pl. 1, figs. 1 and 8, and text fig. 1b). It is considered particularly significant in this species that the posterior rays are rigidly united laterally for some distance above the anal plate (pl. 1, figs. 1 and 8, and text fig. 1b): the most posterior arm of the lp ray becomes free above the IIIBr<sub>4</sub> and the adjacent arm of the rp ray becomes free above the IIIBr<sub>3</sub>. The rays are rigidly united to the level of the IIIBrr<sub>3-4</sub> in the anterior rays. The arms show greater regularity in the anterior rays than in the posterior ones because the

posterior rays are influenced by the huge anal plate. The upper level of close sutural union in the posterior rays is shown in text figure 1b and for the anterior rays in text figure 1d.

The pattern of the la ray is presented in table 1 because the anterior ray is incomplete and because of the obvious irregularities in the posterior rays. The arms of this species are massive, tend to be bulbous, and are long for a lecanocrinid. The Brr of the arms tend to be hemispherical in cross section.

The distal ends of the free arms of this species are tightly coiled upon themselves. The character of the distal ends of the free arms is shown in pl. 1, figures 4, 5, 6, 10, and 11, and text figure 1c.

The perisome is not preserved on the holotype.

The measurements of the type and only known specimen of *Miracrinus perdewi* are: width of the proximal columnal, 4.5 mm.; height of dorsal cup, at posterior side, 5.5 mm.; greatest width of the cup, at the level of the RR-IBr suture, 12 mm.; total height of the specimen, 19.1 mm.; and greatest diameter around the arms, at a level slightly above the middle of the arms, 16.4 mm.

*Remarks.*—Of known lecanocrinids, only *Lecanocrinus* (*Miracrinus*) *magniradialis* (Weller) (1903, p. 299) could be confused with *Lecanocrinus* (*Miracrinus*) *perdewi*. The latter is distinguished from *L. (M.) magniradialis* by having a more bowl-shaped cup, and more bulbous plates of the cup. *Lecanocrinus* (*M.*) *magniradialis* is known only from a poorly preserved cup which seems to be different from *M. perdewi*. The latter is readily distinguished from other lecanocrinids by its bowl-shaped cup (text fig. 1, e and f), long arms, unequal dichotomy of the arms, and the rigidly united arms which form a part of the cup.

*Occurrence.*—The holotype was found near the top of the limestone which is the lower part of the New Scotland formation of the Helderbergian stage (lower Devonian), Sensabaugh quarry, now operating, near the city dump, 1.2 miles N. 30° E. of the junction of Evitts Creek and the Potomac River, 2 miles east of Cumberland.

*Holotype.*—U.S.N.M. No. 118033.

#### RELATIONS OF MIRACRINUS TO OTHER LECANOCRINIDS

*Miracrinus* and *Geroldicrinus* Jaekel are the only lecanocrinids known from the Devonian. These two subgenera seem to be the result of divergent evolution from Silurian lecanocrinids. *Geroldicrinus* from the middle Devonian has only two, possibly three, dichotomies in each ray and the short, stout, slightly coiled arms divide isotomously.

The cup of *Geroldicrinus* is conical and the sutural union of the arms, if present, is confined to the level of the IBrr. It appears probable that the geroldicrinids were derived from Silurian lecanocrinids of the type represented by *Lecanocrinus* (*Lecanocrinus*) *meniscus*, whereas the miracrinids appear to have developed from lecanocrinids of the type represented by *Lecanocrinus* (*Lecanocrinus*) *macropetalus*. A reconstruction of the anterior ray and dorsal cup of *L. macropetalus*, based on specimens in the Springer Collection, U. S. National Museum, No. S1593, is presented in text figure 1, g and d, for comparison with those of *L. (M.) perdewi* presented in text figure 1, d and e.

This crinoid, *L. (M.) perdewi*, is a very important one. There can be no doubt about the relations of *L. (M.) perdewi* to *Lecanocrinus* (s. s.). However, *L. (M.) perdewi* has subhorizontal IBB hidden in the basal concavity (text fig. 1e). This is one of the important characters used by Springer (1920, pp. 117-119) in differentiating the ichthyocrinids from the sagenocrinids and lecanocrinids. The presence of this character of IBB in *M. perdewi* suggests that, although this change from erect to subhorizontal is in some groups a phyletic change which may correlate with classification, it may in some groups of crinoids be of generic or even of infrageneric significance. Thus, one cannot always say that crinoids with erect IBB are primitive and those with invaginated IBB are more advanced. Such criteria of the age of a group of crinoids must be applied with great care.

One of the most startling characters of this interesting crinoid is the way in which the Brr of the arms are rigidly united by close sutures nearly half the length of the arms. *Lecanocrinus* (s.s.) shows some tendency toward this sort of fixation of the IBrr. Ubaghs (1943) discussed a similar form of fixation in the genus *Mespilocrinus*, which is closely related to *Lecanocrinus*. The result seems to be an immobilization of the lower part of the rays and consequent extension of the cup to include a part of the arms of the crinoid.

#### GENERIC ASSIGNMENT OF DEVONIAN LECANOCRINIDS

Only four species of lecanocrinids are known from the Devonian. *Ichthyocrinus magniradialis* Weller (1903, p. 299) from the New Scotland limestone from Nearpass quarry, Delaware, N. J., is tentatively referred to *Miracrinus*, along with *L. (M.) perdewi*, because of the general shape of the cup, although the specimen is poorly preserved and lacks arms. Additional material may show that this species should be referred to *Geroldicrinus* instead. *Lecanocrinus soyei* Oehlert from the lower Devonian, Sable, France, appears to be congeneric with *G.*

*roemeri* (Schultze) and is tentatively referred to that genus. The Devonian species are: *Lecanocrinus* (*Geroldicrinus*) *roemeri* (Schultze), *Lecanocrinus* (?*Geroldicrinus*) *soyei* (Oehlert), *Lecanocrinus* (*Miracrinus*) *perdewi* Bowsher, and *Lecanocrinus* (?*Miracrinus*) *magniradialis* (Weller).

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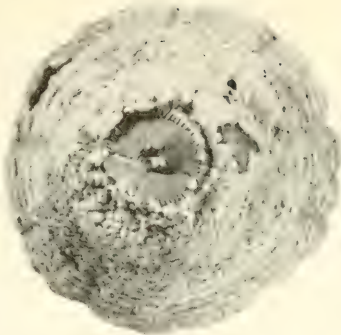
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## PLATE I

*Lecanocrinus* (*Miracrinus*) *perdewi* Bowsher, new subgenus and new species: Holotype. U.S.N.M. No. 118033, New Scotland formation, Cumberland, Md. 1. Posterior interradius,  $\times 1$ . 2. Left anterior ray,  $\times 1$ . 3. Basal view,  $\times 1$ . 4. Top view,  $\times 1$ . 5. Posterior interradius and right posterior ray,  $\times 1$ . 6. Oblique top view showing the coiled arms,  $\times 1$ . 7. Basal view,  $\times 3$ . 8. Posterior interradius,  $\times 3$ . 9. Left anterior ray showing structure of anterior rays,  $\times 3$ . 10. Anterior ray; distal parts of arms missing,  $\times 3$ . 11. Oblique, anterior, top view showing the tightly coiled arms,  $\times 3$ .



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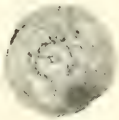
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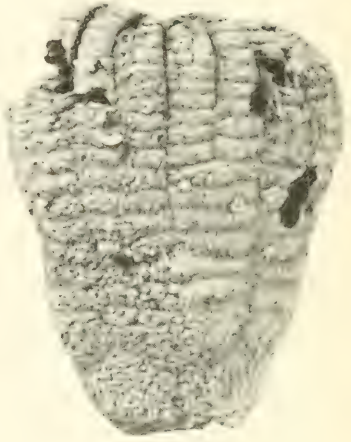
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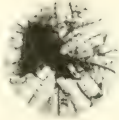
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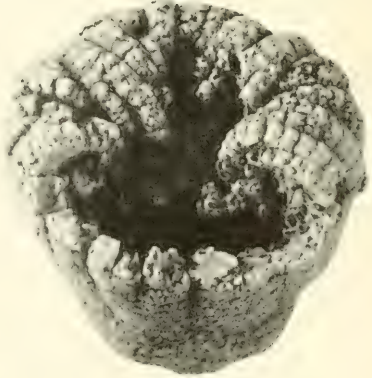
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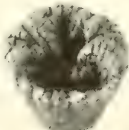
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6

A NEW DEVONIAN CRINOID FROM WESTERN MARYLAND  
(See opposite page for explanation.)









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Charles D. and Mary Vaux Walcott  
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THE TILLODONTIA: AN EARLY  
TERTIARY ORDER OF MAMMALS

(WITH 16 PLATES)

BY

C. LEWIS GAZIN

Curator, Division of Vertebrate Paleontology  
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BALTIMORE, MD., U. S. A.

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THE TILLODONTIA: AN EARLY TERTIARY  
ORDER OF MAMMALS

By C. LEWIS GAZIN

Curator, Division of Vertebrate Paleontology  
United States National Museum

(WITH 16 PLATES)

INTRODUCTION

The Tillodontia is an order of mammals comprising a relatively small number of forms, distinctive in character, obscure in origin, and of seemingly short duration in geologic time. The oldest of these known are Clark Fork or upper Paleocene in age, and no forms in the earlier stages of the Paleocene can be surely identified as ancestral. These creatures were relatively abundant, as represented in collections, but showed little diversity of form in the lower Eocene. By middle Eocene time they became tremendously larger and somewhat more diversified, but exceedingly rare. They apparently evolved very rapidly during lower and middle Eocene time and then became extinct in North America. It would seem, however, that representatives of the order persisted somewhat later in Asia.

As may be expected, the combination of characters distinctive of the order is not so emphasized in the lower Eocene and Paleocene *Esthonyx* as it is in the Bridger *Trogosus* and *Tillodon*. The principal characteristics include in part the enlarged rodentlike incisors in the upper and lower jaws and the basically arctocyonid or almost *Pantolambda*-like construction of the cheek teeth. The tillodont cheek teeth are further characterized by a peculiarly emphasized brachydont-hypsodont condition in which the buccal side of the lower teeth and the lingual side of the upper teeth have become arcuately columnar while their opposite portions remained decidedly cuspsate with prominent styles.

In addition to the suggested affinity with an arctocyonid-pantodont ancestry there are also points of resemblance to insectivores, condylarths, primates, and taeniodonts. All of which indicates derivation

from an early mammalian stock of rather generalized structure. Individually, the characters of *Esthonyx*, or potentialities of these characters, can be found in various Paleocene forms, but collectively no one form or group satisfactorily meets all the requirements. The diversification found in the Insectivora might appear to encompass the requirements and may well have given rise to the tillodonts. On the other hand, skeletal similarities, particularly in the feet, as well as in the teeth, lead me to favor a relationship, though remote in time, with the pantodonts, which in turn seem related (or at least show a resemblance) to some of the arctocyonid creodonts.

#### ACKNOWLEDGMENTS

Investigation of the tillodonts was originally undertaken as a part of a more general study of the middle Eocene mammalian fauna of the Bridger formation. Consideration of the antecedents of the Bridger tillodonts, however, indicated a need for review and revision of the lower Eocene representatives of the order as well. As a consequence the study was expanded to include all known forms of this obscure but compact order. Review of *Esthonyx* material was early planned by Dr. Walter Granger as a further contribution to the "Revision of the Lower Eocene Wasatch and Wind River Faunas," a series of researches carried on by Matthew and Granger but not quite completed. Of Granger's investigation of the tillodonts, however, little remains beyond notes and memoranda on specimen labels and on some of the drawings prepared for his study.

The present study is based on materials from the "Wasatch" of Wyoming and New Mexico, from the Huerfano of Colorado and from the Bridger of Wyoming in the collections of the U. S. National Museum and the American Museum of Natural History. The Clark Fork and lowermost Gray Bull materials are for the most part in the collections of the American Museum and Princeton University. The Bridger materials studied include, in addition, those of Yale University, the Academy of Natural Sciences of Philadelphia, and Walker Museum of the University of Chicago. The lower Eocene materials from the Plateau Valley "Wasatch" are in the collections of the Chicago Museum of Natural History.

I am indebted to Dr. George Gaylord Simpson for permitting me to study the tillodont materials in the American Museum, particularly the beautiful skull herein described as the new species *Trogosus grangeri*, and in turning over to me for use in this publication the many drawings of *Esthonyx* and *Trogosus* material which had been

prepared for Dr. Granger's studies. I am also indebted to Dr. Joseph T. Gregory and Dr. Carl O. Dunbar of Peabody Museum at Yale University for making available for this study the well-preserved skull which Marsh described as *Tillotherium fodiens*, and other Bridger tillodont types and referred specimens. Acknowledgment is due Dr. Charles M. B. Cadwalader, Dr. B. F. Howell, and Miss M. Dorothy Reed, of the Academy of Natural Sciences of Philadelphia, for arranging the loan of the important Leidy types. The Plateau Valley *Esthonyx* specimens in the Chicago Museum and a Bridger *Trogosus* specimen at Walker Museum were loaned through the courtesy of Bryan Patterson and E. C. Olson. The Clark Fork and Gray Bull specimens at Princeton University were made available by Dr. Glenn L. Jepsen. *Trogosus* material from the Eocene of British Columbia in the National Museum of Canada was sent to me for study by Dr. L. S. Russell.

All the wash drawings comprising the plates of this paper, and most of the text figures, were made by William D. Crockett, artist for the division of vertebrate paleontology in the U. S. National Museum. Text figures 2, 3, 5, 7, 9, 10, 11, and 34 were furnished me through the kindness of the American Museum of Natural History, most of which were prepared for Granger's study.

#### HISTORY OF INVESTIGATION

Since the era of Leidy, Cope, and Marsh, the tillodonts have been one of the most neglected groups of mammals. Except for Simpson's (1937) study of the Clark Fork materials, little has been added during the past 50 years to our knowledge of the peculiar forms comprising this order.

The early history of investigation concerning the discovery and description of various tillodont materials involved the independent studies of Leidy and Marsh of the middle Eocene or Bridger forms, and Cope's contributions to our understanding of the "Wasatch" fauna. Leidy's descriptions for the most part preceded those of Marsh and, remarkably enough, no contest for generic and specific names of tillodonts took place between Cope and Marsh, although later polemics developed regarding ordinal relations.

The first tillodont discovered was named *Anchippodus riparius* by Leidy (1868) from a lower cheek tooth (figs. 14 and 17 of this paper) found in Eocene deposits exposed along Shark River in Monmouth County, N. J. The specimen was collected by Dr. Knieskern and given to Conrad, who in turn presented it to the Academy of Natural Sci-

ences of Philadelphia. During the latter part of the summer of 1870, Marsh secured a tillodont lower tooth (fig. 18 of this paper) which he erroneously described as representing a new species of *Palaeosyops*. The specimen, named "*P.*" *minor*, was found in the Grizzly Buttes, not far from Fort Bridger. Marsh's description was published in the July 1871 issue of the American Journal of Science and Arts (p. 36), but his separates, with separate pagination and different type arrangement, bear the date June 21, 1871, with the signature in Marsh's handwriting. This date becomes important when it is realized that the species *Trogosus castoridens*, described by Leidy in the May 1871 Proceedings of the Academy of Natural Sciences, had an actual publication date of July 11 of that year. If Marsh's statement is to be relied on, "*P.*" *minor* is the earliest species name for Bridger tillodonts. The lower jaw of *Trogosus castoridens*, collected by Dr. J. Van A. Carter, was also found in Grizzly Buttes, about 11 miles from Fort Bridger. A little-worn lower incisor (fig. 13 of this paper), also found by Dr. Carter near Fort Bridger, was sent to Leidy in the summer of 1871, and was described in November of that year as *Trogosus vetulus*.

The true affinities of "*P.*" *minor* were not recognized until some time later when Leidy had occasion to see the tooth. His conclusions then of the relationship between "*P.*" *minor*, *Trogosus castoridens*, and *Anchippodus riparius* were brought out in a short note in 1872 (b).

It was not until 1873 that upper teeth of tillodonts were known. In June of that year Marsh (p. 485) described a fragmentary upper jaw portion (fig. 15 of this paper), not associated with lower teeth, to which he gave the name *Tillotherium hyracoides*. No precise locality data were given but a specimen label having the designation "*Tillotherium hyracoides* type" in Marsh's handwriting also carries the information "Grainger Station." The Bridger beds exposed around Granger are considered as Bridger "B," although upper Bridger is exposed in the higher cliff sections several miles to the south. Comparison between this material and earlier-described jaws could not be made, but Marsh noted the possibility of *Tillotherium's* being generically identical to *Anchippodus* (or *Trogosus*). In the spring of 1874 Marsh (p. 533) named a second species of *Tillotherium*, *T. latidens*, on a relatively large, isolated second upper molar (fig. 16 of this paper), which he misidentified as the last molar. The specimen is described as coming "from the same geologic horizon" as *T. hyracoides*, but this may have no greater significance than implying some part of the Bridger beds. Unfortunately, and as is well known, Marsh

was very cautious in giving out information about localities where his fossils were found.

The discovery of associated skull and lower jaw material (pls. 14-16 of this paper), together with other parts of the skeleton, was announced in 1875 (b) when Marsh published a brief description of *Tillotherium fodiens*. The specimen was described as coming from the "Dinoceras beds," which would place it in the upper part of the Bridger. However, several field labels associated with the skeletal fragments belonging to the skull, and identified by the same catalog number as the skull, carry the information "Millersville." This place, no longer designated on maps of the area, has been demonstrated from various independent sources to have been near the confluence of Smith's and Black's Forks, hence in Bridger "B." *Trogosus castoridens* and "*P.*" *minor* are from the lower Bridger exposed at Grizzly Buttes. The *T. fodiens* material was more fully described in 1876 but in all no statement appears as to its distinctness from the genotype, *T. hyracoides*, or from *T. latidens*. Moreover, no certain evidence can be gleaned from the literature as to the horizons of the Bridger the latter two may represent.

Cope's contributions to the literature on tillodonts began in 1874 with his descriptions of the new materials which he collected while with the Wheeler Survey in New Mexico. These include the types of *Esthonyx bisulcatus* (fig. 1 of this paper), *E. burmeisterii*, *E. acer*, and *E. miticulus* from the so-called "Wasatch" beds which Simpson has named the San Jose. The latter form, however, has since been shown to represent a different group of mammals. In 1880 he described *Esthonyx spatularius* (fig. 4 of this paper) as coming from the Wind River beds, and in 1881 described *Esthonyx acutidens* (fig. 6 of this paper) from the same formation, restating the description of *E. spatularius* as though it belonged to the same fauna. However, in 1884 (a) *E. spatularius* was attributed to the Big Horn Basin, and under the discussion of this form evidence is brought out in the present paper demonstrating a Gray Bull origin.

During the above history of discovery and later, it is interesting to follow the development of Cope's systematics, particularly as it applies to the tillodonts. He at first (1869, 1873) regarded the middle Eocene forms as perissodactyls, but at the time of his description of the New Mexican lower Eocene material (1874) it seems evident, though not clearly stated, that he regarded *Esthonyx*, as well as *Ectoganus*, as representing the Toxodontia, an opinion not long held. The following year (1875, p. 23), in further comments on the Eocene of New Mexico, he noted the resemblance between *Esthonyx* and *Pelycodus*

and considered the lower molars as not unlike those in *Ectoganus*, the latter being known then only from deciduous teeth. Cope (1876a) came to recognize Marsh's Tillodontia, as a suborder, Tillodonta, for the middle Eocene *Anchippodus*, but included in it the taeniodont *Ectoganus*. The history of Cope's investigations of the various tillodonts was closely tied to his study of the taeniodonts, which he considered as closely allied. His reasons for believing in this relationship were based on a misinterpretation of dental homologies. The evidence used in identifying the various teeth in these forms, including the caniniform teeth, was in turn derived from his observations on *Esthonyx*. Strangely enough, he never regarded *Esthonyx* as a tillodont, but placed it in the Insectivora because of its resemblance to the hedgehog, *Erinaceus*.

Cope's classification of these forms in 1876 (a, p. 447-448) was an arrangement which included the "Tillodonta" and Creodonta as suborders of the Insectivora, and in the same year (1876b) he proposed the Taeniodonta as an additional suborder for *Ectoganus* and *Calamodon*. However, upon later discoveries of Paleocene mammals, he placed *Conoryctes* and *Psittacotherium* in the Tillodontia. By 1877 the major elements of Cope's classification were more or less crystallized, and in his monograph on the New Mexico collections he proposed the order Bunotheria to include the suborders Creodonta, Mesodonta, Insectivora, Tillodonta, and Taeniodonta. The Tillodonta were characterized as before by scalpriform incisors, growing from persistent pulp, and distinguished from the Taeniodonta which were described as having incisors truncate. Cope also called attention to the similarity of the tillodont dentition to that of insectivores, but justified the separation on the basis of the incisors, a gap diminished by the genus *Esthonyx*. *Esthonyx* was retained in the Insectivora but later discovery of the forefoot of this form, demonstrating a separate scaphoid and lunar, caused Cope to regard the relationships to *Erinaceus* as more remote. Hence, in 1884 (b, p. 351), grouping *Esthonyx* with the leptictids, he placed it in the Creodonta. Separate family rank in the Creodonta, the Esthonychidae, however, was proposed in 1889 (b, p. 876).

Little more was added by Cope to our knowledge of the tillodonts and later references to members of this order were essentially reiterations and defenses of his arrangement and interpretation of the relationships of the various parts of the "Bunotheria." It may be further noted that Cope regarded the tillotheres (including *Psittacotherium*) as standing in ancestral relationship to the rodents, a conclusion un-

tenable with our present understanding of the morphology and chronology of the forms concerned.

Contemporary opinion, while largely dependent on Cope's original investigations, often disagreed with his conclusions in biological interpretation, and we find Osborn, Wortman, and others following Marsh in considering *Esthonyx* as tillodont in affinities. Wortman (1897) was the first to straighten out the confusion between the genera of tillodonts and taeniodonts, and although his conclusions with regard to edentate relationships of the taeniodonts are not in agreement with most later investigators, he laid the foundation for the orders as now recognized. His studies of these forms were published within a month of Cope's death, and in the same year (1897) Osborn described "*Tillotherium*" remains from Huerfano beds of Colorado, earlier reported by R. C. Hills.

Since Cope's death the literature of vertebrate paleontology shows a dearth of references to the tillodonts, with very few contributions to our knowledge of this order. References for the most part are citations in faunal lists or reiterations in textbooks of the descriptions and conclusions of the earlier investigations, although in several instances independent conclusions as to relationships were advanced. A. S. Woodward, for example, in his textbook on vertebrate paleontology (1898, p. 374) placed the tillodonts in the Rodentia. Weber (1904, p. 513, and 1928, p. 168) was not in agreement with such an arrangement and retained the order Tillodontia, and Gregory, in "The Orders of Mammals" (1910, p. 292), strongly supported Weber in criticism of such an implied relationship, enumerating and commenting on the many morphological criteria against suggested rodent affinities. In Zittel's textbook (1923, p. 450), Schlosser followed Cope's earlier thinking in retaining the tillodonts in the order Insectivora, as did Abel (1914, p. 52; 1919, p. 728) in his textbook treatment. Winge (1923, p. 133) went even further and included the taeniodonts there as well.

The first report involving original investigation of new materials, the results of later field explorations, in what might be termed a second era of paleontological exploration and researches was in the form of an abstract by Granger in 1918. In this he told briefly of the finding of a nearly perfect skull and jaws of a tillodont in the Huerfano beds of Colorado, description of which is a part of the present paper. Summarizing his unpublished study, he concluded that the form represented was near *Trogosus* and that the age of the uppermost Huerfano was slightly older than lower Bridger.

The principal contribution to our understanding of the previously known tillodont materials outside of North America is P. Teilhard de Chardin's (1922, vol. 11, p. 63) revision of esthonychid materials discovered in the lower Eocene of France. In his study of the fauna from d'Épernay he redescribed Lemoine's *Plesiesthonyx munieri* and referred it to *Esthonyx*. At the same time he recognized that *Platychoerops* (= *Miolophus*) is not to be distinguished from *Plesiadapis*, removing it from consideration with regard to *Esthonyx*, once a "bone of contention" between Cope and Lydekker.

The most recent tillodont studies include Russell's description in 1935 of the *Trogosus* tooth from Eocene beds of British Columbia, extending the known range of the middle Eocene forms, and Simpson's description of the Clark Fork specimens and analyses of the Paleocene and lower Eocene representatives of the order in 1937. The occurrence of *Esthonyx* in the Paleocene was first reported by Sinclair and Granger (1912) in beds below the Knight (Gray Bull) to the southwest of McCulloch Peak and on Big and Little Sand Coulee in the Big Horn Basin. Simpson's treatment of the Clark Fork material is the first systematic study of *Esthonyx* since Cope and includes, in addition to a description of the new species recognized in the Clark Fork (and Sand Coulee), a statistical analysis of the Gray Bull materials for comparative purposes. In addition to these studies, Young (1937, p. 434) has described the form *Adapidium* from the early Tertiary of Yuanchü, which he considered tentatively as a primate. It almost certainly represents a tillodont, close in size to *Esthonyx*, but exhibiting a dental pattern strikingly like *Trogosus*.

#### GEOGRAPHIC AND GEOLOGIC OCCURRENCE

Our knowledge of the geographic distribution of extinct forms of life is necessarily incomplete, obviously limited to a consideration of the distribution of fossil-bearing rocks of the proper age. It seems likely that *Esthonyx* was widely distributed in the Northern Hemisphere during lower Eocene time, as collections representative of the land faunas of that age in this country almost invariably include remains of *Esthonyx*, and in addition to its recognition in the lower Eocene of France, a closely related esthonychid, as noted above, seems present in the early Tertiary of China. In this country its occurrence is recorded in beds of Wasatchian age from Wyoming to New Mexico and in the late Paleocene of Wyoming. During middle Eocene time, however, distribution of tillodonts, so far as known, is limited to North America, with their remains occurring in New Jersey and British Columbia, as well as Wyoming and Colorado.



The recorded range of the tillodonts in geologic time is astonishingly brief, one of the shortest, for an order of mammals, but at the same time witnessing what appears to be one of the most rapidly evolving mammalian phyla. *Esthonyx* first appears in the Clark Fork or uppermost Paleocene, represented by at least three species and associated with a fauna of definitely lower Eocene affinities. These species appear to be carried over into the Sand Coulee beds at the base of the Eocene, but only one or two forms seem represented in the Gray Bull and in the San Jose of New Mexico. Ascending to the Wind River horizons, we find evidence of possibly two species in the Lysite, and probably only the large *E. acutidens* in the Lost Cabin member, which might conceivably have given rise to the middle Eocene forms.

It has long been held that *Trogosus* did not first appear until Bridger time; however, more recent evidence has come to light, from more than one source, demonstrating the presence of trogosine remains in the Cathedral Bluff tongue of later Wasatchian time, to the northwest of the Red Desert in Wyoming, and in typical exposure of this tongue to the south. Nevertheless, an appreciable interval of time is represented by the gap between Lost Cabin and lower Bridger stages, which may be partially filled by the upper beds of the Huerfano. The hiatus between fossiliferous zones of the Huerfano may not be so great. The Bridgerian horizon in the Huerfano, though relatively barren, has yielded a surprisingly large proportion of tillodont remains, including two of the four known skulls and a good number of isolated fragments. This stage appears from other faunal evidence to be slightly older than Bridger B, although tillodonts recognized are in all probability *Trogosus*, originally described from the lower Bridger. Tillodonts are exceedingly rare in the Bridger and it seems evident that their numbers were waning from a maximum in the Huerfano stage to about middle Bridger time, when it is presumed that they became extinct in North America. It seems likely from all evidence at hand, including the observations of several seasons in the Bridger, that tillodonts are limited to the lower horizons of the Bridger. Their most advanced stage, so far as known, is admirably exhibited by the skull and skeletal portions of the type of *Tillodon fodiens*.

#### ENVIRONMENT

The environmental conditions under which the tillodonts lived and thrived are among the best documented for any portion of geologic time. The associated faunas, except for the interval between Wind River and Bridger ages, have been the subject of numerous investi-

gations, and although addition, revision, and much more precise data will be forthcoming from future exploration and studies, the Wasatchian and Bridgerian faunas are comparatively well known. The tillodonts first appear slightly in advance of the majority of modern mammalian lines of descent, associated with late survivors of typical Paleocene groups. Almost all the Clark Fork genera are of archaic forms otherwise peculiar to the Eocene. During the second recorded stage of tillodonts, their association was with the first appearances and early development of forms belonging to *Perissodactyla* and *Artiodactyla*, and the early development of rodents. A variety of primates and insectivores was also present, but their recorded ancestry began much earlier. The lower Eocene was further characterized by a flourishing of such archaic groups as the creodonts, condylarths, and pantodonts.

With regard to the floristic and climatic environment of the tillodonts, we are permitted an unusually vivid picture by the remarkable mass of information that has been accumulated on the Green River formation. Although deposition of a significant part of the Green River lake beds took place during the interval of time between Wind River and Bridger proper, it is known that the lacustrine deposits interfingered with beds of Wind River age below (Gazin, 1952) and with Bridger above. In the work of Sears and Bradley (1924) and Bradley (1926) the nature of the relation between the lacustrine and older fluvial deposits is clearly demonstrated. A relatively important and extensive segment of Wasatchian material, the Cathedral Bluffs tongue, is included between the main body of Green River and the Tipton tongue below, in the marginal areas of the basin. Above, the transition to Bridger, as I have observed, is not abrupt, and tongues of Green River are not uncommon interfingering with the Bridger facies. Moreover, considering a section southeastward across the Bridger Basin, the lower members of the Bridger are replaced by Green River facies in this direction, so that eventually only upper Bridger is found to rest on Green River beds. This retreat of the lake was in the direction presumably of its outlet, around the east end of the Uinta Mountains.

From the above evidence, it is reasonable to assume that the environmental conditions brought to light by the paleontology, paleobotany, and limnology of the Green River beds are applicable to portions of the Knight and Bridger and to the intervening period which part of the Green River represents, and during which the tillodonts undoubtedly flourished.

For comprehensive and detailed studies of the Green River we are indebted to W. H. Bradley and R. W. Brown, of the U. S. Geological Survey. Revealing conclusions as to the climate and environment have resulted from Bradley's analysis of the varves, together with the microfauna and microflora, and studies of the shore phases of the formation. In Bradley's summary (1929, p. 87)—

A climate is postulated which was characterized by cool, moist winters and relatively long, warm summers. Presumably the temperature fluctuated rather widely from a mean annual temperature that was of the order of 65° F. The rainfall varied with the seasons and probably also fluctuated rather widely from a mean annual precipitation between 30 and 43 inches.

Bradley further concludes (p. 89)—

. . . that the mountain ranges and high divides that form the rim of the Gosiute drainage basin were probably somewhat higher with respect to the floor of the basin during Eocene time than at present. The floor of the basin, however, in common with the general level of that part of the continent, was probably less than 1000 feet above sea level.

R. W. Brown, in a study of the Green River flora (1929, p. 281) envisions—

. . . a broad, low-lying warm inland region, with shallow ponds, lakes, and marshes, fed by slow streams, which meandered through muddy and sandy swamps as they flowed out of the distant cooler foothills and surrounding mountains. In these waters or in the adjacent open marshes grew *Sparganium*, *Cyperus*, *Arundo*, *Juncus*, *Equisetum*, and no doubt *Potamogeton*, *Alisma*, and other plants whose remains have not yet been found or identified. On the sandy or muddy flats farther back grew palms, *Acrostichum*, *Aneimia*, *Ficus*, *Sophora*, and other Leguminosae, together with such lianes as *Dalbergia* and *Cucurbita*. These were succeeded gradually on drier ground by *Orcodaphne*, *Zizyphus*, *Planera*, *Ternstroemia*, *Maytenus*, *Cinnamomum*, *Lomatia*, *Banksia*, *Myrica*, *Cassia*, *Mimosites*, *Sapindus*, *Celastrus*, *Euonymus*, *Pimelca*, *Thouinia*, *Rhus*, *Taxodium* (if *Taxites* is interpreted as that), and such lianes as *Banisteria*, *Cissus*, and the fern *Lygodium*. Along the streams and adjacent meadows higher in the foothills flourished willows, poplars, *Aralia*, *Ilex*, Apocynaceae, *Clethra*, *Sambucus*, *Juglans*, *Hicoria*, *Liquidambar*, *Potentilla*, *Betula*, *Alsinites*, *Acer*, *Quercus*, *Fraxinus*, species of *Rhus*, *Ailanthus*, and the vine *Parthenocissus*. Oaks and maples finally gave way to forests of pine and spruce at higher altitudes.

Of such an environment as I have conjured up for the Green River flora there is perhaps no exact duplicate on the earth today, but the climatic conditions of the southeastern Gulf States plus those of parts of the Great Valley of California would, it seems to me, roughly approximate those of the Green River Lake area.

Studies by both Bradley and Brown have shown that climatic conditions during Green River time were highly variable, and that although the climate was essentially warm temperate, the amount of moisture varied widely, with repeated droughts, during which there were great fluctuations of the level of the lakes.

Eventually, during later Green River time, the fluviatile phase, encroaching from the north and west over the former lake bottoms, restricted the lake area, and finally, probably accompanying diastrophic change, Green River deposition ended and only Bridger facies persisted.

#### CLASSIFICATION

The order Tillodontia is retained to include the compact and closely related groups of animals ranging, so far as known, from *Esthonyx* to *Tillodon*. The ordinal usage here is not in the original sense, as defined by Marsh, which included the Stylinodontidae, but as revised by Wortman (1897), and recognized by Simpson (1945). Recognition of ordinal status for this very small group of genera seems entirely justified by the unique combination of characters exhibited by the contained elements; moreover, reference of these forms to any other order of mammals would promote more confusion than simplification.

The family names which have been proposed for the tillodonts are Anchippodontidae, Tillotheriidae, and Esthonychidae. However, it seems likely that but one family is represented, as maintained by Simpson (1945), although Hay (1930) went so far as to use all three names, and others have used Esthonychidae in combination with one or the other names for the middle Eocene genera. The earliest name proposed is Gill's Anchippodontidae and this also is based on the first named genus. Simpson suppressed Anchippodontidae as of doubtful validity in favor of Marsh's Tillotheriidae. Marsh, however, recognized the possibility of the names being synonymous. Actually, Tillotheriidae, on the basis of the present studies, cannot be defended, inasmuch as the genus "*Tillotherium*" is based on a genotype, *T. hyracoides*, which exhibits no characters generically separable from *Trogosus* (or for that matter *Anchippodus*). However, there is precedent for retaining a family name, not necessarily the oldest, which may be considered as more representative of the known forms. Cope's name Esthonychidae is selected as the remaining family name that can be regarded as stable.

The taxonomic situation that exists among the latter tillodonts is, as intimated above, unusually complex for so small a group of forms, not simplified by the relatively small amount of material involved. The few remarkably good specimens extant indicate that more than one genus should be recognized, but the original genotypes themselves are based on fragmentary materials which for the most part exhibit characters scarcely of generic value. *Anchippodus riparius*, the earliest name, was based on an isolated lower tooth from New Jersey. While

a careful examination of the specimen convinces me that the form represented is a tillodont and not to be confused with any other group of mammals, the material is not adequate to determine generic relations with Bridger material.

The earliest named genus based on a Bridger species is *Trogosus*. The genotype, *T. castoridens*, was described on an incomplete lower jaw which, fortunately, exhibits characters permitting comparisons on a generic level. The earliest named species, however, from the same horizon and locality, is "*Palaeosyops*" *minor*, which has for a type an isolated lower molar, but such comparisons as may be made are not sufficiently conclusive to identify the species with one, and only one, of two recognized Bridger forms of *Trogosus*.

Our understanding of the genus *Tillotherium* was derived almost entirely from Marsh's description of the magnificent skull he secured from the Bridger and named *Tillotherium fodiens*. At that time no reference was made to the genotype *Tillotherium hyracoides*, based on a fragmentary upper dentition, presumably from the lower Bridger. The latter specimen presents no information regarding the characteristics later attributed to *Tillotherium*, and its distinction from *Trogosus* cannot be upheld. Also, more complete material in the American Museum from the lower Bridger, but possibly from higher levels in Bridger "B" than *Trogosus castoridens*, so closely resembles the *T. hyracoides* type as to be surely conspecific. The information presented by this better material further supports reference of this species to *Trogosus*.

The tillodont genera and species recognized in this paper, and the horizons in which they are found, are presented below.

## ESTHONYCHIDAE

### ESTHONYCHINAE

#### *Esthonyx*

- E. grangeri* Simpson ..... Clark Fork and lower Gray Bull.  
*E. latidens* Simpson ..... Clark Fork and lower Gray Bull(?).  
*E. spatularius* Cope ..... Lower Gray Bull and Clark Fork.  
*E. bisulcatus* Cope ..... San Jose, Gray Bull, and Lysite.  
*E. acutidens* Cope ..... Lost Cabin, upper Knight, and Lysite.  
*E. munieri* (Lemoine) ..... d'Eprenay, France.

#### Incertae sedis

#### *Adapidium*

- A. huanghoense* Young ..... Yuanchü, China.

## TROGOSINAE

*Trogosus*

- T. hillsii*, new species.....Huerfano B.  
*T. grangeri*, new species.....Huerfano B.  
*T. castoridens* Leidy.....Bridger B.  
*T. hyracoides* (Marsh) .....Bridger B.  
*T. ? latidens* (Marsh).....Bridger B and Cathedral Bluff tongue.

*Tillodon*, new genus

- T. fodiens* (Marsh).....Bridger B.

*Anchippodus*

- A. riparius* Leidy.....Shark River, New Jersey.

## SYSTEMATIC REVISION OF THE TILLODONTIA

## Family ESTHONYCHIDAE Cope, 1883

Anchippodontidae Gill, 1872, is clearly the oldest tillodont family name and based on the first named genus. However, Esthonychidae is here used because it is based on the more-representative and better-known genus *Esthonyx* as permitted under both the Stricklandian and International Codes.

The characters for the family are essentially those distinguishing tillodonts from other orders of mammals. The dental formula for the known forms is  $I_{3-1}^2$ ,  $C_1^1$ ,  $P_3^3$ ,  $M_3^3$ . The second incisors above and below are progressively enlarged and may be rooted (*Esthonyx*) or have grown from persistent pulp (*Trogosus* and *Tillodon*). The third incisor above became progressively enlarged but remained rooted, whereas the first and third lower incisors became relatively reduced, as in *Trogosus* (although  $I_1$  would appear to have become rootless), or were lost, as evident in *Tillodon*. The canines are prominent, but overshadowed by the incisors in the more advanced genera. The premolars increase in complexity from second to fourth, the former being simple and single- or double-rooted, whereas the latter is nearly molari-form above and below.

The upper molars are characterized by a large protocone with a slightly lower but widely flaring hypoconal crest. Anterior cingulum moderate to absent. Buccal margin of upper molars may exhibit a wide shelflike cingulum. Particularly characteristic of the upper cheek teeth is the prominence of the parastyle and metastyle, although on  $M^2$  the metastyle is weak or absent. The lower molars and  $P_4$  show an elevated, U-shaped trigonid with a lingually placed paraconid. The

Stages	WYOMING			COLORADO		NEW MEXICO
	Big Horn Basin	Wind River Basin	Washakie, Bridger, and Fossil Basins	Plateau Valley	Huerfano Basin	San Juan Basin
Bridgerian . . . . .	Horizons Bridger "B"		<i>Tillodon fodiens</i>			
			<i>Trogosus? latidens</i> <i>T. hyracoides</i> <i>T. castoridens</i>			
	Huerfano "B"		<i>T. ? latidens</i> <i>E. sp.</i>		<i>Trogosus grangeri</i> <i>T. hillsi</i>	
Wasatchian . . . . .	Cathedral Bluff Tongue					
	Lost Cabin	<i>E. acutidens</i>	<i>E. cf. acutidens</i> (U. Knight)	<i>E. cf. acutidens</i>	<i>E. sp.</i> (Huerfano "A")	
	Lysite	<i>E. bisulcatus</i>	<i>E. cf. acutidens</i> (Knight)	<i>E. bisulcatus</i>		<i>E. bisulcatus</i> (San Jose)
	Gray Bull	<i>E. bisulcatus</i>				
Clarkforkian . . . . .	Sand Coulee	<i>E. grangeri</i> <i>E. bisulcatus</i> <i>E. spatularius</i>				
	Clark Fork	<i>E. grangeri</i> <i>E. latidens</i> <i>E. spatularius</i>				

talonid is basined, lower than the trigonid, except in advanced wear, and in the first two molars the occlusal area is nearly equal to or slightly larger than that of the trigonid. The talonid in  $P_4$  may be relatively small but in  $M_3$  it is elongate, nearly or quite bilobed, and exhibits a prominent hypoconulid. Particularly characteristic of lower molars of the tillodonts is the presence of a metastylid, a small cuspule about midway vertically on the posterior slope of the metaconid. Moreover, the enamel of the cheek teeth has a vertical distribution which is much greater on the buccal wall of the lower series and perhaps somewhat greater on the lingual wall of the upper series. Eruption of the lower cheek teeth appears to have been more rapid on the outer side so that the teeth may have actually rotated on an antero-posterior axis during wear, which has certainly taken place at a differential rate between the two sides. In advanced wear the small amount of enamel remaining may become about equal on the two sides of the tooth. There is less evidence for such a rotation in the upper dentition, although the most marked attrition took place in the talon area.

#### Subfamily ESTHONYCHINAE Zittel and Schlosser, 1911

The subfamily Esthonychinae includes tillodonts having relatively large, rooted second incisors above and below. In these teeth the enamel on the anterior surface is limited to an elongate crown portion. Moreover, the second premolars (first of the series) above and below are two-rooted. So far as known, the Esthonychinae includes only *Esthonyx*, and possibly *Adapidium*.

Recognition of subfamilies among so small a group of genera seems unnecessary, and in the present arrangement may not follow the best interpretation of the meaning of subfamilies, i. e., as phylogenetic lines within a family. There appears, nevertheless, to be some overlap or a partial parallel arrangement of the subfamilies in the Cathedral Bluff stage of Wind River time. The separation here proposed is based essentially on significant structural differences, thought by some to be of family rank, in which the middle Eocene forms representing more than one group are allied to one another in a way which distinguishes them from the characteristic lower Eocene and upper Paleocene genus. *Adapidium*, if this form is correctly regarded as a tillodont, may represent survival into post-Bridger time in Asia of an esthonychid, possibly an esthonychine, since free communication of faunas between the two continents does not appear to have taken place during the middle Eocene, in which case a parallel arrangement of subfamilies would be further emphasized.



Genus **ESTHONYX** Cope, 1874

*Synonym.*—*Plesiethystonyx* Lemoine, 1891.

*Type.*—*Esthonyx bisulcatus* Cope.

*Generic characters.*—In addition to the rooted character of the second incisors observed as characterizing the subfamily, these teeth are more nearly oval in cross section at the alveolar border. The canines of *Esthonyx* are observed to be relatively large and the anterior cheek teeth less reduced, with  $P_4$  having a better-developed talonid than in the Trogosinae. The upper molars have a shelflike external cingulum and a distinct cingulum on the anterior margin of the talon in  $P^4$  to  $M^3$ . Moreover, no evidence is seen for the cuspule or enamel flexure observed in the center of the median basin in the upper molars of *Trogosus*.

**ESTHONYX BISULCATUS** Cope, 1874

Text figures 1-3, 34

*Synonyms.*—*Esthonyx burmeisterii* Cope, 1874; *Esthonyx acer* Cope, 1874.

*Type.*—Left lower jaw with the three molars,  $P_3$ , and two associated incisors, U.S.N.M. No. 1103.

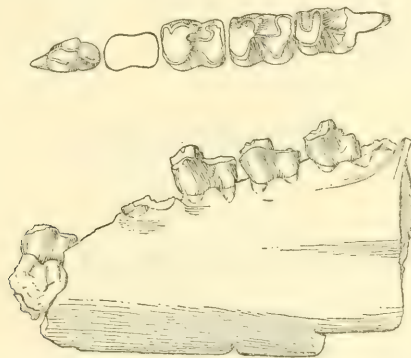


FIG. 1.—*Esthonyx bisulcatus* Cope: Left ramus of mandible (U.S.N.M. No. 1103), type specimen, occlusal and lateral views,  $\times 1$ . San Jose lower Eocene, New Mexico.

*Horizon and locality.*—“Wasatch” or San Jose of New Mexico, Eocene of the divide between Chama and San Juan Rivers.

*Specific characters.*—A species of comparatively small size, but showing much individual variation.  $P_2^2$  evidently two-rooted. Cusps of teeth moderately acute, with parastyle, metastyle, and external cingulum on upper molars and  $P^4$  prominent. Hypocone well developed.

*Discussion.*—The species *Esthonyx bisulcatus*, the genotype, is represented by a very considerable number of specimens, including material from the Wasatchian of the Big Horn Basin and from the Plateau Valley of Colorado, as well as the San Juan Basin in New Mexico. Its range in geologic time extends presumably through the

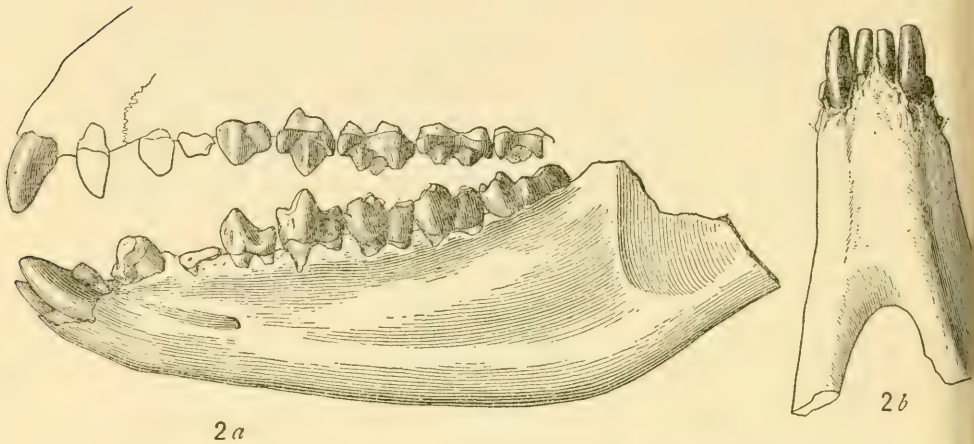


FIG. 2.—*Esthonyx bisulcatus* Cope: *a*, Left upper dentition ( $P^3$  drawn from right side) and lower jaw (drawing reversed from right side), lateral view; *b*, symphyseal portion of lower jaw, inferior view (A.M. No. 4275),  $\times 1$ . Gray Bull lower Eocene, Wyoming.

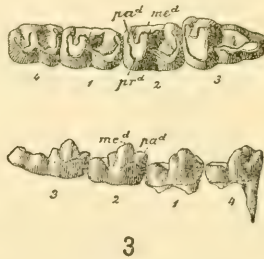


FIG. 3.—*Esthonyx bisulcatus* Cope: Lower dentition (A.M. No. 4276), occlusal and lingual views,  $\times 1$ . Gray Bull lower Eocene, Wyoming.

fossiliferous horizons of the Almagre and Largo of New Mexico, and from the Sand Coulee through the Gray Bull to the Lysite of Wyoming and the Lysite equivalent in Colorado.

The types of *Esthonyx burmeisterii* and *Esthonyx acer* from New Mexico, described by Cope (1874) along with *E. bisulcatus*, do not appear to be significantly different from *E. bisulcatus* and are retained in synonymy.

Simpson (1937, p. 6) has discussed the homogeneity of the Gray Bull collections and presented data showing that on the basis of size of teeth there would be no justification for recognizing more than one species in the material so allocated. The results from a larger sample, based on  $M_1$  as well as  $M_2$ , and including materials in both the U. S. National Museum and the American Museum are given below. Moreover, comparison is made with the limited sample known from the San Jose beds in New Mexico.

## GRAY BULL COLLECTIONS

	Number	Observed range	Mean	Standard deviation	Coefficient of variation
Length of $M_1$ .....	60	7.0-9.3	8.01 $\pm$ .06	.43 $\pm$ .04	5.3 $\pm$ 0.5
Length of $M_2$ .....	62	7.3-9.1	8.30 $\pm$ .05	.42 $\pm$ .04	5.1 $\pm$ 0.5

The frequency distribution in .3-mm. groups is as follows:

$M_1$	$M_2$
7.0-7.2: 2	7.3-7.5: 4
7.3-7.5: 6	7.6-7.8: 5
7.6-7.8: 14	7.9-8.1: 11
7.9-8.1: 16	8.2-8.4: 22
8.2-8.4: 15	8.5-8.7: 10
8.5-8.7: 4	8.8-9.0: 8
8.8-9.0: 1	9.1-9.3: 2
9.1-9.3: 2	

## SAN JOSE COLLECTIONS

	Number	Observed range	Mean	Standard deviation	Coefficient of variation
Length of $M_1$ .....	9	7.0-8.0	7.47 $\pm$ .11	.33 $\pm$ .08	4.5 $\pm$ 1.1
Length of $M_2$ .....	6	7.1-8.4	7.72 $\pm$ .17	.41 $\pm$ .12	5.4 $\pm$ 1.6

The frequency distribution in .3-mm. groups is as follows:

$M_1$	$M_2$
7.0-7.2: 3	7.1-7.3: 1
7.3-7.5: 3	7.4-7.6: 2
7.6-7.8: 1	7.7-7.9: 1
7.9-8.1: 2	8.0-8.2: 1
	8.3-8.5: 1

COMPARISON OF GRAY BULL AND SAN JOSE  $M_1$ 

	$N$	$M$	$\sigma_m$	$\sigma_m^2$
Gray Bull .....	60	8.01	.055	.003025
San Jose .....	9	7.47	.111	.012321

From these data the difference in means between the Gray Bull and San Jose first molars is .54 and the standard error,<sup>1</sup>  $\sigma_d$ , is .148, giving  $d/\sigma_d = 3.65$ .

COMPARISON OF GRAY BULL AND SAN JOSE  $M_2$ 

	$N$	$M$	$\sigma_m$	$\sigma_m^2$
Gray Bull .....	62	8.30	.053	.002809
San Jose .....	6	7.72	.169	.028561

The difference in mean above is .58 and the standard error is calculated to be 0.178, giving  $d/\sigma_d = 3.25$ .

In the calculations for both  $M_1$  and  $M_2$  it is seen that the difference in means is between three and four times the standard error. This would appear to be "significant." However, it should be noted that  $N$  instead of  $N-1$  was used in the calculations of the smaller as well as the larger sample. Interestingly enough the range of the larger Gray Bull sample includes the limits of the smaller San Jose sample, and one wonders if the difference in means would change much with a more satisfactory sample of San Jose material. The Gray Bull and San Jose materials may well represent different species, as suggested

MEASUREMENTS IN MILLIMETERS OF *Esthonyx bisulcatus* SPECIMENS

	U.S.N.M. No. 20113	A.M. No. 4275	A.M. No. 15111
Upper dentition:	Gray Bull	Gray Bull	Gray Bull
$I^2$ , greatest diameter at alveolus.....	6.3	7.0	...
$I^3$ , greatest diameter at alveolus.....	5.7	...	...
C, greatest diameter.....	6.3	...	...
$P^2$ , anteroposterior diameter.....	5.2	...	...
$P^2$ , transverse diameter.....	3.3	...	...
$P^3$ , anteroposterior diameter.....	...	8.7	7.8
$P^3$ , transverse diameter.....	...	7.4	7.5
$P^4$ , anteroposterior diameter, externally.....	...	7.7	7.5
$P^4$ , transverse diameter, anteriorly.....	...	10.0	10.0
$M^1$ , anteroposterior diameter, externally.....	7.8	8.0	8.2
$M^1$ , transverse diameter, anteriorly.....	...	11.8	11.4
$M^2$ , anteroposterior diameter, externally.....	8.5	8.7	8.4
$M^2$ , transverse diameter, anteriorly.....	...	13.8	12.3
$M^3$ , anteroposterior diameter, perpendicular to anterior face .....	6.5	7.5a	7.3
$M^3$ , transverse diameter, anteriorly.....	...	13.5a	12.3

<sup>1</sup> Calculated from the formula:

$$\sigma_d = \sqrt{\frac{N_1}{N_2} \sigma_{m_1}^2 + \frac{N_2}{N_1} \sigma_{m_2}^2}$$

(See Simpson and Roe: Quantitative Zoology, p. 192, 1939.)

	A.M. No. 16764	U.S.N.M. No. 30113	A.M. No. 4275
Lower dentition: <sup>2</sup>	San Jose	Gray Bull	Gray Bull
I <sub>1</sub> , greatest diameter at alveolus.....	3.5	...	3.5
I <sub>2</sub> , greatest diameter at alveolus.....	5.8	5.8	6.0
I <sub>3</sub> , greatest diameter of crown.....	...	...	2.4
C, greatest diameter at alveolus.....	5.6	5.2	6.0
P <sub>2</sub> , anteroposterior diameter.....	3.8	4.4	...
P <sub>2</sub> , transverse diameter.....	2.8	2.9	...

	U.S.N.M. No. 1103	U.S.N.M. No. 1104	A.M. No. 16764	A.M. No. 4275	A.M. No. 15111
	Type	Type of <i>E. acer</i>	Jose San	Gray Bull	Gray Bull
P <sub>3</sub> , anteroposterior diameter.....	6.8	...	5.5	6.8	6.9
P <sub>3</sub> , transverse diameter.....	4.3	...	3.8	4.5	4.2
P <sub>4</sub> , anteroposterior diameter.....	...	7.4	7.5	8.8	8.0
M <sub>3</sub> , anteroposterior diameter.....	8.0	7.7	7.2	8.4 <sub>a</sub>	8.3
M <sub>2</sub> , anteroposterior diameter.....	8.4	7.7	7.7	8.6	8.1
M <sub>3</sub> , anteroposterior diameter.....	11.0 <sub>a</sub>	10.6	9.6	11.5	10.0
M <sub>3</sub> , anteroposterior diameter.....	<sup>3</sup> 10.4				

*a*, approximate.

by the above comparison; however, I see no way as yet of distinguishing one from the other, except statistically, and as Simpson has intimated, the difference may be only racial. It is also noteworthy that the type of *Esthonyx bisulcatus* is the largest of the San Jose specimens that I have examined and is very near the mean for the Gray Bull sample.

#### ESTHONYX SPATULARIUS Cope, 1880

Text figures 4-5

*Type*.—Eight separate teeth, including M<sub>3</sub> and questionably associated incisors, canines, premolar, and a molar fragment, A.M. No. 4809.

*Horizon and locality*.—Gray Bull, presumably the lower part, in the Big Horn Basin, Wyo.

*Specific characters*.—Distinctly small. Trigonid of M<sub>3</sub> relatively short anteroposteriorly. Validity of species in doubt.

*Discussion*.—Although Simpson (1937) has shown by analysis that the specimen which is the type of *E. spatularius* falls within the size range for *E. bisulcatus*, near its lower limits, he has suggested that it

<sup>2</sup> Because of the peculiar form and eruption of tillodont lower molariform teeth, their transverse diameters cannot be given with any meaning.

<sup>3</sup> U.S.N.M. No. 1105, type of *Esthonyx burmeisterii*.

may represent a distinct species for which the type is not near its mean. In consideration of certain specimens which he mentioned as coming from Sand Coulee and Clark Fork horizons, and which seem to be distinct from *E. bisulcatus*, but cannot be logically distinguished from *E. spatularius*, we are faced with the following alternatives: allocating all to *E. bisulcatus*, which appears to be an unlikely arrangement; naming a new species on one of the geologically older and perhaps more typical specimens, with *E. spatularius* in synonymy with *E. bisulcatus*, though certainly within the size range of the new named form; or retaining *E. spatularius* as the name for these distinctly small individuals of *Esthonyx*, appreciating that the *E. spatularius* type may

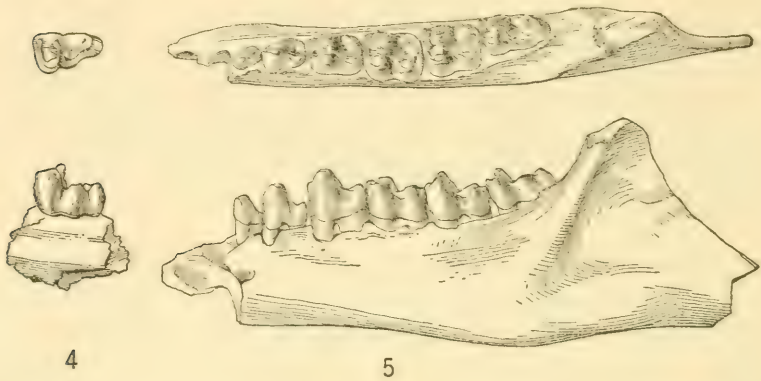


FIG. 4.—*Esthonyx spatularius* Cope: Portion of left ramus of mandible with  $M_3$  (A.M. No. 4809), type specimen, occlusal and lateral views,  $\times 1$ . Sand Coulee or lower Gray Bull lower Eocene, Wyoming.

FIG. 5.—*Esthonyx* cf. *spatularius* Cope: Left ramus of mandible (A.M. No. 16065), occlusal and lateral views,  $\times 1$ . Clark Fork upper Paleocene, Wyoming.

not be near the mean. As a tentative measure, until such time as a more adequate representation of Clark Fork and Sand Coulee populations are at hand to verify or indicate a more satisfactory conclusion, I propose to retain *E. spatularius*. Such a tentative solution has in its favor the evidence outlined below, demonstrating a Gray Bull, and a highly probable lower Gray Bull or Sand Coulee, origin for the *E. spatularius* type.

Further investigation of the probable locality from which Wortman obtained the type of *E. spatularius* has demonstrated beyond reasonable doubt that the specimen is not from the Wind River basin as Cope first announced. In the original description (1880, p. 908) Cope stated, "The following species have been received from Mr. Wortman from beds of the Wind River group subsequent to the publication of

my last notice of his discoveries." There follows his description of *Esthonyx spatularius*, *Didymictis leptomytus*, and *Hyoopsodus speirianus*. Subsequently, Matthew (1915, p. 314), in his discussion of *H. speirianus*, made the following observations, which because of their importance in fixing the *E. spatularius* locality are quoted:

The type (*Haplomytus speirianus*) was originally described with other fossils as from the Wind River basin, but in 1885 the locality was definitely stated as Bighorn Valley. In cataloguing the Cope Collection in 1896 I referred this discrepancy to the collector, Dr. Wortman, who informed me that although most of his collections of 1880 came from the Wind River Valley and of 1881 from the Bighorn Basin, he did obtain a few specimens in 1880 from the Bighorn which were at first wrongly supposed by Professor Cope to have come from the Wind River Valley, the error being subsequently corrected. I cite these circumstances, because later collecting indicates that this genus is wholly limited to the lower part of the Wasatch, and is a valuable horizon-indicator (leitfossil). This is equally true of *Didymictis leptomytus*, described in the same notice as *H. speirianus*, as from the Wind River.

Matthew did not mention the first of the three species, *E. spatularius*, described in the same notice, and what appears to be a lapsus calami in Cope's "Tertiary Vertebrata," in which *E. spatularius* is cited as coming from the "Basin of the Big Horn River," is the emendation referred to by Wortman (in Matthew). This was applied in the "Tertiary Vertebrata" to each of the three forms included in the 1880 notice cited above. Cope also included the correct information on his specimen label for *E. spatularius*, although Matthew does not appear to have followed up on this with regard to his new specimen label after his discussion with Wortman.

Speculating from here, it seems probable that Wortman obtained the three specimens from about the same locality and horizon, inasmuch as a collector of Wortman's experience would, in these beds, have obtained much more material had he at that time extended his examination over any appreciable area. Two of the species Matthew has shown are lower Gray Bull, and such an assignment for *E. spatularius* is entirely compatible, and can be maintained by much the same evidence.

Among the specimens tentatively embraced by the name *E. spatularius* are the lower jaw (fig. 5 of this paper), A.M. No. 16065, from the Clark Fork beds, which Simpson figured as *Esthonyx ?bisulcatus* (1937, fig. 1); three Sand Coulee specimens, including A.M. Nos. 16144 and 16873; and a few fragmentary, unnumbered Gray Bull specimens in the collections of the American Museum. There is, moreover, a single, decidedly small specimen in the U.S.N.M. New Mexico collections, No. 17156, consisting of a jaw fragment with  $M_3$

which has the same dimensions as the type of *E. spatularius*. Its dimensions are approximately 18 to 20 percent less than for the *E. bisulcatus* type, whereas the types of the invalid species *E. acer* and *E. burmeisterii* are roughly 4 percent and 8 to 10 percent smaller, respectively. However, the small size of No. 17156 is even less significant in the New Mexico collections than the proportions of the type of *E. spatularius* are in the Gray Bull population, inasmuch as mean for the New Mexico material is somewhat lower.

The Clark Fork specimen included in the above tentative assignment, and to a certain extent the type, exhibit an almost intangible condition, more distinctive in the large *E. grangeri* from the same beds, i. e., a somewhat inflated or more circular appearance of the cusps than in Gray Bull materials, a condition, of course, not reflected in the statistical analyses of tooth lengths. This probably represents a more primitive condition of *Esthonyx*, indicating a more bunodont, less crescentic tooth pattern in the ancestry. Possibly further collecting will demonstrate that the Clark Fork specimen represents a distinctive species. It should be noted, however, that the third molars in A.M. No. 16065 and the type of *E. spatularius* are much more alike than the drawings (figs. 4 and 5, made by different artists) would seem to indicate.

MEASUREMENTS IN MILLIMETERS OF *Esthonyx spatularius* SPECIMENS

	A.M. No. 4809	A.M. No. 16065 Clark Fork
$P_2$ , anteroposterior diameter.....		4.2
$P_2$ , transverse diameter.....		2.5
$P_3$ , anteroposterior diameter.....	5.3	6.0
$P_3$ , transverse diameter.....	3.7	4.1
$P_4$ , anteroposterior diameter.....		7.4 <sup>a</sup>
$M_1$ , anteroposterior diameter.....		7.8
$M_2$ , anteroposterior diameter.....		7.8
$M_3$ , anteroposterior diameter.....	8.8	9.4

a, approximate.

ESTHONYX ACUTIDENS Cope, 1881

Text figures 6-8

*Type*.—Left  $M_2$  and  $M_3$ , A.M. No. 4807.

*Horizon and locality*.—Wind River formation, Wind River Basin, Wyo.

*Specific characters*.—Size distinctly larger than *E. bisulcatus*. Rostrum more elongate and upper incisors relatively larger;  $P^2$  and (in



some specimens)  $P_2$  single-rooted, and  $P_4$  more molariform. Parastyle on  $P^1$ - $M^3$  and metastyle on  $P^3$ - $M^2$  well developed, with cingulum extending outward and forward from the metastyle widely flaring. Cingulum on anterior surface of talon reduced. Upper molars transversely broad. Lower molars elongate, and bases relatively broad as compared to width at occlusal surface. Talonid of  $M_3$  comparatively elongate.

*Discussion.*—The type (fig. 6) and referred upper dentition (A.M. No. 4808, fig. 7 of this paper) of *E. acutidens* described by Cope do not have accurate locality data other than Wind River Basin. It seems likely, however, that these are from the Lost Cabin horizon. Sinclair and Granger (1911, p. 104), in naming the Lost Cabin beds, noted that the *Lambdotherium* zone had previously been synonymous with Wind

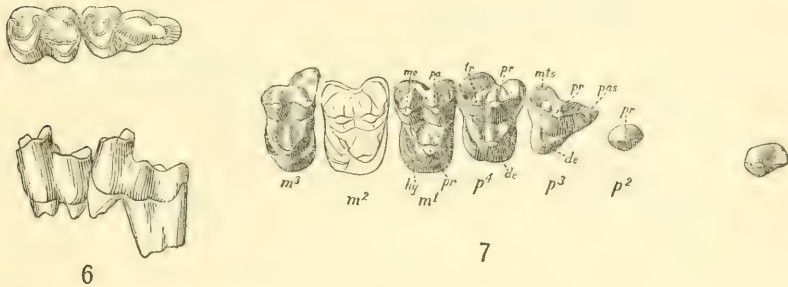


FIG. 6.—*Esthonyx acutidens* Cope: Left  $M_2$  and  $M_3$  (A.M. No. 4807), type specimen, occlusal and lateral views,  $\times 1$ . Lost Cabin lower Eocene, Wyoming.

FIG. 7.—*Esthonyx acutidens* Cope: Right upper dentition (A.M. No. 4808), occlusal view,  $\times 1$ . Lost Cabin lower Eocene, Wyoming.

River. However this may be, only *E. acutidens* has been certainly recorded from the Lost Cabin beds, and material known from Lysite localities may include both *E. bisulcatus* and *E. acutidens*.

Among the more significant specimens of *E. acutidens*, in addition to the two collected by Wortman and originally described by Cope, are the greater part of a lower dentition, A.M. No. 14738, collected by George Olson on Alkali Creek (Lost Cabin); skull fragments and part of the upper dentition which have been incorporated into a generalized skull restoration, together with some vertebrae and limb portions, A.M. No. 14735, collected by Walter Granger on Alkali Creek; and a rostral portion of a large skull (fig. 8) including representation of all the upper teeth except the third upper incisor (or canine?), U.S.N.M. No. 18202, collected by Harry Tourtelot, of the U. S. Geological Survey, in beds identified by him as Lost Cabin in age. *Esthonyx* material collected by Patterson from the Plateau Valley beds in Colorado in-

cludes a lower jaw portion with a single molar from the Lost Cabin equivalent and two lower molars from beds intermediate to the Lysite and Lost Cabin equivalents which correspond rather closely to the type of *E. acutidens*.

The specimen of *Esthonyx acutidens* collected by Tourtelot in the Wind River Basin was discovered in about section 12 of T. 39 N., R. 94 W., not far from, and a little lower than, material of *Eotitanops*. According to Tourtelot,<sup>4</sup> the Lost Cabin beds here are nearly horizontal and the Lysite is not exposed, having gone underground about 15 or 20 miles to the east. This specimen of *E. acutidens* is distinctly large for the species and decidedly advanced among Wasatchian esthony-

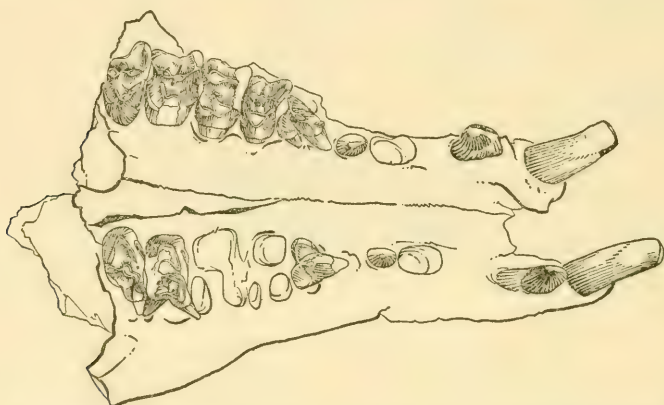


FIG. 8.—*Esthonyx acutidens* Cope: Rostral portion of skull (U.S.N.M. No. 18202), ventral view,  $\times \frac{2}{3}$ . Lost Cabin lower Eocene, Wyoming. (The loose teeth drawn in the position of  $I^2$  may be canines.)

chids. It is the only Wind River specimen so far found exhibiting the anterior portion of the rostrum.

The rostral portion, as exhibited by U.S.N.M. No. 18202, is distinctly enlarged anteriorly, approaching in appearance the equivalent portion of a skull of *Trogosus hyracoides*. The anterior incisors are robust, but rooted, with the enamel limited to the crown portion.  $I^2$  has a nearly triangular cross section with the posterior surface of the tooth much worn so that no enamel remains. Also, the anterior surface of the tooth is slightly beveled by attrition so that a small patch of enamel has been removed adjacent to the cutting edge.

The alveoli for  $I^3$  and canines are both large and of about the same diameter. A marked diastema is present between these teeth, but following the canine the diminutive, single-rooted second premolar and

<sup>4</sup> Personal communication.

remaining cheek teeth are in close sequence. The cheek teeth in U.S.N.M. No. 18202 are appreciably larger than in the American Museum specimens Nos. 4808 and 14735, but probably not beyond the range of the species.

A pair of loose teeth associated with the Lost Cabin rostrum, U.S.N.M. No. 18202, are uncertainly identified as the canines, but may possibly be the third or posterior upper incisors as depicted in figure 8. These are large but vertically short-crowned, with very robust and decidedly curved root portions. Wear has taken place only along the anterior slope of the crest and on the apex. The crowns of these teeth resemble in form a canine belonging to A.M. No. 4808 of *E. acutidens*, but are distinctly larger—larger even than the canine of *Trogosus hyracoides* (U.S.N.M. No. 17886). The third upper incisor in A.M. No. 4808, like *E. bisulcatus*, is long-crowned, not sharply curved, and has the enamel distributed well down the outer side, lower than in the questioned teeth of the Tourtelot specimen. Also in A.M. No. 4808, as in *E. bisulcatus*, both the posterior and anterolingual margins of the crown portion of the tooth are characterized by a relatively sharp longitudinal rib, between which, on the posterolingual wall of the tooth, the enamel recedes toward the apex of the tooth. The characteristics of  $I^3$  in A.M. No. 4808 strongly suggest that the isolated teeth in U.S.N.M. No. 18202 are canines. On the other hand, the latter strikingly resemble much larger, loose teeth interpreted as third incisors of *Tillodon*, and to some extent  $I^3$  in *Trogosus hyracoides*, although here  $I^3$  appears more hypsodont.

MEASUREMENTS IN MILLIMETERS OF *Esthonyx acutidens* SPECIMENS

Upper dentition:	U.S.N.M.	A.M.	A.M.
	No. 18202	No. 4808	No. 14735
$I^3$ , greatest diameter, at alveolus.....	9.5	...	...
C, greatest diameter.....	8.4	...	...
$P^2$ , anteroposterior diameter.....	5.8	5.5	...
$P^2$ , transverse diameter.....	3.6	3.6	...
$P^3$ , anteroposterior diameter.....	9.5	9.8	8.5
$P^3$ , transverse diameter.....	9.5	8.8	7.9
$P^4$ , anteroposterior diameter, externally.....	9.0a	8.8	9.4
$P^4$ , transverse diameter, anteriorly.....	13.7	11.4	11.3
$M^1$ , anteroposterior diameter, externally.....	10.0a	8.6	8.6
$M^1$ , transverse diameter, anteriorly.....	14.0a	13.5a	12.5
$M^2$ , anteroposterior diameter, externally.....	11.0a	...	9.2
$M^2$ , transverse diameter, anteriorly.....	17.0a	...	14.5
$M^3$ , anteroposterior diameter, perpendicular to anterior face .....	8.5	...	...
$M^3$ , transverse diameter, anteriorly.....	16.2	...	...

Lower dentition:	A.M. No. 4807	A.M. No. 14738
P <sub>3</sub> , anteroposterior diameter.....	...	6.7
P <sub>3</sub> , transverse diameter.....	...	4.2
P <sub>4</sub> , anteroposterior diameter.....	...	8.8
M <sub>1</sub> , anteroposterior diameter.....	...	8.9
M <sub>2</sub> , anteroposterior diameter.....	9.4	9.3
M <sub>3</sub> , anteroposterior diameter.....	13.0	12.3

*a*, approximate.

**ESTHONYX GRANGERI** Simpson, 1937

Text figures 9, 10

*Type*.—Left lower jaw with P<sub>4</sub>-M<sub>3</sub>, A.M. No. 16067.

*Horizon and locality*.—Clark Fork or Sand Coulee, at head of Big Sand Coulee, Clark's Fork Basin, Wyo.

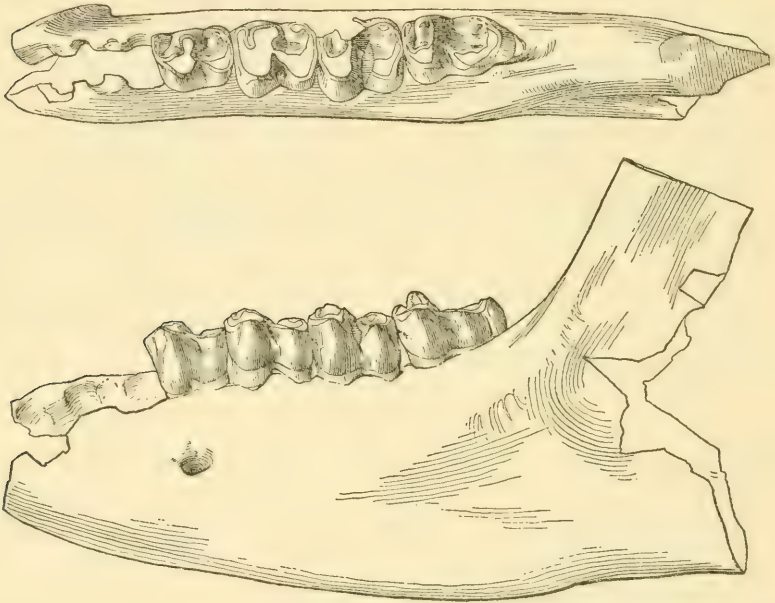


FIG. 9.—*Esthonyx grangeri* Simpson: Left ramus of mandible (A.M. No. 16067), type specimen, occlusal and lateral views,  $\times 1$ . Clark Fork upper Paleocene or Sand Coulee lower Eocene, Wyoming. (After Simpson, 1937.)

*Specific characters*.—Significantly larger than *Esthonyx bisulcatus*, but approached in size by individuals of *E. acutidens* and *E. latidens*. Characterized in part by inflated appearance of tooth cusps, and by the less striking development of styles and cingula of the upper cheek teeth. P<sup>1</sup> shows an advanced degree of separation of the metacone (or tritocone), but with hypocone (or tetartocone) undeveloped. Molarization of P<sub>4</sub> well advanced.

*Discussion.*—This particularly large species of *Esthonyx* is known only from the Clark Fork and Sand Coulee horizons, unless it is represented by a Princeton Gray Bull specimen (No. 14727, see fig. 21), and so far as we know, did not give rise to any of the later species. The diversification of species in these, the earliest horizons for known tillodonts, approaches that in the Bridger, whereas in most of Watschian time a single or possibly two species were known to be extant in any one horizon.

*E. grangeri*, though large, exhibits structural characters which may be regarded as primitive, and not evident in *E. bisulcatus*. Although the extent to which the premolars have become molarized is comparable (except for the lack of development of the hypocone in P<sup>4</sup>), the



FIG. 10.—*Esthonyx grangeri* Simpson: Left maxilla (A.M. No. 16123), occlusal view,  $\times 1$ . Clark Fork upper Paleocene. (After Simpson, 1937.)

more inflated or bunodont appearance of the cusps, together with the less flaring development of the styles and cingula on the outer walls of the upper teeth, suggest a less advanced condition than in *E. bisulcatus*. This is indicated in the lower dentition by the lack of development of the metastylid, the less marked hypsodonty of the outer lobes, as well as by the cusp inflation, the latter effecting somewhat shallower, distinctly less concave basins. These characteristics may be shared in certain respects by *E. latidens*, and by the Clark Fork specimen referred to *E. spatularius*.

#### MEASUREMENTS IN MILLIMETERS OF *Esthonyx grangeri* SPECIMENS

Upper dentition:	A.M. No. 16123
P <sup>3</sup> , anteroposterior diameter.....	10.5a
P <sup>4</sup> , anteroposterior diameter.....	10.4a
P <sup>4</sup> , transverse diameter.....	13.5a
M <sup>3</sup> , anteroposterior diameter, perpendicular to anterior face.....	9.3
M <sup>3</sup> , transverse diameter, anteriorly.....	16.7a

	A.M. No. 16067	A.M. No. 15858
Lower dentition:	Type	
I <sub>2</sub> , greatest transverse diameter.....		10.0
P <sub>3</sub> , anteroposterior diameter.....		8.8
P <sub>3</sub> , transverse diameter across talonid.....		7.2
P <sub>4</sub> , anteroposterior diameter.....	10.7	11.4
M <sub>1</sub> , anteroposterior diameter.....	11.0	11.0
M <sub>2</sub> , anteroposterior diameter.....	11.0	...
M <sub>3</sub> , anteroposterior diameter.....	15.1	13.6

*a*, approximate.

### ESTHONYX LATIDENS Simpson, 1937

#### Text figure 11

*Type*.—Left maxilla with Dp<sup>3</sup>-M<sup>1</sup>, right maxilla with Dp<sup>4</sup>, left ramus with Dp<sub>3</sub>-M<sub>1</sub>, also upper incisors in premaxillary portions of both sides, A.M. No. 16066.



FIG. 11.—*Esthonyx latidens* Simpson: Left maxilla with I<sup>2</sup>, I<sup>3</sup>, Dp<sup>3</sup>, Dp<sup>4</sup> and M<sup>1</sup>; and left ramus of mandible with I<sub>2</sub>, Dp<sub>3</sub>, Dp<sub>4</sub>, and M<sub>1</sub> (A.M. No. 16066); type specimen, occlusal views,  $\times 1$ . Clark Fork upper Paleocene, Wyoming. (After Simpson, 1937.)

*Horizon and locality*.—Clark Fork beds, 3 miles east of Pat O'Hara Creek, Clark's Fork Basin, Wyo.

*Specific characters*.—Intermediate in size between *E. grangeri* and *E. bisulcatus*. Characterized principally by the low width-to-length ratio of M<sup>1</sup>.

*Discussion*.—Little can be added to Simpson's definition of *E. latidens*. Only the first upper molar of the permanent dentition is preserved in the type, the remaining two teeth representing the deciduous series. Dp<sup>3</sup> can scarcely be distinguished from a Dp<sup>3</sup> in *E. bisulcatus* (A.M. No. 15113) and the Dp<sup>4</sup>'s are similar, although in the *E. bi-*

*sulcatus* specimen the hypocone base has an almost periptychid appearance.  $M_1$  of *E. latidens* is markedly narrow, transversely, as compared to its anteroposterior length. The cusps are stout and the hypocone and external cingulum are both relatively strong, but not so flaring as is characteristic of *E. bisulcatus*. The external cingulum, moreover, is continuous around the paracone and metacone, joining the protoconule and metaconule rather more noticeably than in *E. bisulcatus*, with a less prominent union of the parastyle and metastyle crests with their associated primary cusps. The talonid and its basin in the lower molar of the type of *E. latidens* could scarcely be distinguished from that in an unworn  $M_1$  of *E. bisulcatus*, but in the trigonid the cusps are emphasized at the expense of a well-formed crest.

MEASUREMENTS IN MILLIMETERS OF TYPE SPECIMEN OF *Esthonyx latidens*,  
A.M. NO. 16066

Upper dentition:

$Dp^3$ , anteroposterior diameter.....	8.5
$Dp^3$ , transverse diameter.....	7.3
$Dp^4$ , anteroposterior diameter, externally.....	10.5a
$Dp^4$ , transverse diameter, posteriorly.....	10.7a
$M^1$ , anteroposterior diameter, externally.....	10.6
$M^1$ , transverse diameter.....	12.6

Lower dentition:

$Dp_3$ , anteroposterior diameter.....	7.2
$Dp_3$ , transverse diameter.....	4.5
$Dp_1$ , anteroposterior diameter.....	10.8
$M_1$ , anteroposterior diameter.....	10.4

a, approximate.

**ESTHONYX MUNIERI (Lemoine), 1889**

*Type*.—Right  $M_3$ , Lemoine collection in Museum of Paris.

*Horizon and locality*.—Sparnacian or Cuisian (Agéien), lower Eocene in the vicinity of d'Epernay, France.

*Specific characters*.—Size of  $M_3$  close to that of *Esthonyx bisulcatus*, but described as having a lower or secondary parastylid. No mention is made of a metastylid, but a slight development of this cusp seems evident in Teilhard de Chardin's illustration (1922, pl. 3, fig. 19a). The occlusal view (1922, pl. 3, fig. 19) also shows a relatively brief third lobe for this tooth.

*Description*.—The third lower molar, selected as the type, is one of the two teeth which Teilhard de Chardin retained in the species *E. (Plesiesthonyx) munieri* from out of the four described by Lemoine. The two upper teeth in Lemoine's collection he referred to

*Phenacodus*. The other lower tooth, a  $P_4$ , was regarded as perhaps showing a relationship to *Esthonyx*.

Teilhard's description of the two lower teeth follows:

$M_2$  (long. = 10) très caractéristique: trigone bien plus haut que le talon; paraconide très distinct, mais fortement rapproché du métaconide, et relié au protoconide par une crête qui forme, à l'angle antéro-externe du trigone, un coude prononcé (caractère de Chiromyidé); parastylide fort, ayant au-dessous de lui un deuxième parastylide secondaire; talon creux; troisième lobe simple, bien marqué, et légèrement retroussé postérieurement.

$P_4$  fortement molarisée: paraconide transverse et tranchant; métaconide peu détaché du protoconide; talon circulaire, creux, à bords coupants; émail plissé sur la face extérieure du trigone. La forme générale de la dent rappelle, en un peu plus court,  $P_4$  de *Phenacodus*.

The rugosity of the outer wall of trigonid of  $P_4$  seems unusual, and may be exaggerated in Lemoine's figures (1891, pl. 10, figs. 32s and 32i).

The upper molar, formerly included with material of *Propachynolophus gaudreyi*, which Teilhard referred tentatively to *Esthonyx munieri*, appears to be incomplete externally, or did not have the characteristic external styles and shelflike cingulum. Moreover, the anterior cingular crest, or "ectocone" seems relatively better developed and more nearly comparable to the hypoconal ridge than observed in "Wasatch" *Esthonyx*.

#### Subfamily uncertain

#### Genus ADAPIDIUM Young, 1937

*Type*.—*Adapidium huanghoense* Young.

*Generic characters*.—Not distinguished by Young from those of the species, but lowness of paraconid and distinctly lingual junction of hypoconid crest with trigonid may be significant.

#### ADAPIDIUM HUANGHOENSE Young, 1937

*Type*.—Portion of right ramus of mandible with  $M_2$  and  $M_3$ , Y. Y. Lee's collection, Cenozoic Research Laboratory, Geological Survey of China.

*Horizon and locality*.—Upper Eocene? Basin in the Yuanchü-Mienchih border along the Huangho, China. (Locality F. 12 of Lee.)

*Specific characters*.—Species of large size compared with those of *Esthonyx*, considerably smaller than forms of *Trogosus*. Length of lower molars equivalent to those in *E. grangeri*, but more hypsodont and slender, and lower jaw shallower.

*Discussion*.—It is an interesting fact that those characters to which Young (1937) has called attention in distinguishing *Adapidium* from



*Adapis* are indicative of the Tillodontia. In size the form does not differ greatly from *Esthonyx grangeri*, but the tooth pattern is more suggestive of *Trogosus*. The external hypsodonty of the lower teeth as compared with the more brachydont appearance of the lingual wall is characteristic of all the tillodonts, but becomes increasingly distinctive in the later forms. The same may be said of the degree to which the selenodont pattern is developed. The position at which the talonid crest joins the trigonid in *Adapidium*, that is, between the metaconid and metastylid, is distinctly like *Trogosus*. In *Esthonyx* this junction is at a more median position on the posterior wall of the trigonid. An interesting condition described in *Adapidium* is the union by a transverse crest of the hypoconid and entoconid across the talonid of  $M_3$ , more completely defining a third lobe carrying the hypoconulid. This development has been observed in a more advanced stage, in which the transverse crest divides the basin, in various relatively unworn third lower molars of *Trogosus* from the Huerfano B horizon, and with a tendency in this direction in certain, though not all, Bridger last lower molars. In *Esthonyx* the talonid may be constricted immediately anterior to the hypoconulid, but the hypoconulid is less distinctly set off and in no case does the basin appear divided. The lingual profile of  $M_3$  shown by Young (1937, fig. 16) is strikingly like that seen in certain Huerfano B specimens.

There is no information on the extent to which the incisors of *Adapidium* may have been developed, hence its subfamily reference cannot be made. Its occurrence in deposits believed to be younger than Bridger suggests survival of a stage of development approximately equivalent to that intermediate between Lost Cabin and Huerfano B, or to represent independent and parallel development in Asia from an earlier Eocene stage when Wasatchian forms are known to have migrated more freely between the eastern and western hemispheres, and *Esthonyx* is known to have been present in the Sparnacian or Cuisian of France.

#### TROGOSINAE, new subfamily

The subfamily Trogosinae is proposed for the tillodonts having enlarged, rootless second incisors above and below. In these forms the enamel on the anterior face of the second incisors is not limited to the crown portion and these teeth grow from persistent pulp. Moreover, the second premolars (first of the series) above and below are single-rooted. As presently arranged, the Trogosinae includes the middle Eocene forms *Trogosus*, *Tillodon*, and presumably *Anchipodus*.

Genus ANCHIPPODUS<sup>5</sup> Leidy, 1868

*Type*.—*Anchippodus riparius* Leidy.

*Generic characters*.—Not determinable from the known material representing the genotype.

## ANCHIPPODUS RIPARIUS Leidy, 1868

Text figures 14, 17

*Type*.—Left lower molar, presumably M<sub>2</sub>, A.N.S. No. 10338.

*Horizon and locality*.—Middle (?) Eocene, Shark River, Monmouth County, N. J.

*Specific characters*.—Large tillodont with lower molars equaling in size those of *T. fodiens* from the Bridger formation.

*Description*.—The type and only known specimen representing this, the first described tillodont, is an isolated lower molar believed to be M<sub>2</sub>. It is clearly tillodont, beyond reasonable doubt, exhibiting the characteristics of a tillodont lower molar. The tooth is moderately well worn but preserves the metastylid. The trigonid is elevated with respect to the talonid and both exhibit the nearly equal U-shaped occlusal surfaces, slightly compressed buccally in the stage of wear presented. The enamel is distributed well down the outer surface of the tooth to a point well below the maximum width of the strongly convex columns. Lingually, the enamel is limited downward to a level immediately below the opening to the talonid basin, a condition duplicated in Bridger tillodont teeth.

*Discussion*.—Geographically, the Shark River and the Bridger formations are widely separated, and outside of the tillodont evidence little information is available on the relative stratigraphic position of the two deposits. Moreover, more than one genus of Bridger tillodonts is recognized, and these are currently distinguished by characters not clearly provided by the material of *Anchippodus riparius*, so that for taxonomic purposes we are compelled to disregard this form, at least until such time as diagnostic material is forthcoming from the New Jersey deposits.

MEASUREMENTS IN MILLIMETERS OF TYPE SPECIMEN OF *Anchippodus riparius*,  
A.N.S. NO. 10338

Lower molar, anteroposterior diameter.....	20.9
Lower molar, greatest width of trigonid perpendicular to lingual wall.....	17.10
Lower molar, greatest width of talonid perpendicular to lingual wall.....	15.10
<i>a</i> , approximate.	

<sup>5</sup> In this, and certain taxonomic headings to follow, names which must be disregarded will not appear in boldface type.

Genus **TROGOSUS** Leidy, 1871

*Synonym.*—*Tillotherium* Marsh, 1873.

*Type.*—*Trogosus castoridens* Leidy.

*Generic characters.*—Skull relatively short or of moderate length. Lachrymal foramen located midway on orbital rim. Rostrum short among tillodonts, with canine set off by slight or no diastemata, to somewhat longer with diastemata of moderate length. Molar teeth above with high acute cusps and relatively open external folds. Greatest width of cheek teeth in  $M^3$ .  $I_1$  and  $I_3$  present. Lower teeth anterior to  $P_3$  closely spaced or crowded with a short or no diastema between  $P_2$  and  $P_3$ . Lower molars high-crowned with external columns distinctly convex in a transverse vertical plane, but dorsally not so sharply convergent with the inner wall as in *Tillodon*.

**TROGOSUS MINOR** (Marsh), 1871

Text figure 18

*Type.*—Right lower molar,  $M_2$ , Y.P.M. No. 11083.

*Horizon and locality.*—Bridger B, Grizzly Buttes, Bridger Basin, Uinta County, Wyo.

*Specific characters.*—Moderate-sized tillodont, otherwise indeterminate.

*Discussion.*—This is the earliest specific name applied to Bridger tillodont material, first referred by Marsh to *Palaeosyops*. Leidy (1872b) recognized its true relationships and regarded his *T. castoridens* as a synonym under *Anchippodus minor*. The material, however, is inadequate as the species cannot be defined. No one of the species of *Trogosus* can be exclusively restricted to it as the specimen can be matched in material of *Trogosus hyracoides* as well as in *Trogosus castoridens*. In consequence, the name *T. minor* must necessarily be disregarded, unless it can be demonstrated that *T. hyracoides* and *T. castoridens* are dimorphs of the same species, possibly male and female, or simply variants, in which case *Trogosus minor* as the earliest name might be defended as valid.

MEASUREMENTS IN MILLIMETERS OF TYPE SPECIMEN OF *Trogosus minor*,  
Y.P.M. NO. 11083

Lower molar, anteroposterior diameter.....	21.0
Lower molar, transverse diameter of trigonid perpendicular to inner wall..	17.0a
Lower molar, transverse diameter of talonid perpendicular to inner wall..	16.0a
a, approximate.	

**TROGOSUS CASTORIDENS** Leidy, 1871

Text figure 12

*Type*.—The anterior portion of the right and left rami of the mandible, including the large incisors,  $M_2$ , a part of  $M_1$ , and the root or alveolar representations of other teeth, A.N.S., Philadelphia, No. 10337.

*Horizon and locality*.—Bridger B, Grizzly Buttes, Bridger Basin, Uinta County, Wyo.

*Specific characters*.—Small among middle Eocene tillodonts with a relatively short skull indicated. Anterior extremity of lower jaw noticeably shallow. Cheek teeth of moderate size and those anterior to  $P_4$  in the lower jaw decidedly crowded.

*Discussion*.—The jaw which Leidy described as the type of *Trogosus castoridens* is evidently from a relatively small and short-faced form. The masseteric fossa extends forward beneath  $M_3$  and the posterior portion of this tooth is actually embedded in the base of the anterior face of the ascending ramus. Alveoli are present for  $I_1$  and for C,  $P_2$  and  $P_3$ , and the latter three teeth may have been of relatively small size. Alveoli for  $I_3$  are not preserved, and indeed this tooth may have been crowded out; however, both rami of the mandible are here broken down to a depth perhaps below that for the root of  $I_3$ .

MEASUREMENTS IN MILLIMETERS OF TYPE SPECIMEN OF *Trogosus castoridens*,  
A.N.S. NO. 10337

Length of symphysis.....	70.5
Depth of jaw, internally below point between $M_2$ and $M_3$ .....	46.0
Thickness of jaw beneath $M_2$ .....	21.5
Posterior margin of alveolus for $I_2$ to anterior margin of alveolus for $P_3$ , estimated .....	19.0
Length of tooth series $P_4$ to $M_3$ , inclusive, at alveolar border.....	79.5
Length of molars, $M_1$ to $M_3$ , inclusive, at alveoli.....	65.5
$I_2$ , anteroposterior diameter of exposed portion.....	13.0
$M_1$ , anteroposterior diameter at occlusal surface.....	20.0
$M_2$ , transverse diameter of trigonid perpendicular to inner wall.....	17.5 $a$
$M_2$ , transverse diameter of talonid perpendicular to inner wall.....	15.5 $a$

$a$ , approximate.

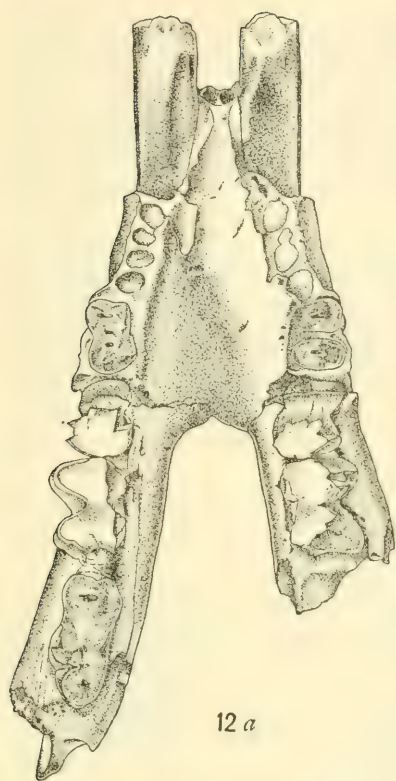
**TROGOSUS? VETULUS** Leidy, 1871

Text figure 13

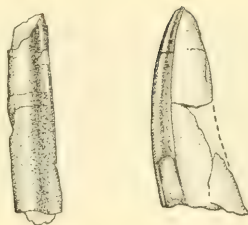
*Type*.—The erupted portion of a right lower  $I_2$ , possibly deciduous, A.N.S., Philadelphia, No. 10336.

*Horizon and locality*.—Bridger B, vicinity of Fort Bridger, Bridger Basin, Uinta County, Wyo.

*Specific characters*.—Described by Leidy as being a species of smaller size than *T. castoridens*.



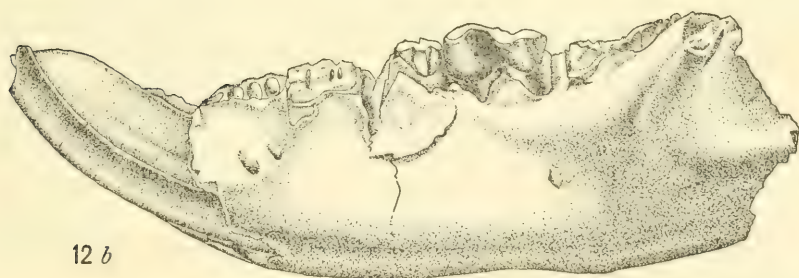
12 a



13



14



12 b

FIG. 12.—*Trogosus castoridens* Leidy: Portions of both rami of mandible (A.N.S. No. 10337), type specimen; *a*, occlusal view; *b*, lateral view of left ramus;  $\times \frac{2}{3}$ . Bridger (B) middle Eocene, Wyoming.

FIG. 13.—*Trogosus? vetulus* Leidy: Portion of  $I_2$  (A.N.S. No. 10336), type specimen, anterior and medial views,  $\times \frac{2}{3}$ . Bridger (B) middle Eocene, Wyoming.

FIG. 14.—*Anchippodus riparius* Leidy: Left  $M_2?$  (A.N.S. No. 10338), type specimen, occlusal and lateral views,  $\times \frac{2}{3}$ . Shark River Eocene, New Jersey.

*Discussion.*—The diameter of the incisor in Bridger tillodonts changes noticeably with increased age and wear. The type of *T. ? vetulus* is presumed to represent a youthful individual with the incisors but little worn, or perhaps of the deciduous series. Except for size, which is a function of age, no characters are exhibited which would distinguish it from *T. castoridens*, or any of the other Bridger tillodonts.

#### TROGOSUS HYRACOIDES (Marsh), 1873

Plates 1-4; text figures 15, 30, 31(part), 32, 33, 37(part), and 38e and g

*Type.*—Right maxillary and premaxillary portions, including  $M^1$  to  $M^3$ , parts of  $I^2$  and  $P^4$ , and incomplete alveolar representations of  $I^2$  to  $P^3$  (?); Y.P.M. No. 11084.

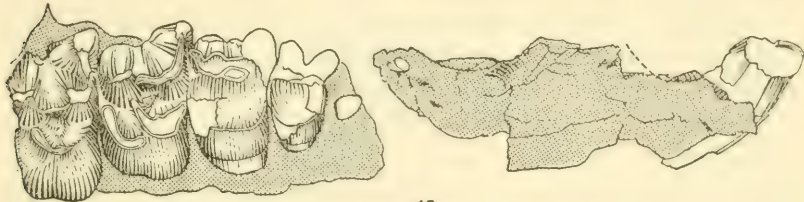
*Horizon and locality.*—Bridger B, "Grainger Station," Bridger Basin, Sweetwater County, Wyo.

*Specific characters.*—A tillodont of larger size and with a relatively longer rostrum than in *Trogosus castoridens*. Upper teeth between  $I^3$  and  $P^3$  well spaced.  $I_1$  very long and slender, but possibly rooted, with enamel on anterior surface as in  $I_2$ . Molar teeth comparable in size to those in *T. castoridens*. Talonid basin of  $M_3$  open between second and third lobes, with little or no division, and hypoconulid closely joined with entoconid.

*Discussion.*—In addition to fragmentary material in the Marsh collection, constituting the type, there is a specimen in the collections of the American Museum, No. 18982, having upper molars so nearly like those in the type that they must surely represent the same species. The American Museum specimen consists of an incomplete rostral portion of a skull and lower jaws, together with limb fragments including the greater part of a forefoot, and was collected by Olsen in 1922 along Middle Cottonwood Creek in about the middle of horizon "B." Although the preserved teeth in this specimen retain their natural shape and something of their relative positions in the jaws, the bony portions have much disintegrated, and except for a small portion of the right premaxilla, little can be ascertained as to the character of the specimen between  $I^2_{\frac{2}{2}}$  and the molars. However, it is interesting to note that the first lower incisors are preserved in place between the large second incisors.

A skull and lower jaws (pls. 1-4), exhibiting a beautifully preserved dentition, together with a radius (fig. 30) and a complete forefoot (figs. 32, 33), in the collection of the U. S. National Museum, No. 17886, are also referred to *Trogosus hyracoides*. The specimen was found by G. F. Sternberg while with the 1947 Smithsonian Insti-

tution expedition, in the Bridger "B" horizon near the top of a westward-facing escarpment about a mile and a half due south of Church Buttes. The skull belonging to this individual is moderately large and comparatively slender, with the rostrum elongate and the anterior teeth above well spaced, while those below are uncrowded. However, the



15



16



17



18



FIG. 15.—*Trogosus hyracoides* (Marsh): Portions of right maxilla and premaxilla with I<sup>2</sup> and P<sup>1</sup> to M<sup>2</sup>, incl. (Y.P.M. No. 11084), type specimen, occlusal view,  $\times \frac{3}{2}$ . Bridger middle Eocene, Wyoming.

FIG. 16.—*Trogosus? latidens* (Marsh): Right M<sup>2</sup> (Y.P.M. No. 11085), type specimen, occlusal view,  $\times \frac{3}{2}$ . Bridger middle Eocene, Wyoming.

FIG. 17.—*Anchippodus riparius* Leidy: Left M<sub>2</sub>? (A.N.S. No. 10338), type specimen, occlusal and lateral views,  $\times \frac{3}{2}$ . Shark River Eocene, New Jersey.

FIG. 18.—*Trogosus minor* (Marsh): Right M<sub>2</sub>? (Y.P.M. No. 11083), type specimen, occlusal and lateral views,  $\times \frac{3}{2}$ . Bridger (B) middle Eocene, Wyoming.

upper molars are slightly smaller than in the type or than in A.M. No. 18982. The lower jaw is longer and deeper, and the anterior teeth much less crowded than in Leidy's type of *Trogosus castoridens*.

*Trogosus hyracoides* was described by Marsh as the type of the genus *Tillotherium*. The characterization was made on the basis of an upper dentition, and at that time comparison with Leidy's *Trogosus castoridens* was not feasible, inasmuch as upper and lower tillodont

teeth had not been found associated. Nevertheless, Marsh suspected their generic identity, as noted in his discussions, but later (1875b, p. 241), in naming the skull and jaws of *T. fodiens*, he called attention to differences from the *Trogosus castoridens* jaw. These differences served to distinguish *T. fodiens* but not the genotype, *T. hyracoides*, which was subsequently ignored. Careful examination of the type of *T. hyracoides*, aided by associated skull and jaw material described above, has failed to reveal differences between *T. hyracoides* and *T. castoridens* of more than species value.

It is suspected, however, as has been mentioned under discussion of the type of *T. minor*, that the differences between *T. hyracoides* and *T. castoridens* may be dimorphic and not taxonomic. The possibility of such an interpretation was brought to mind by the parallel differences between these two Bridger species and the two Huerfano types. The differences amount to the recognition of a long-faced and a short-faced form in both horizons. As to whether such a difference might logically be attributed to a dimorphic state is debatable, and with scarcely more than one truly diagnostic specimen representing each of the forms involved the possibility lacks the force of demonstration, and indeed may be impossible to demonstrate, so that the differences are here retained as taxonomic.

MEASUREMENTS IN MILLIMETERS OF *Trogosus hyracoides* SPECIMENS

Skull:	U.S.N.M. No. 17886
Length from anterior margin of premaxillae to posterior surface of postglenoid process .....	272.0
Distance from posterior margin of alveolus for I <sup>2</sup> to posterior surface of postglenoid process.....	253.0
Distance from posterior margin of alveolus for I <sup>2</sup> to posterior margin of palate at narial aperture.....	137.0
Distance from posterior margin of alveolus for I <sub>2</sub> to anterior margin of orbit at lachrymal foramen.....	97.0
Distance between lachrymal foramen and posterior surface of postglenoid process .....	157.0
Length of nasals.....	122.0
Greatest width of rostrum above canines.....	58.7
Width across postorbital processes.....	79.0
Width of palate between second molars.....	36.0a
Depth of rostrum posterior to canine.....	53.0a



Upper dentition:	Y.P.M.	A.M.	U.S.N.M.
	No. 11084	No. 18982	No. 17886
	Type		
Length of upper dentition I <sup>2</sup> -M <sup>3</sup> , incl.....	...	...	163.0
Distance between I <sup>2</sup> and P <sup>2</sup> at alveoli.....	59.5 <i>a</i>	...	50.0
Length of P <sup>3</sup> to M <sup>3</sup> , incl.....	...	...	83.1R to 85.6L
Length of molars, externally.....	60.0 <i>a</i>	63.0 <i>a</i>	56.1R to 57.6L
I <sup>2</sup> , greatest diameter at alveolus.....	...	20.0	20.0
I <sup>3</sup> , greatest diameter at alveolus.....	...	...	12.0
C, anteroposterior diameter of crown.....	...	...	8.0
C, transverse diameter.....	...	...	5.5
P <sup>2</sup> , anteroposterior diameter.....	...	...	7.3
P <sup>2</sup> , transverse diameter.....	...	...	4.9
P <sup>3</sup> , anteroposterior diameter, externally....	...	...	16.6
P <sup>3</sup> , transverse diameter perpendicular to buccal surface .....	...	...	15.8
P <sup>4</sup> , anteroposterior diameter, externally....	...	...	15.1
P <sup>4</sup> , transverse diameter, anteriorly.....	...	...	22.5
M <sup>1</sup> , anteroposterior diameter, externally... ..	...	18.0 <i>a</i>	16.8
M <sup>1</sup> , transverse diameter, anteriorly.....	...	...	23.5
M <sup>2</sup> , anteroposterior diameter, externally... ..	23.0	23.0	21.3
M <sup>2</sup> , transverse diameter, anteriorly.....	35.0	33.5	29.7
M <sup>3</sup> , anteroposterior diameter, perpendicular to anterior face.....	21.5	20.0	20.3
M <sup>3</sup> , transverse diameter, anteriorly.....	38.0 <i>a</i>	36.0	35.5R to 33.5L

## Lower jaw:

Length from posterior margin of alveolus for I <sub>2</sub> to posterior surface of condyle..	...	...	21.7 <i>a</i>
Length from posterior margin of alveolus for I <sub>2</sub> to posterior margin of angle....	...	...	21.6 <i>a</i>
Length of symphysis.....	...	...	75.0 <i>a</i>
Depth of jaw internally beneath point be- tween M <sub>2</sub> and M <sub>3</sub> .....	...	...	55.0 <i>a</i>
Distance between top of coronoid process and bottom of angle.....	...	...	136.0
Thickness of jaw beneath M <sub>2</sub> .....	...	...	23.5

## Lower dentition:

Cutting edge of I <sub>2</sub> to posterior margin of M <sub>3</sub> .....	...	148.0
Posterior margin of alveolus of I <sub>2</sub> to anterior margin of alveolus for P <sub>3</sub> .....	...	27.3
P <sub>3</sub> to M <sub>3</sub> , inclusive.....	...	92.0 <i>a</i>
M <sub>1</sub> to M <sub>3</sub> , inclusive.....	...	66.6 <i>a</i>

	A.M. No. 18982	U.S.N.M. No. 17886
I <sub>2</sub> , greatest diameter at alveolus.....	20.0 <sup>a</sup>	20.0
I <sub>3</sub> , greatest diameter of crown.....	...	4.5
C, anteroposterior diameter of crown.....	...	7.1
C, transverse diameter.....	...	5.6
P <sub>3</sub> , anteroposterior diameter.....	...	11.5
P <sub>3</sub> , transverse diameter across talonid.....	...	8.5
P <sub>4</sub> , anteroposterior diameter.....	15.8	15.6
M <sub>1</sub> , anteroposterior diameter at occlusal surface....	17.2 <sup>a</sup>	16.8
M <sub>2</sub> , anteroposterior diameter at occlusal surface....	21.0	18.7
M <sub>3</sub> , anteroposterior diameter.....	33.0 <sup>a</sup>	28.2

## Limb and foot material:

Greatest length of radius.....	...	152.0
Greatest diameter of proximal extremity of radius..	...	28.5
Transverse diameter of distal extremity of radius... ..	...	33.5
Greatest length of 1st metacarpal.....	36.0	34.3
Greatest diameter of proximal extremity of 1st metacarpal .....	18.0	17.0
Greatest length of 2d metacarpal.....	...	43.5
Transverse diameter of proximal extremity of 2d metacarpal .....	13.3	12.5
Greatest length of 3rd metacarpal.....	53.0	48.6
Transverse diameter of proximal extremity of 3rd metacarpal .....	12.0	11.5
Greatest length of 4th metacarpal.....	...	43.7
Transverse diameter of proximal extremity of 4th metacarpal .....	...	12.3
Greatest length of 5th metacarpal.....	...	8.5
Transverse diameter of proximal extremity of 5th metacarpal .....	...	17.2
Length of proximal phalanx of 3d digit.....	25.1	24.9
Length of medial phalanx of 3d digit.....	20.3	18.5
Greatest length of distal phalanx of 3d digit.....	...	35.0 <sup>a</sup>
Length of astragalus proximodistally.....	36.0 <sup>a</sup>	...
Greatest width of astragalus.....	40.2	...

*a*, approximate.

**TROGOSUS? LATIDENS (Marsh), 1874**

Text figure 16

*Type*.—Right second upper molar, Y.P.M. No. 11085.

*Horizon and locality*.—Bridger formation, Bridger Basin, Wyo.

*Specific characters*.—Undeterminable except for very large size. No other characters of specific significance are evident.

*Discussion.*—The above isolated tooth is the type of the second species which Marsh described as *Tillotherium*. The principal characters which were attributed to *T. latidens* resulted from a misconception of the position of the tooth in the dental series. He regarded it as a third molar, whereas it must surely be a second, as determined by the development of the metastyle and hypoconal crest. The external cingular cusps are distinctive but not unique, as these have been noted in a less-developed condition in certain other specimens.

This species is retained as distinct from *Trogosus hyracoides* because of the remarkably large size of the teeth. The possibility of its representing *Tillodon* rather than *Trogosus* has not been overlooked but the crown of the type tooth is distinctly less brachyodont than the corresponding tooth in *T. fodiens*, although the external folds of the tooth approach the sharpness seen in the latter.

A second specimen referred to this species is an isolated  $M^3$  obtained by a Princeton University party in the Cathedral Bluffs tongue exposed in the Washakie Basin. It corresponds exceptionally well with the type, considering the difference in position in the cheek-tooth series.

Portions of both rami of a mandible with  $M_1$ ,  $M_2$ , and most of  $M_3$  in the left, but only  $M_2$  in the right ramus, in the collections of the National Museum of Canada may represent *Trogosus? latidens*. This specimen, like that earlier described by Russell (1935) as possibly representing *Trogosus minor*, was found in a coal mine at Princeton, British Columbia, in beds determined as the Princeton group. It certainly contains the largest tillodont lower teeth known, a size entirely appropriate for *T. ? latidens*; however, the lingual and buccal surfaces of the teeth appear to converge dorsally somewhat more rapidly than, for example, in *Trogosus hyracoides*, suggestive rather of *Tillodon fodiens*. The Canadian specimen is much too large to be referred to *Tillodon fodiens* and in the absence of associated upper and lower teeth is retained tentatively and questionably in *T. ? latidens*.

MEASUREMENTS IN MILLIMETERS OF *Trogosus? latidens* SPECIMENS

$M^2$ (type, Y.P.M. No. 11085), anteroposterior diameter, externally, perpendicular to anterior face.....	26.2
$M^2$ (type, Y.P.M. No. 11085), transverse diameter, anteriorly.....	41.5
$M^3$ (U.S.N.M. No. 18480, cast of P.U. specimen), anteroposterior diameter, externally, perpendicular to anterior face.....	23.4
$M^3$ (U.S.N.M. No. 18480, cast of P.U. specimen), transverse diameter, anteriorly .....	39.8
$M_1$ (N.M.C. No. 8709), anteroposterior diameter.....	20.5
$M_2$ (N.M.C. No. 8709), anteroposterior diameter.....	26.3

**TROGOSUS GRANGERI**, new species

Plates 5-8; text figures 22, 23, 25-28

*Type*.—Skull, lower jaws, atlas, several dorsal and lumbar vertebrae, scapulae, limb fragments, and a forefoot; A.M.N.H. No. 17008.

*Horizon and locality*.—Huerfano B, Huerfano-Muddy divide, 3 miles west of Gardner, Huerfano Basin, Colo.

*Specific characters*.—Skull of moderate size and relatively broad. Frontal region decidedly broad and prominently arched in longitudinal profile. Palate broad and zygomae widely arched. Cranium and basicranial region noticeably short. Jaws deep. Anterior cheek teeth well developed above and below, but second incisors comparatively slender (probably due to advanced wear) and molars anteroposteriorly short in type. Canine well spaced from I<sup>3</sup> and P<sup>2</sup> in upper jaw and uncrowded in lower jaw, with a short diastema between P<sub>2</sub> and P<sub>3</sub>.

*Discussion*.—The breadth of the skull of *T. grangeri* is particularly noticeable in comparison with the National Museum skull referred to *T. hyracoides*, although the rostral lengths are about equal. Its shortness is emphasized in comparison with the type of *T. fodiens*. The shortness and relative breadth of the basicranial region posterior to the pterygoids is also noticeable when viewed with the skull of *T. fodiens*.

An interesting detail noted in various dentitions of Huerfano specimens in which the teeth are not too well worn is the appearance of the talonid of M<sub>3</sub>. Unlike the few Bridger specimens exhibiting a sufficiently unworn M<sub>3</sub>, the entoconid is separated from the posterior crest and strongly united with the hypoconid crest, dividing the talonid basin in two, with the posterior basin open lingually through a sharp, though deep, notch. Due to wear or incompleteness, it is not known whether this is characteristic of *T. grangeri* or of *T. hillsii*, but possibly of both.

The material comprising the type of *Trogosus grangeri* was collected by Dr. Walter Granger of the American Museum of Natural History in 1916 from the upper Huerfano beds in the Huerfano basin of Colorado. It includes the third skull of a middle Eocene tillodont to be found, which, except for the teeth, is clearly the most nearly perfect extant.

MEASUREMENTS IN MILLIMETERS OF TYPE SPECIMEN OF *Trogosus grangeri*,  
A.M. NO. 17008

## Skull:

Length from anterior margin of I <sup>2</sup> at alveolus to crest of supra-occipital .....	309.0
Length from anterior margin of I <sup>2</sup> at alveolus to posterior surface of occipital condyle .....	281.0
Distance from posterior margin of alveolus for I <sup>2</sup> to posterior surface of postglenoid process.....	245.0
Distance from posterior margin of alveolus for I <sup>2</sup> to posterior margin of palate at narial opening.....	133.0
Distance from posterior margin of alveolus for I <sup>2</sup> to anterior margin of orbit at lachrymal foramen.....	102.0
Distance from anterior margin of orbit at lachrymal foramen to posterior surface of postglenoid process.....	147.0
Length of nasals.....	108.0
Greatest width of rostrum above canines.....	62.0
Width across postorbital processes.....	103.0
Width of cranium at postorbital constriction.....	58.3
Width across zygomae.....	215.0a
Width across occiput.....	121.0
Width of palate between second molars.....	47.0a
Depth of rostrum posterior to canines.....	60.0
Height of occiput above lower margin of condyles.....	98.0a

## Upper dentition:

Anterior margin of I <sup>2</sup> at alveolus to posterior margin of M <sup>3</sup> .....	151.0
Posterior margin of I <sup>2</sup> at alveolus to anterior margin of alveolus for P <sup>2</sup> .....	55.0
P <sup>2</sup> -M <sup>3</sup> at alveoli.....	85.0
M <sup>1</sup> -M <sup>3</sup> at alveoli.....	49.5
I <sup>2</sup> , greatest diameter at alveolus.....	19.0
I <sup>3</sup> , greatest diameter.....	12.6
P <sup>4</sup> , anteroposterior diameter, externally.....	14.9
P <sup>4</sup> , transverse diameter.....	21.1
M <sup>1</sup> , anteroposterior diameter, externally.....	17.0
M <sup>1</sup> , transverse diameter, anteriorly.....	23.5a
M <sup>3</sup> , anteroposterior diameter, perpendicular to anterior face.....	18.0
M <sup>3</sup> , transverse diameter, anteriorly.....	32.3

## Lower jaw:

Length from posterior margin of alveolus for I <sub>2</sub> to posterior surface of condyle .....	230.0
Length from posterior margin of alveolus for I <sub>2</sub> to posterior margin of angle .....	228.0
Length of symphysis.....	76.8
Depth of jaw beneath point between M <sub>2</sub> and M <sub>3</sub> , internally.....	58.0
Distance from top of coronoid process to bottom of angle.....	138.0
Thickness of jaw beneath M <sub>2</sub> .....	22.5

## Lower dentition:

Cutting edge of I <sub>2</sub> to posterior margin of M <sub>3</sub> .....	146.0
Posterior margin of alveolus for I <sub>2</sub> to anterior margin of alveolus for P <sub>3</sub> .....	34.0
P <sub>3</sub> to M <sub>3</sub> , inclusive at alveoli.....	89.0
M <sub>1</sub> to M <sub>3</sub> , inclusive.....	61.8
I <sub>2</sub> , greatest diameter at alveolus.....	18.5
P <sub>3</sub> , anteroposterior diameter.....	12.0
P <sub>3</sub> , transverse diameter across talonid.....	8.2
P <sub>4</sub> , anteroposterior diameter.....	15.2
M <sub>1</sub> , anteroposterior diameter at occlusal surface.....	15.0
M <sub>2</sub> , anteroposterior diameter at occlusal surface.....	18.5
M <sub>3</sub> , anteroposterior diameter.....	28.5

## Other skeletal portions:

Greatest width of atlas.....	98.8
Width across articular surfaces of atlas for condyles of skull.....	50.5
Width across articular surfaces of atlas for axis.....	47.0
Length of clavicle.....	102.0
Length of scapula from anterior margin of glenoid surface to supra- scapular border .....	175.0
Anteroposterior diameter of glenoid surface.....	38.5
Transverse diameter of glenoid surface.....	27.0 <sup>a</sup>
Greatest diameter of proximal extremity of radius.....	28.8
Transverse diameter of distal extremity of radius, perpendicular to axis of shaft.....	31.5 <sup>a</sup>
Greatest diameter of proximal extremity of first metacarpal, perpen- dicular to shaft.....	18.2
Greatest length of second metacarpal.....	42.4
Transverse diameter of proximal extremity of second metacarpal....	11.3
Greatest length of third metacarpal.....	47.2
Transverse diameter of proximal extremity of third metacarpal.....	10.5
Greatest length of fourth metacarpal.....	44.3
Transverse diameter of proximal extremity of fourth metacarpal....	12.4
Greatest length of fifth metacarpal.....	40.2
Transverse diameter of proximal extremity of fifth metacarpal.....	16.0 <sup>a</sup>
Transverse diameter of proximal extremity of fibula, perpendicular to axis of shaft.....	21.0

<sup>a</sup>, approximate.

**TROGOSUS HILLSII, new species**

Plates 9-12; text figures 29(part), 31(part), 35(part)

*Type*.—Skull and jaws, U.S.N.M. No. 17157.

*Horizon and locality*.—Huerfano B, Huerfano Basin, Colo.

*Specific characters*.—Skull smaller and much shallower than that of *T. grangeri*. Rostrum short and cranium relatively elongate. Frontal region narrow and very little arched. Palate broad and zygomae widely expanded. Diastemata separating canine from I<sup>3</sup> and P<sup>2</sup> very

short and lower anterior cheek teeth crowded. Molars distinctly larger and slightly more brachydont than in *T. grangeri*.

*Discussion.*—The type of *T. hillsii* was collected about 1885 by R. C. Hills and J. Milligan in the upper Huerfano beds of Colorado. The material was sent to Marsh for study in 1889, and in 1899 the collection was given by Hills to the National Museum. The crowns of the teeth are missing from the skull and jaws, but casts of P<sup>3</sup>, M<sup>2</sup>, and M<sup>3</sup> were obtained from impressions in the accompanying matrix. Associated limb fragments included the proximal and distal extremities of humeri and femora, proximal portions of ulnae and a tibia, the distal end of a radius and an ilium; representing two (or more) individuals of about the same size.

The lower jaw belonging to the skull of *T. hillsii* exhibits a shortness nearly comparable to that in the type of *T. castoridens*, with the masseteric fossa extending well forward and the posterior portion of M<sub>3</sub> arising from the base of the anterior face of the ascending ramus. However, the anterior extremity of the jaw is not so shallow and the teeth are noticeably larger. The skull is, in nearly all respects, shorter, shallower, and broader than U.S.N.M. No. 17886 referred to *T. hyracoides*.

The type of *T. hillsii* is much shallower and has a shorter rostrum than the type of *T. grangeri*, but the length of cranial portion of the skull from the last molar to the condyles is about equal. Nevertheless, the basicranial region, posterior to the pterygoids, is a little narrower and longer than in the *T. grangeri* skull. Notwithstanding the apparently significant differences noted between the two skulls from the Huerfano beds, differences which seem almost of generic magnitude, there is a curious resemblance of one to the other not shared with the Bridger skulls. The points of similarity include the widely expanded zygomae, the almost identical position and appearance of the lachrymal foramen, and the presence of prominent longitudinal swellings located dorsolaterally on each of the parietals, above the cerebral hemispheres. These resemblances may not be significant other than indicating a closer relationship than with the Bridger forms, but should their meaning be interpreted as indicating specific identity, then the marked differences in relative proportions throughout the skulls could only be accounted for by a surprising degree of individual variation, or again a dimorphism which one hesitates to advance with so few specimens at hand. It should be noted that in many groups of animals where sexual dimorphism is very marked, that the differences between the two forms are often in an order of magnitude that would likely be attributed to generic separation were dimorphism not known to exist.

MEASUREMENTS IN MILLIMETERS OF TYPE SPECIMEN OF *Trogosus hillsii*,  
U.S.N.M. NO. 17157

## Skull:

Distance from posterior margin of alveolus of I <sup>3</sup> to posterior surface of occipital condyles.....	233.0
Distance from anterior margin of orbit at lachrymal foramen to posterior surface of postglenoid process.....	142.0a
Width across postorbital processes.....	89.8
Width of cranium at postorbital constriction.....	46.1
Width across zygomae, estimated.....	180.0
Width of palate between second molars.....	36.5
Depth of rostrum posterior to canines.....	52.0a

## Upper dentition:

P <sup>3</sup> to M <sup>3</sup> , inclusive, at alveoli.....	83.8
M <sup>1</sup> to M <sup>3</sup> , inclusive, at alveoli.....	52.5
P <sup>4</sup> , anteroposterior diameter.....	15.2a
M <sup>1</sup> , anteroposterior diameter, externally.....	23.0a
M <sup>2</sup> , transverse diameter, anteriorly.....	33.0a
M <sup>3</sup> , anteroposterior diameter, perpendicular to anterior face.....	17.5a
M <sup>3</sup> , transverse diameter, anteriorly.....	35.0a

## Lower jaw:

Length of symphysis.....	68.0
Depth of jaw internally beneath point between M <sub>2</sub> and M <sub>3</sub> .....	52.0
Thickness of jaw beneath M <sub>2</sub> .....	23.0

## Lower dentition:

Posterior margin of alveolus for I <sub>2</sub> to posterior margin of alveolus for M <sub>2</sub> .....	114.0a
Posterior margin of alveolus for I <sub>2</sub> to anterior margin of alveolus for P <sub>3</sub> .....	24.0a
P <sub>2</sub> to M <sub>3</sub> , inclusive, at alveoli.....	89.5
M <sub>1</sub> to M <sub>3</sub> , inclusive, at alveoli.....	66.0

a, approximate.

**TILLODON, new genus**<sup>6</sup>

*Type*.—*Tillotherium fodiens* Marsh.

*Generic characters*.—Skull elongate through both cranial and rostral portions. Lachrymal foramen well forward of orbital rim. I<sub>3</sub> and

<sup>6</sup> It is a regrettable circumstance that *Tillotherium* cannot be defended as a valid genus, as this name has become fixed in the literature and associated with the only complete skull material hitherto described. Moreover, it was adopted as representing the best known material for the family name Tillotheriidae. There appears, nevertheless, reasonable evidence for recognizing a second genus of tillodonts in the Bridger, based on the species *T. fodiens* Marsh, and in order to preserve a part of the original name structure to which the ordinal name was related, *Tillodon* is proposed.



apparently  $I_1$  absent. Marked diastemata separating upper canine from  $I^3$  and  $P^3$ . Lower canine and  $P_2$  spaced and well separated from  $P_3$ . Upper and lower cheek teeth distinctly brachydont, with cusps of upper teeth obtuse, and outer walls of lower teeth very sloping or markedly convergent upward toward inner wall. Folds between external styles of upper cheek teeth compressed. Greatest width of cheek teeth across  $M^2$ .

**TILLODON FODIENS (Marsh), 1875**

Plates 13-16; text figures 19, 20, 24, 37 (part), and 38d, h, and i

*Type*.—Skull, lower jaws, and some fragmentary remains of other portions of the skeleton, Y.P.M. No. 11087.

*Horizon and locality*.—Bridger B, Millersville, Bridger Basin, Uinta County, Wyo.

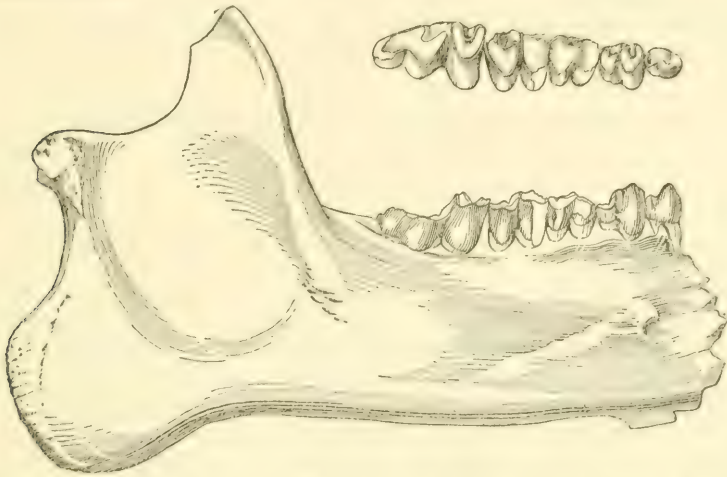


FIG. 19.—Cf. *Tillodon fodiens* (Marsh), new genus: Right ramus of mandible (U.S.N.M. No. 18164), occlusal and lateral views,  $\times \frac{3}{4}$ . Bridger (B) middle Eocene, Wyoming.

*Specific characters*.—Skull massive and elongate, broad through frontals and rostrum. Basicranial area broad and elongate. Lower jaws thick and deep. Teeth moderately large. Other specific characters not distinguished from generic.

*Discussion*.—The type of *Tillodon fodiens* includes the first complete skull and jaws found, and is the first material to have given an adequate conception of the tillodonts. It demonstrated the relationship between the types of teeth seen in the skull and jaws, the two having never before been found associated.

A lower jaw (fig. 19), U.S.N.M. No. 18164, with rather large, well-preserved teeth from  $P_3$ - $M_3$ , is referred to this species. The specimen

was found by the writer in beds considered to be low in Bridger B, a little over 2 miles south of Church Buttes and not far from Black's Fork. The anterior extremity of the jaw, forward of  $P_3$ , is missing, but the preserved portion is very deep and elongate and the posterior termination of the symphysis is well forward. The teeth are very broad at the base, but markedly convergent or tapering upward. The specimen compares favorably with the type except in being less thickened transversely beneath the cheek teeth and having a little longer tooth row.

Some associated and relatively unworn upper teeth in the National Museum collection, No. 17158, including second and third incisors and  $P^3$ - $M^1$ , are referred to *T. fodiens*. These teeth were found by the writer in 1941 about 24 miles southeast of Granger, in beds regarded as well up in Bridger B. They are of a size comparable to those in the type, and  $M^1$  illustrates particularly well the highly brachydont character attributed to *Tillodon fodiens* molars.

MEASUREMENTS IN MILLIMETERS OF *Tillodon fodiens* SPECIMENS

	Y.P.M. No. 11087
Skull:	Type
Length from posterior margin of alveolus for $I^2$ to posterior surface of condyles .....	310.0a
Distance from posterior margin of alveolus for $I^2$ to posterior surface of postglenoid process.....	288.0a
Distance from posterior margin of alveolus for $I^2$ to posterior margin of palate at narial opening.....	170.0a
Distance from posterior margin of alveolus for $I^2$ to anterior margin of orbital rim at lachrymal foramen.....	120.0a
Distance from anterior margin of orbital rim at lachrymal foramen to posterior surface of postglenoid process.....	170.0a
Length of nasals.....	140.0a
Width of rostrum above canines.....	80.0a
Width across postorbital processes.....	130.0a
Width of cranium at postorbital constriction.....	70.0a
Width of palate between second molars.....	51.0
Depth of rostrum posterior to canines.....	58.0a
	U.S.N.M. No. 17158
Upper dentition:	
Posterior margin of alveolus for $I^2$ to posterior margin of $M^3$ .....	160.0a
Distance between $I^2$ and $P^2$ at alveoli.....	61.0a
$P^3$ to $M^3$ , inclusive, at alveoli.....	86.5
$M^1$ to $M^3$ , inclusive, at alveoli.....	58.5
$I^2$ , greatest diameter.....	21.5

	U.S.N.M. No. 17158	Y.P.M. No. 11087
I <sup>3</sup> , greatest diameter.....	13.5	...
P <sup>3</sup> , anteroposterior diameter, externally at occlusal surface.....	...	16.8
P <sup>3</sup> , transverse diameter, perpendicular to outer wall.....	17.0a	17.0a
P <sup>4</sup> , anteroposterior diameter, externally.....	15.0	14.0
P <sup>4</sup> , transverse diameter.....	23.5	24.5
M <sup>1</sup> , anteroposterior diameter, externally.....	21.3	18.0
M <sup>1</sup> , transverse diameter, anteriorly.....	31.5	39.3
M <sup>2</sup> , anteroposterior diameter, externally.....	...	23.0
M <sup>2</sup> , transverse diameter, anteriorly.....	...	35.5
M <sup>3</sup> , anteroposterior diameter, perpendicular to anterior face.....	...	18.2
M <sup>3</sup> , transverse diameter, anteriorly.....	...	34.5
	U.S.N.M. No. 18164	
Lower jaw:		
Length from posterior margin of alveolus for I <sup>2</sup> to posterior surface of condyle.....	...	248.0
Length of symphysis.....	...	91.0
Depth of jaw internally beneath a point between M <sub>2</sub> and M <sub>3</sub> .....	63.5	66.0
Distance from top of coronoid process to bottom of angle.....	165.0a	...
Thickness of jaw beneath M <sub>2</sub> .....	24.5	28.0
Lower dentition:		
Posterior margin of alveolus for I <sub>2</sub> to posterior margin of M <sub>3</sub> .....	...	135.0a
Posterior margin of alveolus for I <sub>2</sub> to anterior margin of alveolus for P <sub>3</sub> .....	...	38.0
P <sub>3</sub> to M <sub>3</sub> , inclusive.....	100.5	93.0a
M <sub>1</sub> to M <sub>3</sub> , inclusive.....	73.7	70.0
P <sub>3</sub> , anteroposterior diameter.....	12.5	11.7
P <sub>3</sub> , transverse diameter.....	9.5	9.1
P <sub>4</sub> , anteroposterior diameter.....	16.3	13.5
M <sub>1</sub> , anteroposterior diameter at occlusal surface....	16.5	16.7
M <sub>2</sub> , anteroposterior diameter at occlusal surface....	21.8	20.0
M <sub>3</sub> , anteroposterior diameter.....	37.7	32.3
Other skeletal portions:		
Width of third cervical vertebra across transverse process.....	56.0a	...
Distance across postzygapophyses of third cervical vertebra.....	45.0a	...
Length of centrum of third cervical vertebra along upper surface.....	22.8	...
Greatest diameter of proximal extremity of humerus, perpendicular to axis of shaft.....	56.5	...

	U.S.N.M. No. 18164	Y.P.M. No. 11087
Transverse diameter of proximal extremity of humerus across tuberosities.....	55.5	...
Greatest width of distal extremity of ulna.....	...	29.5
Greatest length of first metacarpal.....	...	39.3
Greatest diameter of proximal extremity of first metacarpal .....	...	21.5
Greatest length of second metacarpal.....	...	46.8
Transverse width of proximal extremity of second metacarpal .....	...	15.4
Greatest width of proximal extremity of fibula.....	...	30.8
Greatest length of calcaneum.....	...	74.2
Transverse width dorsally of proximal extremity of third metatarsal .....	...	12.0
Transverse width dorsally of proximal extremity of fourth metatarsal .....	...	13.5

a, approximate.

## THE TILLODONT SKELETON

### SKULL

In a discussion of the tillodont skull one is limited largely to the end products, *Trogosus* and *Tillodon* of the middle Eocene, as the earlier form, *Esthonyx*, though known by more numerous remains, is actually far less well represented so far as quality or completeness of the material is concerned. The Wasatchian materials are for the most part more poorly preserved, often crushed, distorted, and have a mineral encrustation that can be satisfactorily removed with only the most painstaking preparation. Of the fragmentary skull portions known, other than maxillae, two fair, but exasperatingly incomplete specimens are known from the Wind River stage. A few, much-encrusted skull fragments, among the many dentitions, are included in lower Wasatchian or Gray Bull materials, and the Clark Fork has furnished only maxillae and lower jaws.

The tillodont skull possesses an archaic appearance, shared by many of the Eocene and Paleocene mammals, but is unusual in its modification of the rostral portion accompanying the tremendous enlargement of the second incisors. In its gross form the rostrum is elongate, somewhat tapering, slightly to markedly concave above, and anteriorly resembling that of a hedgehog on a much larger scale. The ventral surface is broad, particularly in the posterior portion, across the large, relatively brachydont molar teeth, and is moderately concave between the tooth rows. The frontal area is especially broad, and dorsally more or less inflated, giving the skull, particularly that of *T. grangeri* (pl.

6), a "high brow" appearance. The orbits are low and widely separated, and the zygomae well expanded. The postorbital processes are weak but the temporal crests well defined, though less prominently in the *T. hillsii* skull (pl. 9), forming the anterodorsal extent of the deep temporal fossae. The sagittal crest, developed to varying amounts anteriorly, has a pronounced saddle about midway of its length, over the narrow brain case, and rises to considerable prominence posteriorly as it joins the heavy lambdoidal crests. Ventrally, the pterygoids project prominently and the basicranial area posterior to these is very short and broad. The occipital area, as observed in *T. grangeri*, has an outline that is almost semicircular, though slightly acute dorsally, and viewed from the sides is nearly vertical in the lower part, but the dorsal half curves backward toward the inion (pl. 6).

In greater detail, the rostrum of the tillodont skull exhibits a number of features which should be brought out, in addition to the peculiar dental specialization characterizing the order. Beginning with the dorsal surface, the nasals are very elongate, extending well back between the frontals. Forward, the sides of the nasals are nearly parallel or somewhat converging, but posteriorly these bones widen markedly, with the greatest width between the maxillofrontal sutures. Posteriorly, the nasals may terminate in a broad V-shaped wedge between the frontals, as in *T. fodiens* (pl. 13), or form a broad, nearly rectangular reentrant as in *T. grangeri* (pl. 5) or *T. hillsii* (pl. 9). The skull referred to *T. hyracoides* (pl. 1) shows an intermediate form, with a noticeable pit at the apex, probably due to an injury.

The premaxilla occupies an unusually large proportion of the lateral and dorsolateral surface of the snout. In its surface expression, this bone extends posteriorly to a point about even with a position intermediate between the infraorbital foramen and the orbit. The premaxillo-maxillary suture extends from its posterior limit obliquely across the face to a midposition between the third incisor and the canine, resulting in a surface distribution for the premaxilla which is approximated, but not quite reached, in the living hedgehog, *Erinaceus*. Between  $I^2$  and C the suture is deflected to the canine alveolus (not as shown in Marsh's illustration, 1876, pl. 9) and then extends abruptly forward, passing close to  $I^3$ , to the anterior palatine foramen. The premaxilla is prominently flexed over the unerupted portion of  $I^2$  which extends through this bone and terminates posteriorly in the maxilla at a position slightly above and inward from the anterior opening of the infraorbital foramen. Anteriorly, the premaxillae join in a pair of backward-directed wings, partially or completely separating the anterior palatine foramina, and producing a wide palatal notch opening forward between

the large incisors. The anterior portion of the nasal cavity, as noted in the *T. hyracoides* skull, shows a nearly lemniscate outline in a vertical section, in which prominent ridges on the mesial walls of the premaxillae, presumably for attachment of the maxilloturbinals, partially constrict the nasal passage into upper and lower chambers. These may correspond to the middle and inferior meatuses of the nose. The superior meatuses are defined by the arcuate form of the inferior surface of the nasals as seen from in front. In the *T. hillsii* skull the nasal section observed is more posterior in position, showing a less pronounced horizontal stricture, and in which the outline of the section is somewhat more bell-shaped, with the nasal fossae partially separated by the sutural ridge of the maxillae, and possibly by a part of the vomer.

In a ventral aspect of the rostrum it has been observed that the maxillae widen very greatly from the position of P<sup>2</sup> backward; however, with the increase in size of the cheek teeth posteriorly, the effective width of the palate between the lingual margins of the teeth increases but little from the incisors back. The anterior margin of the maxillae and the anterior palatine foramina are far forward on the palatal surface, in a position median to the third incisors, almost as far forward as in *Erinaceus*.<sup>7</sup>

Weak posterior palatine foramina appear in the customary position at or near the suture between the maxillae and palatines, but a nonsymmetrical scattering of such foramina occur forward of this position, and a pair of much-better-developed foramina, with well-defined forward continuing grooves are to be found median to the third premolars in three of the skulls, and opposite the second premolars in *T. fodiens* (pl. 15).

The nasal wing of the maxilla makes but a short contact with the nasal bone and is excluded from participation in the anterior margin of the orbit by the lachrymal and jugal bones, except in the *T. hyracoides* skull where the edge of the maxilla forms a part of the rim. The anterior opening of the infraorbital canal is above a point between P<sup>3</sup> and P<sup>4</sup>. Posteriorly its opening into the orbital fossa is very large and bounded above by the lachrymal and below by the orbital plate of the maxilla. The ascending plate of the palatine does not appear to take part in the foramen. The orbital plate of the maxilla is a broad shelflike structure of considerable extent, and a conspicuous feature of the tillodont skull when viewed from above and behind.

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<sup>7</sup> In making comparisons with the European hedgehog, it should be borne in mind that the highly specialized incisors are probably not homologous in the two forms. This tooth is I<sup>1</sup> in the hedgehog.

The lachrymal bone is well developed and prominently exposed on the outer surface of the rostrum anterior to the orbital rim in all but the *T. hyracoides* (pl. 2) skull, and there the development is similar but the most prominent crest of the orbital margin has a more forward position. The lachrymal foramen in *T. fodiens* (pl. 14) is well forward and completely out of the orbital fossa. In the two Huerfano skulls the foramen is situated about midway fore and aft on the broad convexity of the orbital rim and surmounted by a distinct lachrymal process. In the *T. hyracoides* skull the foramen is located in a depressed portion of the rim, neither anterior nor completely posterior to it, but facing well outward.

The frontal segment of the skull is broadly expanded and markedly convex dorsally between the subdued but widely separated postorbital processes. The frontals are deeply notched anteriorly by an invasion of the nasals but their posterior margin or suture extends rather uniformly across the skull just posterior to forward extent of the sagittal crest in all the skulls except that of *T. grangeri*. In the latter the anterodorsal margins of the temporal fossae unite to form the sagittal crest on the adjacent portion of the parietal. The orbital and temporal portions of the lateral plate of the frontal are indistinctly divided but the temporal portion would appear to be much the larger, as a result of the marked surface extent of the lachrymal in the orbital fossa. The lower portion of the lateral plate is bounded posteriorly by the alisphenoid and above this by the parietal. Below, the lateral plate of the frontal is bounded by the orbitosphenoid, palatine, and possibly by a small segment of the orbital plate of the maxilla forward.

Posterior to the coronal suture the parietals are anteroposteriorly elongate to near the lambdoidal crest and envelope the sides of the brain case over its most constricted part, terminating below at the alisphenoid, and at the squamosal posteroventrally. The sagittal crest is relatively subdued anteriorly, concave in profile, and high and rugged posteriorly as it rises to join the lambdoidal crest at the inion. The parietals are deeply excavated posteriorly on either side of the sagittal crest, and with the adjacent squamosals here show several large asymmetrically placed vascular foramina (Edinger, 1933, p. 271).

The squamosal exhibits a semicircular or fan-shaped temporal portion and a sturdy zygomatic process. The latter arises from the posteroventral portion of the temporal plate and carries a broad glenoid surface for articulation of the lower jaw. The glenoid surface extends well out onto the zygoma and has its long axis anterolateral rather than strictly transverse. The rather prominent postglenoid process is limited to the posteromedial extent of the surface, although a prominence at

the posterolateral extremity of the broad lateral portion of the surface gives further support to the condyle of the jaw. About midway between the inner and outer extremities the glenoid surface may be somewhat constricted fore and aft. Outward and forward from the strong support to the glenoid surface the zygomatic process tapers rapidly and extends superior to the slender, less sturdy jugal.

The separate elements of the occiput cannot be clearly distinguished and the presence or absence of an interparietal cannot be determined, as coossification has obliterated sutures in those specimens having this portion preserved.

Although the cranial portion of the tillodont skull is moderately long and decidedly slender, the most striking characteristic in the ventral aspect, particularly in *Trogosus*, is the extremely short basicranial area posterior to the axis of jaw articulation. The outstanding lambdoidal crests in *Trogosus grangeri* extend downward, below their union with the superior crest of the zygomatic arches, to a prominent anteroposteriorly compressed process lateral to each of the condyles. In *Tillodon* this process is more bulbous. Its identity or composition is not certainly determined but it would appear to involve both the mastoid and exoccipitals and may well have a covering from the squamosal on its forward surface, forming the posterior wall of the audital canal, although this has not been clearly determined. The channel for the audital tube, between this process and the postglenoid process, is narrow but deeply impressed, with the postglenoid process close to the occipitomastoid process and almost as posterior in position as the occipital condyles.

The basioccipital in *Trogosus* is relatively short, though less so in *Tillodon*, and broad, but the proportions of the basisphenoid cannot be clearly determined in the material at hand. The alisphenoid is well developed and extends forward and upward occupying a significant portion of the lateral surface of the cranium. The orbitosphenoid is less distinctly outlined but appears to be restricted to a relatively small area anterior to the sphenoidal fissure. The ascending plate of the palatine also appears restricted forward to a slender wedge between frontal and maxilla. Posteriorly, the suture between the palatine and alisphenoid is indistinct. The pterygoids project prominently downward from the well-developed lamellae laterally bounding the posterior narial passage. The ventral aperture of the passage ends forward between the third molars. The posterior margin of the hamular process rises abruptly to join the crest of the pterygoid plate of the alisphenoid, which is slightly offset lateral to the pterygoid. The crest then con-



tinues backward, upward, and then outward to the squamosal where, subdued, it reaches the inner margin of the glenoid surface.

The foramina of the basal portion of the cranium are decidedly more simple than in most modern mammals. Considerably posterior to the infraorbital canal, within the ascending plate of the palatine, and completely behind the orbital plate of the maxilla is the large posterior opening of the palatine foramen, including also the sphenopalatine foramen as indicated by the partition evident in the *Trogosus hyracoides* skull. The large sphenoidal fissure is deeply recessed below the more constricted portion of the cranium and is apparently the common aperture for the second, third, fourth, and sixth nerves, as well as both the first and second divisions of the fifth or trigeminal. There is no foramen rotundum and the optic foramen does not appear to be separate externally, although Marsh (1876), in discussing the endocranial cast of *T. fodiens* noted that, "the exit for the optic nerve is quite large." If the optic foramen is separate from the sphenoidal fissure internally, as the cast surely indicates, they evidently became confluent at the external aperture as shown by the absence of a separate optic foramen, externally, in the *T. grangeri* specimen. There is also evidence, in a broken section through this part of the skull of *T. hillsii*, of a separation posteriorly of the optic foramen, if these elements are correctly identified. A small foramen well forward of the sphenoidal fissure and somewhat above the posterior palatine foramen, which earlier I tentatively regarded as for the optic nerve, so far as I can determine is actually located at the suture between the frontal and orbitosphenoid, hence it is in all probability the ethmoidal foramen. In addition to the above-enumerated nerves, the opening of the sphenoidal fissure apparently also transmitted the external carotid. The presence of an alisphenoid canal is clearly evident in the *Trogosus hyracoides* and *Tillodon fodiens* skulls, less so in the *Trogosus grangeri* skull. In the type of *T. fodiens* the covering of the canal has been destroyed so that the smooth channel can be followed from its separation from the sphenoidal fissure to a low saddlelike separation from the foramen ovale. The foramen ovale is of good size and normal in position immediately above and lateral to the outward sweeping crest of the alisphenoid, but well separated from the glenoid articular surface.

In the absence of an osseous bulla the basicranial foramina in the auditory region are uncovered ventrally and for the most part enter the cranial cavity anterior and posterior to the petrosal through or near the open positions of the foramen lacerum medium and foramen lacerum posterius. The internal carotid entered the skull along a broad,

well-marked sulcus between the basisphenoid and the pterygoid plate of the alisphenoid, then through the aperture anterior to the petrosal. Lateral to this, and extending upward from the medial margin of the glenoid surface, is an open sulcus on the squamosal apparently for the venous system which would exit through the postglenoid foramen. This canal becomes covered anterior to the petrosal, where it separates from the opening for the internal carotid and enters the squamosal. Posterior to the petrosal is a large, posteriorly well-rounded aperture, the position of the foramen lacerum posterius, for the ninth, tenth, and eleventh nerves. Lateral to this the bone, presumably the mastoid, is notched, evidently for the facial nerve which would enter the periotic immediately above and anterolateral to the posterior lacerate foramen. Posteromedial to the posterior lacerate foramen, and about midway to the condyle, is a large, circular hypoglossal or condylar foramen.

The petrosal or petrous portion of the periotic, an element of very considerable interest in mammalian anatomy, is unfortunately missing or badly damaged in the four skulls at hand, so that little other than its small size and anteromedial elongation can be ascertained.

#### ENDOCRANIAL CAST

The endocranial cast of *Tillodon fodiens* made for Marsh appears to be rather poorly prepared, and Marsh's illustration (1876, fig. 1) of it is much reduced and rather generalized. It was figured in greater detail by Edinger (1929, fig. 119b, c), whose drawings are here reproduced (fig. 20a, c) with the addition of a ventral view (fig. 20b). Marsh's description (p. 250) of the cast is very brief, consisting essentially of a statement of relative development of the cerebellum, cerebrum, and olfactory lobes, and the relative size of the whole. Edinger's discussion (pp. 148-149) is brief but with a number of

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#### EXPLANATION OF FIGURE 20

- |   |   |
|---|---|
| 1. Olfactory lobes (incomplete).                              | 11. Fossa for petrosal.                     |
| 2. Commissure of II or optic nerve.                           | 12. Flocculus?                              |
| 3. Contents of sphenoidal fissure.                            | 13. Crest of cerebellum.                    |
| 4. Pyriform lobe?   | 14. Position of posterior lacerate foramen. |
| 5. Cerebrum.  | 15. Medulla oblongata.                      |
| 6. Position of hypophysis.                                    | 16. Commissure of XII or hypoglossal nerve. |
| 7. Third branch of V or trigeminal nerve.                     | 17. Position of venus canal.                |
| 8. Pons?  | 18. Foramen magnum.                         |
| 9. Position of median lacerate foramen.                       |   |
| 10. Commissure of VII and VIII or facial and auditory nerves. |   |

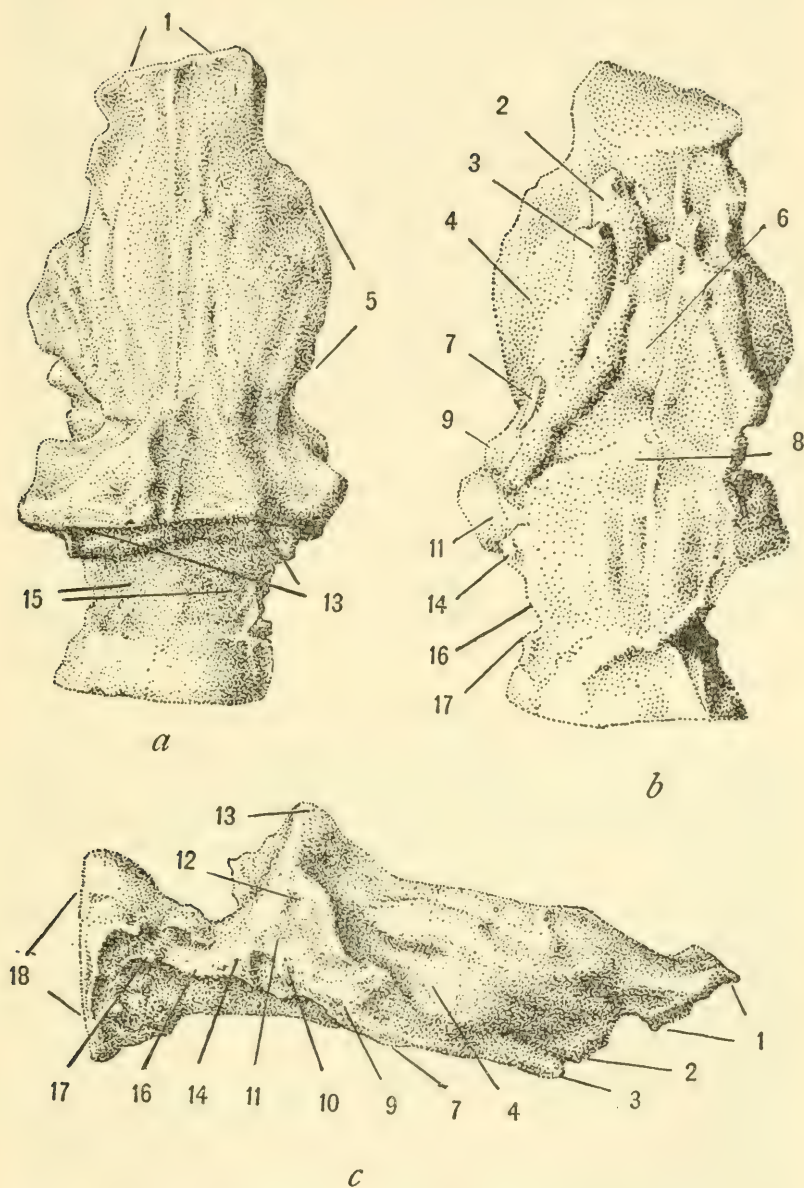


FIG. 20.—*Tillodon fodiens* (Marsh), new genus: Endocranial cast (Y.P.M. No. 11087), from type specimen; *a*, dorsal view; *b*, ventral view; *c*, right lateral view; approximately  $\times \frac{1}{3}$ . (*a* and *c* after Edinger, 1929; *b*, drawn by Mrs. Sally Lee.) For explanation see opposite page.

pertinent comments regarding its form. She was, however, handicapped in her discussion by not having the skull at hand. The form is there regarded as insectivore, and comparison is made with the hedgehog.

The cast, extrapolating for the probable size of the olfactory lobes, is about 30 to 33 percent of the length of the skull. The rhinencephalon is incompletely represented, although Marsh has shown the olfactory lobes in his drawing. The skull was broken and somewhat restored at this point so that it is likely that the form of the lobes was not preserved. As noted by Edinger, the cerebrum is slender and flattened; however, the latter should not be too emphasized as the cranial portion of the skull has been somewhat flattened by crushing, most noticeably on the left side. The sculpturing on the dorsal surface of the cerebral portion was noted to be indistinct, and is evidently complicated by marks of the preparator's tools, as well as by crushing. Such sulci and gyri as may have existed are obscured; moreover, it is more than likely that this group was lissencephalic. Fissura on the left side in the dorsal view tempt interpretation as the sylvian sulcus and the rhinal fissure, but this is the more-crushed side, and on the right the fissura rhinalis may be indicated lower, beneath(?) the widest point, with the pyriform lobe visible only in the lateral and ventral views.

The cerebellum is noticeably shortened anteroposteriorly, but, as noted by both Marsh and Edinger, it is high and wide, more so than the cerebrum. It does not exhibit a median lobe or vermis but is peculiarly depressed medially, immediately anterior to the transverse crest. There is no indication on the cast, as noted by Marsh, of a tentorial crest (of the skull), concomitantly the mesencephalon is not exposed dorsally. However, the cerebrum and cerebellum are separated laterally by a deep invagination anterior to the flocculus.

The medulla oblongata is broad and somewhat flattened, in part through crushing. Much of the dorsoventral expansion of the cast shown posteriorly is outside the foramen magnum.

Detailed features in the lateral view, concealed from above by a large lobe of the widely expanded crest of the cerebellum, apparently the flocculus, include a fossa for the petrosal and a median swell or commissure for the seventh and eighth or facial and auditory nerves, with protuberances representing the dorsomedial openings of the median and posterior lacerate foramina, ventral to the fore and aft extremities of the fossa. Forward, the inferior profile of the cast shows approximately the position at which the nerves carried by the sphenoidal fissure leave the cranium, and the separate, large, and

closely adjacent commissure of the optic nerve. Posteriorly, on the lateral margin of the medulla oblongata, the position at which the hypoglossal emerges is indistinct, as the foramen had not been prepared prior to casting. This is followed by an incomplete lateral protuberance near the posterior margin of the cast that is the filling of an opening of a venous canal in the occipital just within the foramen magnum.

In the ventral view, in addition to the forward positions of the representation of the optic nerve and the contents of the sphenoidal fissure, there is beneath a position just posterior to the midpoint of the cerebrum a subdued but elongate-oval prominence interpreted as the position of the hypophysis. Posterior to this a depression is followed by a somewhat irregular, wide, raised area, presumably the pons, just ahead of the anteroposteriorly elongate lobes of the medulla oblongata. On the right side (left of the illustration), anteroventral to the filling of the internal opening of the foramen lacerum medium, is a protuberance representing the commissure of the third branch of the trigeminal. Also in the lateral view, the indication of the hypoglossal and the vein leaving the exoccipital can be seen posterior to the foramen lacerum posterius, on the lateral margin of the right side of the medulla oblongata.

#### MANDIBLE

In a description of the tillodont lower jaw, unlike the skull, there is available for study much *Esthonyx* material, in addition to the few, though better-preserved, *Trogosus* and *Tillodon* specimens. The principal change in outline of the jaw that has taken place between *Esthonyx* and *Trogosus* has been a marked deepening of the ramus beneath the posterior premolars and first molar, so that the inferior border is more nearly parallel to the occlusal surface of the tooth row as far forward as  $P_3$ . In the much smaller *Esthonyx* (fig. 2a), the inferior margin converges rapidly with the tooth row from a point beneath  $M_3$  to the incisors. The anterior cheek teeth are relatively much reduced in *Trogosus* and *Tillodon*, and the depth of the jaw falls away rapidly anterior to  $P_3$  (pl. 2).

The symphysis of the jaws in both the lower and middle Eocene forms is strong and elongate. In *Esthonyx* (fig. 2b) this extends posteriorly from between the incisors, and with increasing depth, to a position between and below about the contact of the third and fourth premolars. In the middle Eocene forms (pls. 4, 8, 12, and 16), the symphysis extends back to a point beneath  $M_1$  and in some instances

almost or quite to below the anterior margin of  $M_2$ , accommodating the basal portion of the enlarged incisors. It is interesting to note that, in this respect, the Bridger tillodont jaws appear most advanced in that they are fused farther back than those from the Huerfano beds. Likewise, the *Esthonyx* material from the Clark Fork is least advanced and the two rami may not always be well fused.

The mental foramina on the anterior portion of the outer surface of the jaw in both the esthonychinae and trogosinae are remarkably variable and may consist of from one large to four or five smaller openings of irregular arrangement, often differing on the two rami of the same individual. When more than one opening is seen, these may be in part above one another or scattered from beneath  $P_2$  to  $P_4$ . When single or closely grouped, the usual position is nearly under  $P_3$ .

The coronoid, condylar, and angular portions of the *Esthonyx* jaws are poorly represented and for the most part no significant details can be obtained. There is, however, a remarkable pair of lower jaws (fig. 21) of an unusually large esthonychid in the Princeton collections from the Gray Bull horizon showing most of the angle, the condyle, and part of the coronoid process. The anterior portion of the masseteric fossa is observed in many specimens and this depression is seen to be well defined in the Gray Bull material, with a prominent crest anterodorsal to the fossa. The anterior margin of the fossa is rather indistinct in *E. grangeri*, whereas, in the middle Eocene material the fossa is deeply excavated and the marginal crest high and rugged. These jaws show evidence of powerful muscles having insertions in the area of the masseteric fossa, particularly the *masseter lateralis*, with its well-defined attachment area for the posterior branch, and the prominent muscle scar around the broadly expanded angle for the anterior branch. The evidence for a strongly developed *masseter lateralis anterioris* is to be correlated with the obvious development of gnawing incisors.

The Princeton specimen (No. 14727), particularly large for *E. bisulcatus* and possibly a late survival of *E. grangeri* or *E. latidens*, shows a truly tremendous posterior ramal portion. The ridge at the forward margin of the area for insertion of the *masseter lateralis anterioris* is directed forward and upward from near the lower posterior margin of the angle and is remarkably high and rugged. The development of this crest exceeds considerably that observed in middle Eocene materials indicating an exceedingly strong development of the anterior branch of the *masseter lateralis*, associated, nevertheless, with the rooted, esthonychine type, rather than the persistent growing trogosine type of incisors.

The ascending ramus of the middle Eocene jaws shows some small differences between *Trogosus* and *Tillodon*. In *Tillodon* the masseteric fossa extends farther upward, well into the coronoid, and the notch between the coronoid process and the condyle is more widely open. The coronoid appears more truncate and does not curve backward so noticeably as in *Trogosus*. In *Esthonyx*, as evidenced by the Princeton specimen, the condyle is not widely separated from the coronoid, the posterior margin of the latter rising from immediately in front of the condyle, if reliance is to be placed on this specimen as it has been restored.

The articular portion of the condyle as observed in the *Trogosinae* and in the Princeton *Esthonyx* specimen is largely confined to the



FIG. 21.—*Esthonyx*, species: Right ramus of mandible (P.U. No. 14727), lateral view,  $\times \frac{1}{2}$ . Gray Bull lower Eocene, Wyoming.

dorsal surface, suggesting considerable fore and aft motion of the jaw as in gnawing and grinding. This is further reflected in the glenoid surface of the squamosal, which, though quite unlike that in rodents, permits considerable forward motion of the jaw, limited backward, however, by a postglenoid process.

A significant detail observed on the inner face of the lower jaws of *Trogosus* and *Tillodon* is the rather conspicuous sulcus mylohyoideus for the mylohyoid artery and nerve. It was double or consisting of parallel grooves in most specimens examined, extending downward and forward from adjacent to the opening of the mandibular or inferior dental foramen, for a little over 4 cms., to an indefinite point just above the position on the lower margin of the jaw determined by the anterior extent of the angle, about even with the anterior margin of the scar determined by insertion of the *pterygoid internus*. The

sulcus mylohyoideus is stated by Zittel to be especially characteristic of the marsupials; however, it is not uncommon in certain placental groups. It was not definable in carnivores examined, but can be detected in various perissodactyls and artiodactyls, and is prominent in man.

#### DENTITION

Characteristics of the teeth in tillodonts are briefly outlined, as defining the family, in the systematic portion of this paper. The following description is a more detailed study and includes a discussion of the evolution of the teeth within the order.

Both lower and middle Eocene forms have their upper incisors reduced to two, with the loss, apparently, of  $I^1$ . The second incisor is the most strikingly modified of any of the tillodont teeth. In *Esthonyx* (fig. 2a) this tooth is large, but little more so than  $I^3$ . The root is long, only slightly curved and without enamel. Its cross section at about the alveolar opening is a distorted oval, with the posteromedial expansion effecting an approach toward triangular. The crown portion is nearly triangular, scalpriform at the apex and apparently covered with enamel in the unworn state. The posteromedial and posteroexternal angles of the crown are compressed and in early wear the posterior surface shows a slight longitudinal bulge. With wear the enamel is first removed from this bulge and later it is removed, rodentlike, from the entire posterior surface. Enamel is preserved around the medial surface and higher on the broader anterolateral surface, but in advanced wear it is removed part way up the anterior angle, broadening, but somewhat blunting, the cutting edge.

In *Trogosus*  $I^2$  has become relatively much enlarged (see plates). It is long, sharply curved, and evidently grew from persistent pulp. In cross section, which increased markedly in size with growth and eruption during earlier life, it was more decidedly triangular than the root portion in *Esthonyx*. Its anterolateral surface is broadly convex and the shorter medial or anteromedial surface is nearly flat to slightly concave or broadly grooved. The posterointernal and posteroexternal angles are rounded and the intervening posterior surface is rather distinctly concave, more so than the medial surface. Enamel was developed around the anterior portion of the tooth, extending much farther posteriorly on the anterolateral surface than on the medial. As in *Esthonyx*, wear is rodentlike on the posterior surface with a transversely convex cutting edge of enamel.

The third upper incisor has not been observed complete in a premaxilla of *Esthonyx*, unless the loose teeth shown in this position in



figure 8 are actually incisors and not from the canine alveoli, but broken portions and alveoli of other specimens show  $I^3$  to have been only a little smaller than  $I^2$ . It is a little shorter and more nearly oval in cross section at the alveolar margin. The basal portion of the crown shows a compressed anteromedial and posterior longitudinal margin with a broad and strong bulge between the margins posteromedially. In *Trogosus* also,  $I^3$  is relatively large. In the skull of *T. hyracoides* (pls. 2 and 3) it is seen to be strongly curved and probably rooted. It is nearly oval in cross section and enamel covers only the lateral and anterior wall in the stage of wear observed. Wear has truncated the tooth bluntly with the bevel rising forward, resulting from articulation forward with  $I_2$ .

The canines in the tillodonts, unlike the second incisors, show progressive reduction. The upper canine in Gray Bull *Esthonyx* has a diameter not greatly different in size from that of  $I^2$  but is scarcely caniniform in the conventional sense and has a crown rather like that of the somewhat smaller  $P^2$ , single-cusped and posteriorly broad. It does, however, have a single heavy root. In Lost Cabin *Esthonyx* the upper canine is still relatively large, much larger than  $P^2$ , but has lost in relative importance to the incisors. In *Trogosus* (pl. 3) the canine has a simple, transversely compressed but blunt conical crown, scarcely greater in diameter than the root, and nearly as small as  $P^2$ .

$P^2$  in *Esthonyx* (figs. 7 and 8) is a simple, single-cusped, two-rooted tooth, transversely compressed along the anterior margin, but less so posteriorly. In *Trogosus* (pl. 3) the tooth is small and peglike with a somewhat flattened, blunt conical crown, about the same diameter as its single root.

In contrast with  $P^2$ , the third and fourth upper premolars are large and functional teeth in the tillodonts. Both of these have prominent talons, which in  $P^3$  in *Esthonyx* (figs. 7 and 8) is anteroposteriorly narrow, but has a well-developed deuterococone. In  $P^4$  the deuterococone extends prominent crests anteroexternally and posteroexternally toward the external angles of the tooth and may in some individuals, particularly in the Lost Cabin stage, exhibit a small tetartocone or hypocone at the internal extremity of the posterior cingulum. The primary cusp of  $P^3$  is single, but in  $P^4$  a separate tritocone is exhibited. The parastyle on  $P^3$  is generally but weakly developed and not expanded buccally as in  $P^4$ ; however, the metastyle is similarly developed in the two teeth.  $P^3$  lacks a distinct external cingulum on the forward part of the tooth. In *Trogosus* (pl. 3)  $P^3$  and  $P^4$  are surprisingly like those in *Esthonyx*, except for their much greater size; however, the deuterococone of both  $P^3$  and  $P^4$  may be relatively longer

anteroposteriorly and more crested, and in  $P^4$  the tritocone and tetartocone perhaps relatively weaker, although the external styles appear to be more powerfully developed.

The upper molars in tillodonts (figs. 7 and 8; pls. 3, 7, 11, and 15) are characterized by widely sweeping hypoconal crests, which in some material of *Esthonyx* (figs. 10 and 11) appears to be more nearly a cusp. In *Trogosus* the hypoconal crest may sweep higher on the protocone. The basin between the three primary cusps in *Esthonyx* is relatively unadorned, but in *Trogosus* this basin is characterized by a distinctive enamel loop, having in the unworn type tooth of *T. latidens* (fig. 16) somewhat the form of a question mark with its lower point rising as a low ridge medially on the external wall of the protocone. In the external half of the molars the paracone and metacone in Gray Bull *Esthonyx* are moderately prominent, although they appear to be transversely compressed in some material, and exhibit, lateral to each, a wide shelflike cingulum rising to an outstanding style at the anterior and posterior angles of the tooth. The parastyle, the more prominent of the two, increases somewhat from  $M^1$  to  $M^3$ , whereas the metastyle crest is, of course, together with the hypocone, very greatly reduced on  $M^3$ . In *Trogosus* the paracone and metacone show a rather heavier lateral buttress extending to the base at the expense of the cingulum which has lost its shelflike appearance. The anterointernal cingulum of *Esthonyx* is also much reduced or lost in *Trogosus*. The metastyle and particularly the parastyle are well developed in *Trogosus*.

In the lower jaw the incisors are three in number, except in *Tillodon*, and in *Esthonyx*  $I_1$  is only a little smaller than  $I_2$ . The first two lower incisors in *Esthonyx* (fig. 2a, b) are long and but gently curved. Their root portion in cross section is nearly oval with the long axis fore and aft. The posterior portion is more compressed transversely, and enamel extends well down on the forward surface of the root. The crown of  $I_1$  has not been observed, but that of  $I_2$  is much like that of  $I^2$  except that it is smaller, narrower, and the posterior part is compressed transversely and posteriorly extended.

In *Trogosus* the discrepancy in size between  $I_1$  and  $I_2$  is tremendous.  $I_1$  is scarcely or but little larger than in *Esthonyx* whereas  $I_2$  has become several times larger than in the earlier genus.  $I_1$  has become very elongate, however, and, like  $I_2$ , may have had persistent growth. In cross section it appears to have been a transversely flattened oval with a possible increase in the anteroposterior diameter in depth. The cross section of  $I_2$  has changed from a near oval in *Esthonyx*, transversely attenuated posteriorly, to an almost lemniscate outline in some individ-

uals of *Trogosus*, with the anterior lobe the larger. Enamel is limited to the anterior portion in both  $I_1$  and  $I_2$ , and in  $I_2$  it extends somewhat farther back on the lateral than on the medial wall. The diameter of the cross section of the *Trogosus*  $I_2$  increased distinctly with growth and eruption in earlier life, although this process seems to have reversed in more aged individuals with some shrinkage in diameter, a more rounded lateral wall, and disappearance of enamel, to judge by isolated incisors from Huerfano "B" beds. This might appear to discredit growth from persistent pulp; however, there is no doubt but that the incisor was in a process of growth during earlier wear, probably throughout life, and that at no time was the incisor complete.

$I_3$  is very small in both *Esthonyx* (fig. 2a, b) and *Trogosus* (pls. 2 and 4), and apparently lost in *Tillodon* (pl. 16). In the material of *Esthonyx* in which this tooth is preserved, the crown is much less elongate longitudinally and, in the stage of wear presented, enamel is shown only as a small patch on the anterolateral wall, forming the cutting edge. In *Trogosus* this tooth has become peglike with a slightly oblong cross section. In the particular specimen in which this tooth is observed, enamel was preserved around the lateral and anterior surface, apparently in a stage of wear in which only the basal portion of the crown remains.

The lower canine in *Esthonyx* (fig. 2a) is even larger and would appear to be functionally more important than  $I_2$ . The crown portion of this tooth is strikingly like that of  $I_2$  in form, but the root portion is not compressed posteriorly. It is rather distinctly procumbent, almost as much so as the incisors, and closely follows the reduced  $I_3$ . Its functional significance is almost lost in *Trogosus* (pls. 2 and 4) and it has become almost peglike, little larger than  $I_3$ , to which it is closely appressed, and with it decidedly procumbent. In the specimen in which this tooth is preserved, wear has reduced the crown so that the enamel is not complete around the medial and posterior surface.

$P_2$  is simple, but more nearly oval in outline in *Esthonyx*, and in all instances observed the tooth is set with its anterior root noticeably external to the posterior, with its long diameter often about  $45^\circ$  from the alignment of the cheek-tooth series. The second lower premolar is not in place in any of the *Trogosus* jaws at hand and it has not been recognized in loose teeth; however, it is clearly single-rooted and of relatively small size, as shown by its alveolus.

$P_3$  is relatively simple in *Esthonyx* (figs. 1, 2a, and 5) with a moderately high single-cusped anterior portion, but with a basined talonid. No evidence of a paraconid or metaconid was observed in any of the

material at hand, and in the talonid, which is variable in size, only the externally placed hypoconid is distinct on the crest which bounds it.  $P_4$  (figs. 2a, 3, 5, and 9), however, is almost completely molariform. Its distinction from the molars lies in the relatively longer trigonid, with the paraconid widely separated from the metaconid, and the smaller talonid. It also lacks the metastylid characteristic of the molars. In *Trogosus* (pls. 2, 4, 6, and 8) these two premolars have become more globular in appearance, and in both the talonid is relatively much reduced. The trigonid of  $P_3$  in some of the middle Eocene specimens may show evidence of a weak paraconid and metaconid, or, rather, somewhat compressed lingual ridges on the protoconid in these positions, and in  $P_4$  the paraconid is relatively not so widely separated from the metaconid.

Characteristic of the tillodont lower molars (figs. 1-5, 9, 12, 14, 17-19; pls. 4, 7, and 16) is the U-shaped crested trigonid and talonid, in which the trigonid is more elevated, and in *Esthonyx* anteroposteriorly more compressed. The paraconid is lingual in position and the anterior and posterior transverse crests of the trigonid are nearly parallel. The metastylid part way down the posterior margin of the metaconid seems invariably present. The crest of the talonid is not joined directly with the metastylid in *Esthonyx* but originates below the posterior crest of the trigonid about midway on the posterior surface. The crest is continuous to the entoconid, with the hypoconid, hypoconulid, and entoconid distinct, but is separated by a deep notch from the metastylid posteriorly. In *Trogosus* the crest forward from the hypoconid originates closer to the metastylid and may appear to join it directly in some teeth with only a slight groove between, which, of course, would be obliterated by wear. Although most of the *Trogosus* teeth examined are rather worn, the individual cusps forming the crest of the talonid would appear to have lost much of their identity, except in  $M_3$ . In the last lower molar of both *Esthonyx* and *Trogosus* the talonid is distinctly bilobed, but the development of the last lobe or hypoconulid portion appears rather variable both as to its posterior extent and width. A peculiarity noted in the systematic description of the Huerfano "B" materials of *Trogosus* is the more complete division of the talonid basin of  $M_3$  in specimens from that horizon. A feature also noted in a foregoing section, but characterizing the tillodonts as an order, is the discrepancy in the height of inner and outer walls of the lower molars, and perhaps to a lesser extent the upper molars. Viewed from the lingual side the lower molars and posterior lower premolars appear brachydont as well as cuspsate, but externally they are strikingly hypsodont and columnar. This is least

noticeable in Paleocene and Sand Coulee materials, but is climacteric in the Bridger. Wear shows that these teeth must erupt with rotation along an axis parallel to the tooth row.

Very few specimens having milk teeth are known of *Esthonyx* and so far none has been observed of *Trogosus*. Deciduous premolars of *Esthonyx latidens* (fig. 11) were figured by Simpson (1937, fig. 4) and a few juvenile specimens of Gray Bull *E. bisulcatus* are extant.  $Dp^3$  in the Gray Bull material has a talon rather like  $P^3$ , but the parastyle seems better developed with a slightly better-developed external cingulum, and the primary cusp is weakly twinned.  $Dp^4$  is structurally much like  $M^1$ , except that it is relatively narrower transversely and in some specimens the hypoconal portion projects inward more at the base of the crown. In the lower series  $Dp_3$  does not differ greatly from  $P_3$ , except for compressed ridges down the paraconid and metaconid section of the protoconid, observed in *E. grangeri*. The talonid portion of  $Dp_3$  in *E. grangeri* cannot be observed, owing to hematite matrix.  $Dp_4$  in *E. bisulcatus* as well as *E. grangeri* is seen to be very elongate both in the trigonid and talonid portions. The paraconid is well forward of the metaconid as in  $P_4$ , but the talonid basin is larger and more elongate as in  $M_1$ .

#### HYOID ARCH

Right and left portions of elements believed to be the stylohyal and epihyal (fig. 22) are included among the materials of the *Trogosus*



FIG. 22.—*Trogosus grangeri*, new species: Stylohyal and possibly epihyal (A.M. No. 17008), type specimen, outer view,  $\times \frac{3}{8}$ . Huerfano (B) middle Eocene, Colorado.

*grangeri* type. If properly identified and oriented the stylohyal exhibits a prominent bifurcation with a much flattened bladelike process extending downward, separating from the body or shaft well below the proximal extremity which would be joined by cartilaginous material to a small process adjacent to the notch for the facial nerve in the basicranium. The element thought to be the epihyal is elongate and only slightly flattened, but is otherwise without significant features.

## VERTEBRAE

No complete series of tillodont vertebrae are known; however, the general features can be ascertained from segments of the column belonging to different individuals. The atlas, 6 dorsals, and 14 caudals are preserved in the skeletal remains composing the type of *Trogosus grangeri*, A.M. No. 17008. A third cervical is associated with a jaw, U.S.N.M. No. 18164, referred to *Tillodon fodiens* and the fourth cervical to first dorsal, inclusive, are in the material, U.S.N.M. No. 17886, belonging with the Bridger *Trogosus hyracoides* skull. Lumbar bars are represented only in *Esthonyx* material. There are, however, several fragmentary vertebrae, mostly centra, associated with the skull of *Tillodon fodiens*, Y.P.M. No. 11087.

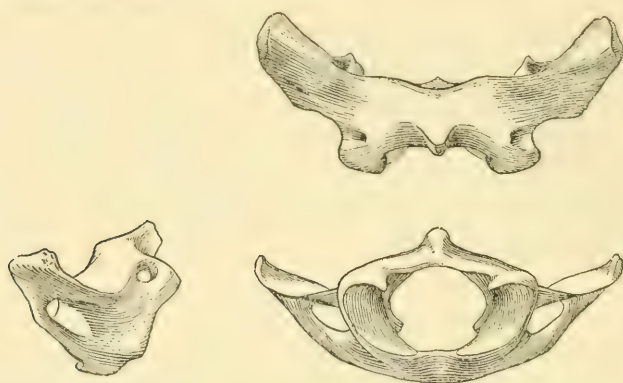


FIG. 23.—*Trogosus grangeri*, new species: Atlas vertebra (A.M. No. 17008), type specimen, dorsal, lateral, and anterior views,  $\times \frac{1}{2}$ . Huerfano (B) middle Eocene, Colorado.

The tillodont cervical vertebrae are characterized by their shortness and noticeable breadth. The processes are strong and the zygapophyses carry relatively large articular surfaces. The atlas (fig. 23) vertebra in *Trogosus grangeri* is remarkably short but exhibits narrow, widely extended transverse processes which sweep backward and upward. The transverse processes are penetrated fore and aft by a strikingly large vertebral arterial canal. The anterior surfaces for articulation with the condyles of the skull are deep and recurved above. Above and posterior to each of the surfaces for the condyles a moderate-size foramen for the first spinal nerve perforates the arch transversely. A rather pronounced process in the position of the spine is developed on the dorsal surface at its forward margin. The large posterior articular surfaces for the axis are gently concave and encroach medially upon the opening of the arch.

The superior surface of an incomplete atlas associated with *Esthonyx* material, A.M. No. 4276, was figured by Cope (1884a, pl. 24c, fig. 3). This atlas is anteroposteriorly shortened as in *Trogosus*, but the specimen is much damaged and the transverse processes are missing, so that detailed comparison is not feasible. It was noted, however, that the foramen for the first spinal nerve has its outer opening more posterior in position.

The axis vertebra is included among the materials, A.M. No. 17011, of *Trogosus* from the Huerfano. The vertebra is very short and its anterior surface shows a large odontoid process and articular surfaces for the atlas. The posterior surface of the centrum is incomplete but in an *Esthonyx* specimen, figured by Cope (1884a, pl. 24c, fig. 4), it

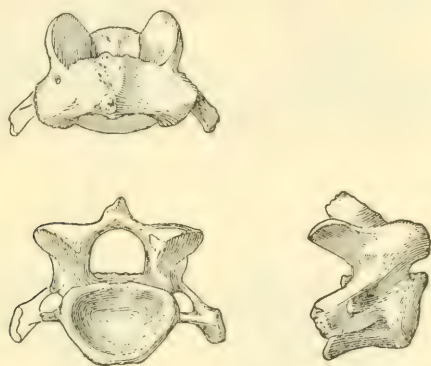


FIG. 24.—Cf. *Tillodon fodiens* (Marsh), new genus: Third cervical vertebra (U.S.N.M. No. 18164), dorsal, posterior, and lateral views,  $\times \frac{1}{2}$ . Bridger (B) middle Eocene, Wyoming.

it seen to have a marked upward and forward slope. The arch is very high in contrast with its shortness, and the superior margin of the spine apparently slopes sharply downward and forward. High on the posterior margin of the arch the large postzygapophyses face downward, outward, and somewhat posteriorly. The transverse processes directed backward and outward from immediately behind the surfaces for articulation with the atlas do not appear to be so well developed as in the atlas and third cervical vertebra (fig. 24). The vertebrarterial canal is obscured by matrix.

The remaining cervicals of *Trogosus*, however, have short, broad centra and sturdy arches. The transverse processes are narrow, backward sweeping and, except for the seventh, have good-sized vertebrarterial canals. The zygapophyses are widely expanded for the nearly circular articular surfaces.

The dorsal series in *Trogosus* is known by but six vertebrae (fig. 25). Four of these are marked as having been found in articulation. The centra are noticeably narrower than in the cervical series and become deeper and more elongate posteriorly. The arches exhibit spines moderately short and slender, which in the forward part of the series of four are directed strongly backward. Posteriorly the spines are shorter and expanded fore and aft. The articular surfaces of the zygapophyses are, of course, much smaller than in the cervical series, and in the fourth of the articulated four, the change from nearly horizontal

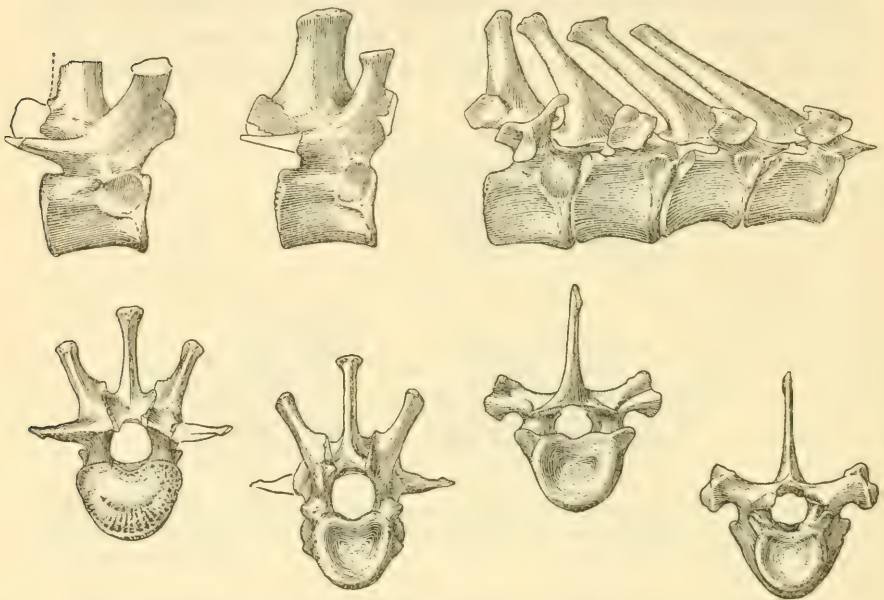


FIG. 25.—*Trogosus grangeri*, new species: Dorsal vertebrae (A.M. No. 17008), type specimen; above, lateral view; below, posterior and anterior views of second vertebra from left and second vertebra from right, respectively, of the series shown above;  $\times \frac{1}{2}$ . Huerfano (B) middle Eocene, Colorado.

to nearly vertical takes place. Also at this point the metapophyses and anapophyses appear slender and elongate, and this may well be the last vertebra to have an articular facet for the tubercle of the rib. The above transition in modern *Canis* and *Felis* is at about the tenth dorsal, suggesting that the four vertebrae preserved are well back in the series. Posteriorly in *Trogosus* the metapophyses and anapophyses are decidedly prominent, the metapophyses rising nearly as strongly as the spine.

Lumbar vertebrae of *Trogosus* are not known but those of *Esthonyx*, if correctly associated, show these vertebrae to be decidedly



elongate, and with the centra dorsoventrally somewhat flattened. The transverse processes are slender, flattened, and strike forward from the upper portion of the centrum. The anterior zygapophyses face medially and are strongly concave. The spine between them is transversely compressed and rises forward over about the anterior half of the length of the vertebra. The lower surface of the centrum is transversely compressed to form a slight keel, but without significant development of a hypapophysis.

A series of 14 caudal vertebrae (fig. 26), apparently in articulation and probably incomplete at both ends, belong to the *Trogosus grangeri* skeleton. These are broad and robust, showing that *Trogosus* had a long and heavy tail. Those preserved increase in length from the first

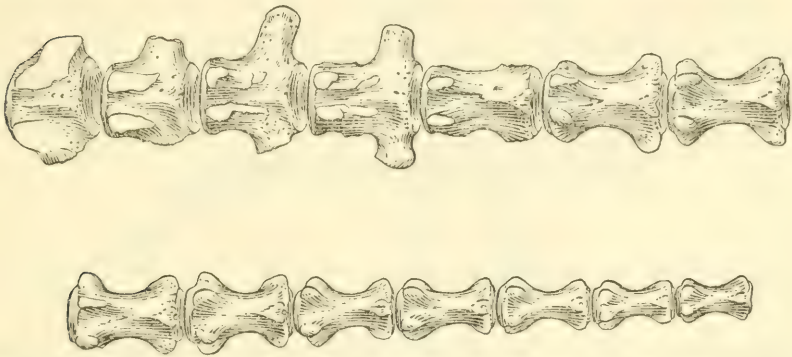


FIG. 26.—*Trogosus grangeri*, new species: Caudal vertebrae (A.M. No. 17008), type specimen, dorsal view,  $\times \frac{1}{2}$ . Huerfano (B) middle Eocene, Colorado.

to the sixth and then shorten again posteriorly. None shows the neural arch complete but it may have originally bridged the neural spine in the first three or four of those present. The first four or five show prominent transverse processes extending laterally from just below the midsection of the posterior portion of the centrum. Posteriorly they are much reduced and the anterior pair becomes equally important. The fifth of the series is the first to show a separate prominent process serially continuous with the pedicles for the postzygapophyses. This is in the form of an arch with a very small longitudinal foramen. In the tenth vertebra this foramen also becomes uncovered dorsally. On the under surface, beginning with about the third or fourth, a pair of anteriorly placed hypapophyses appear, and posteriorly become developed equivalent to the anterior transverse processes and metapophyses. No haemapophyses or chevron-bones were associated with the above described caudal vertebrae.

## RIBS

A portion of the rib basket is included with the material belonging to the type of *Trogosus grangeri*. The series is not sufficiently complete to note detailed changes with position; however, the ribs are well rounded for the most part, becoming flattened only near the extremities. The tubercle and head are about equally developed and show but little difference in spacing through much of the series. The point at which articulation with the transverse process is lost cannot be determined. No sternal ribs are recognized in the collections nor are any portions of the sternum at hand.

## CLAVICLE

The clavicle (fig. 27) belonging to *Trogosus grangeri* is elongate and only a little smaller in diameter than an average rib. The sternal extremity is expanded and markedly cupped for its union with the



FIG. 27.—*Trogosus grangeri*, new species: Left clavicle (A.M. No. 17008), type specimen, anterior view,  $\times \frac{3}{4}$ . Huerfano (B) middle Eocene, Colorado.

presternum. In its double-curved sweep toward the scapula the distal portion becomes flattened for a broad but not sharply defined contact with the acromion.

## SCAPULA

The *Trogosus* scapula, as exemplified by *T. grangeri* (fig. 28), is very broad proximally, giving the bone a nearly quadrangular rather than triangular appearance, with the spine running diagonally from the anterosuperior angle to the posteroinferior portion. The prescapular fossa is thus broad near the glenoid extremity and becomes very narrow though deeply pocketed near the suprascapular border. Conversely, the postscapular fossa is very wide superiorly and narrow below with the glenoid border converging sharply with the spine. The spine itself rises very high with its crest deflected posteriorly in the lower part, presenting an increasingly broad lateral surface toward the acromion. The tip of the acromion projects downward and forward slightly beyond the glenoid cavity but is not bifurcate. The glenoid cavity is a nearly oval-shaped concavity, transversely somewhat restricted forward. The coracoid portion is set off medially from the

anterior extremity of the glenoid surface and, although fused to the scapula, it is separated from the glenoid surface rather distinctively by a deep notch or groove. The subscapular fossa shows no important

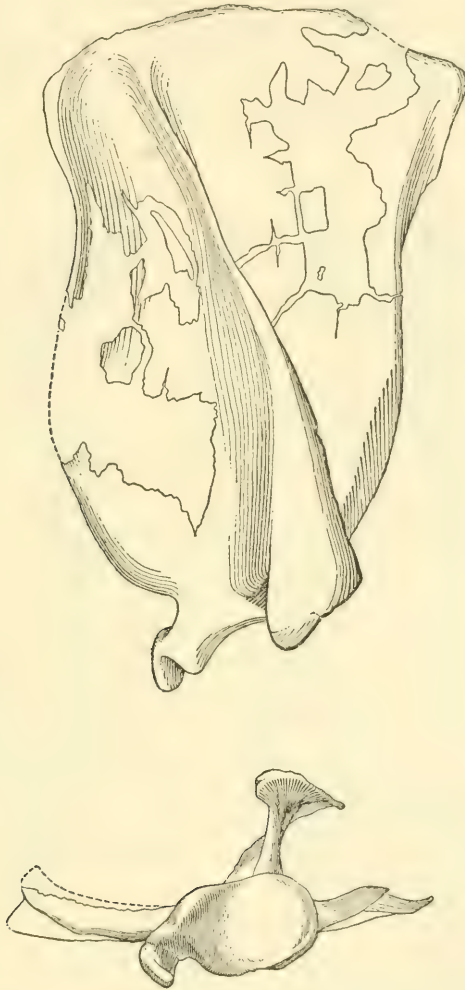


FIG. 28.—*Trogosus grangeri*, new species: Left scapula (A.M. No. 17008), type specimen, lateral and distal views,  $\times \frac{1}{2}$ . Huerfano (B) middle Eocene, Colorado.

details, other than a ridgelike extension downward on its surface of the superior portion of the posterior border, with a strong flange or flexure of the lower part of the posterior border, posterior to the ridge.

The scapula of *Trogosus* is rather unlike that of any other animal to which it might be compared. It does not particularly resemble any

carnivores with which it was compared, and is decidedly different from the scapula of *Stylinodon mirus*. The anterior border expands near the lower extremity somewhat as in *Phenacodus* but no other special resemblances were noted with Cope's figure (1884a, pl. 57c). Among the larger modern insectivores neither *Erinaceus* nor *Solenodon* shows an expansion of the lower part of the prescapular fossa and in these the postscapular border is approximately parallel to the spine. Also, the acromion is strongly bifurcate.

#### HUMERUS

Several incomplete humeri are known belonging to individuals of *Trogosus*, mostly from the Huerfano "B" horizon, and one of a Gray Bull *Esthonyx*. There is, however, a nearly complete humerus belonging with *Trogosus* material bearing A.M. No. 17011 (fig. 29) from the Huerfano. These have a distinctly insectivore-like appearance, rather like that in *Erinaceus* and *Solenodon*. This is most noticeable in the proximal extremity with the head set back more nearly in the line of the shaft than in, for example, the carnivores, and with the tuberosities closely contained. The lesser tuberosity is a broadly rounded protrusion for insertion of the *subscapularis* and projects but little beyond the anteromedial margin of the head. The greater tuberosity is large and prominent, extending very little if any above the head and not flaring forward as in so many carnivores. The greater tuberosity is somewhat as in *Erinaceus*, but with a better-developed bicipital groove and no aperture into the head from between the tuberosities. In *Solenodon* the anterior portion of the greater tuberosity curves inward markedly toward the lesser tuberosity. The outer and posterior surface of the greater tuberosity in *Trogosus* is markedly scarred, apparently for the *teres minor* which would originate on the prominent flange of the lower part of the posterior border of the scapula.

On the shaft of the humerus the deltoid ridge is very outstanding and projects distally below the middle of the bone. The proximal part of this ridge may be weak or subdued where it joins the greater tuberosity, as indicated in various fragmentary humeri of *Trogosus* and *Esthonyx*, but is noticeably outstanding at this point in the complete humerus belonging to A.M. No. 17011. Distally in the latter specimen it becomes very rugged in the vicinity of the insertion of the *deltoid*. The prominence of this abducting muscle is also attested to by the outstanding posterolateral margin of the spine and its acromion on the scapula where a portion of this muscle originates. The deltoid ridge

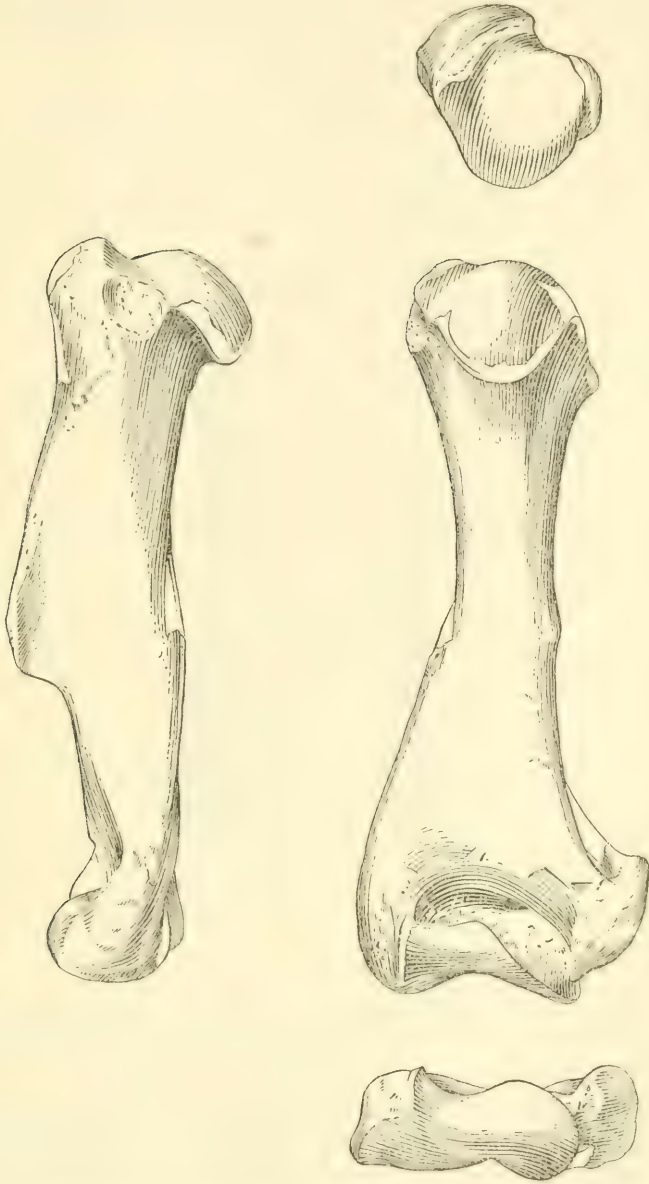


FIG. 29.—*Trogosus*, species: Left humerus (A.M. No. 17011, restored proximally from specimen associated with U.S.N.M. No. 17157), proximal, lateral, posterior, and distal views,  $\times \frac{1}{2}$ . Huerfano (D) middle Eocene, Colorado.

is comparatively weak in *Erinaceus* and though strong in *Solenodon* would appear to be differently constructed, presenting a broad surface posterolaterally between crests running from the anterior as well as the posterior extremities of the greater tuberosity.

On the distal part of the shaft the supinator ridge is prominently

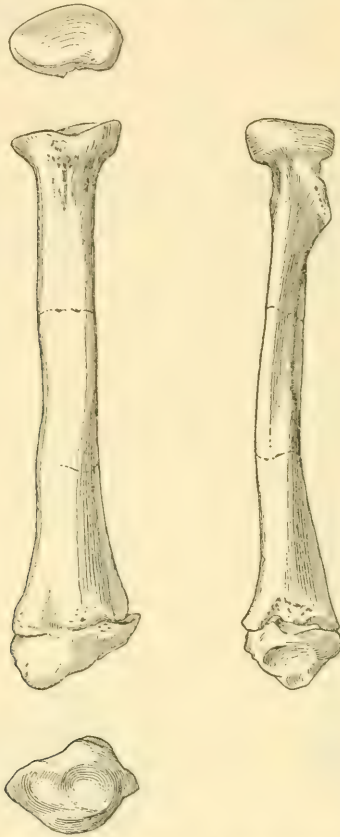


FIG. 30.—*Trogosus hyracoides* (Marsh): Left radius (U.S.N.M. No. 17886), proximal, anterior, lateral, and distal views,  $\times \frac{1}{2}$ . Bridger (B) middle Eocene, Wyoming.

developed and extends farther proximally than in *Solenodon*. It is comparatively weak in *Erinaceus*. Medially, the distal extremity is much expanded and exhibits a large entepicondylar foramen, about as in *Solenodon*. In *Erinaceus* the inner condyle is relatively reduced and there is no entepicondylar foramen. The distal extremity of the *Trogosus* humerus is a little like that in *Patriofelis*, which is of comparable size, but is transversely broader with a wider articular surface. Also,

the supinator ridge extends rather smoothly upward a greater distance on the shaft and apparently is not flexed posteriorly so markedly as in the creodont.

#### RADIUS

A complete radius (fig. 30) was associated with the skull and other material of *Trogosus hyracoides*. Incomplete radii were also found associated with materials of *Trogosus hillsii* and *Tillodon fodiens*. The shaft of the *Trogosus* radius is slender proximally, with a much expanded extremity for articulation with the humerus above and the ulna posteriorly. Just below the proximal expansion, on the posterior surface of the shaft, the tuberosity for the biceps is prominent and rugged. Distally the shaft increases in diameter and the interosseous crest extends prominently along the posterolateral margin. Immediately lateral to the crest proximally, the shaft is longitudinally scarred, possibly for extensor and abductor muscles which would normally originate on this side of the interosseous membrane. Distally, the anterior surface of the radius shows medially only a broad, shallow groove for the radial extensors and externally a less well-defined depression for the digital extensors. The distal extremity of the radius is much enlarged and extends distally a greater distance in its antero-medial portion. Its articular surface for the lunar is a nearly circular, gentle concavity extending more flattened mediolaterally over the scaphoid. On the posteromedial margin there is a small, slightly concave, transverse facet for the ulna.

As might be expected, the portion of a radius included in the *Tillodon fodiens* material is rather distinctly more robust, particularly in the anteroposterior depth of the shaft and, laterally, of the distal extremity. The distal articulation between the radius and ulna would appear to be much broader.

#### ULNA

No complete ulna is extant among the known tillodont materials; however, from the greater part of a shaft and a separate olecranon portion associated with the skull of *T. hillsii*, together with a distal portion from *Tillodon fodiens* and a distal epiphysis belonging to *Trogosus hyracoides*, a composite picture (fig. 31) can be obtained. Among the materials of *Esthonyx* only an olecranon portion was observed.

The *Trogosus* olecranon is elongate, robust, and transversely much expanded at the proximal extremity, giving good leverage and a large area for the insertion of the triceps. The medial surface of the bulbous

extremity is deeply cleft, noticeable also in *Esthonyx*. The sigmoid notch or cavity is widely flaring distomedially and laterally the lesser sigmoid cavity exhibits two well-separated surfaces for the head of the radius. Below the sigmoid cavity the shaft is transversely com-

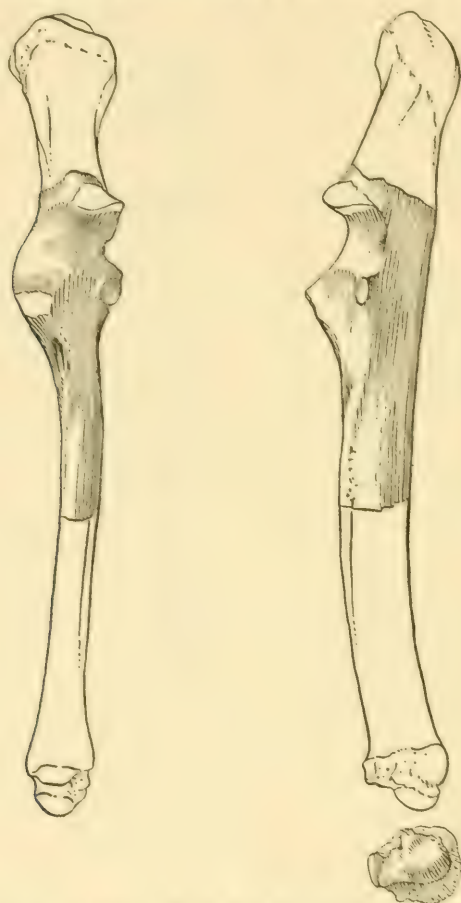


FIG. 31.—*Trogosus*, species: Left ulna (associated with U.S.N.M. No. 17157, type of *Trogosus hillsii*, new species; olecranon restored from second specimen associated with type of *T. hillsii*; distal extremity restored from U.S.N.M. No. 17886 of *Trogosus hyracoides*), anterior, lateral, and distal views,  $\times \frac{1}{2}$ . Huerfano (B) and Bridger (B) middle Eocene, Colorado and Wyoming.

pressed in *Trogosus* with a prominent interosseous crest as in the radius. The distal extremity shows a convex facet on the forward and medial margin for the radius, and a small saddle-shaped surface between that and the styloid process, which, together with the styloid process, articulates with the cuneiform. The posterior portion of the styloid process articulates also with the pisiform.



In *Tillodon fodiens* the distal portion of the shaft represented is considerably more robust, less flattened, and the large styloid process extends relatively farther distally.

#### MANUS

The tillodont forefoot is rather well represented among specimens from the middle Eocene. The type of *Trogosus grangeri* includes

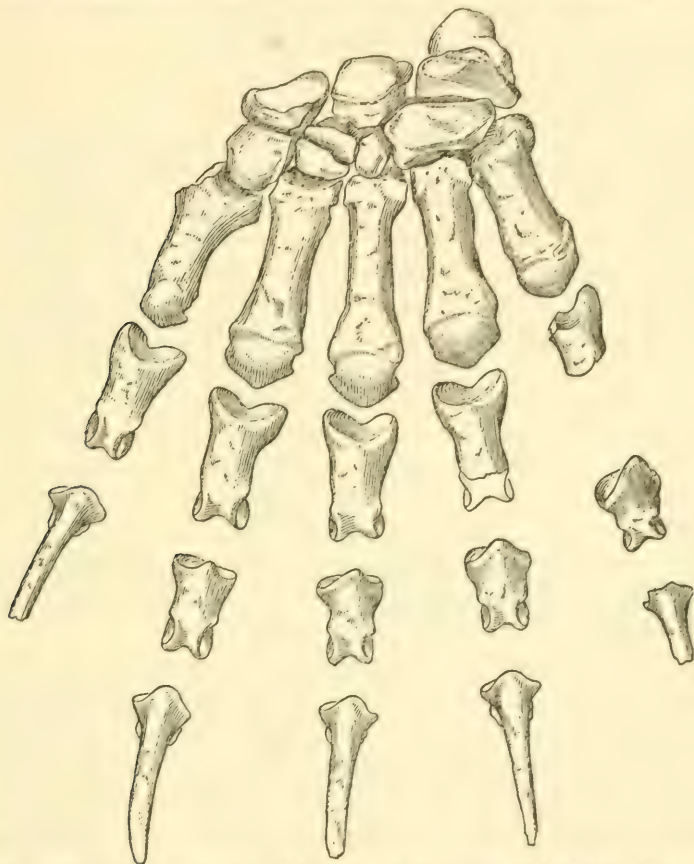


FIG. 32.—*Trogosus hyracoides* (Marsh): Left manus (U.S.N.M. No. 17886), dorsal view,  $\times \frac{3}{4}$ . Bridger (B) middle Eocene, Wyoming.

several phalanges as well as metacarpals and a few carpals, and a second *Trogosus* specimen from the Huerfano, A.M. No. 2692, includes several elements of the manus, principally phalangeal. A specimen regarded as representing *Trogosus hyracoides*, A.M. No. 18982, from the Bridger, includes most of the left manus, and there are portions of the forefoot in the material belonging to the type of *Tillodon fodiens*. The most nearly complete foot (figs. 32 and 33), lacking only

the distal portions of two phalanges, is that associated with the skull of *Trogosus hyracoides*, U.S.N.M. No. 17886. Much of the opposite or right forefoot of the same individual is present also. From the lower Eocene the proximal portion of a manus (fig. 34), including the carpals and proximal portions of the metacarpals in articulation, is associated with jaw material of a Gray Bull *Esthonyx*, A.M. No. 4276 (Cope, 1884a, pl. 24c, figs. 8, 8a, 8b; 1884b, fig. 24b). Caution must be exercised, however, with respect to this manus as a certain admixture of skeletal materials under this number was noted, part of which may be creodont.

The tillodont forefoot appears to be a generalized primitive structure in which the scaphoid, lunar, and centrale are all separate and the five unguiculate digits show nearly equivalent development. As noted by Gregory (1910, p. 445) for the *Esthonyx* specimen, the trapezium is relatively large and the lunar rests about equally on the centrale, magnum, and unciform. He considered the *Esthonyx* carpus as suggestive of the creodont type; however, I see no special resemblance to that group in *Trogosus*, other than a similar primitive arrangement noted in several groups of early mammals, and the hind foot is rather less suggestive of creodonts. The carpus shows a basic arrangement which may be compared favorably to that in the periptychids and in *Pantolambda*, although the details of the individual elements would probably show many differences. The phalanges are, of course, markedly different. It is interesting to note that among insectivora the modern *Erinaceus* has the scaphoid, lunar, and centrale fused, whereas in *Solenodon* they are separate. The tillodont carpus does not otherwise particularly resemble that in *Solenodon*.

*Scaphoid*.—In dorsal view the *Trogosus* scaphoid (fig. 33a) would appear to be a triangular wedge with proximal surface for articulation with the radius converging forward and medially toward the distal surface for the trapezium. Proximally the surface for the radius is dorsopalmar convex and transversely very slightly concave, and has a quadrilateral outline with its shortest side medial. The lateral side of the scaphoid is much higher than the medial, proximodistally, and although it fits snugly with the lunar it shows only a very small facet, adjacent to the proximopalmar extremity of the facet for the radius, for articulation with the lunar. Along the distal margin of the external surface, the scaphoid exhibits a slender facet for the centrale. Distally the scaphoid shows a large and nearly rectangular facet, slightly concave dorsally and convex palmar, for the trapezium. The palmar surface and the palmar portion of the medial surface of the scaphoid pro-

ject prominently to form a deep, transversely elongate, and smoothly rounded process presumably having a ligamentous attachment.

The scaphoid of the *Esthonyx* specimen (fig. 34) would appear to be much like that in *Trogosus* except that it is relatively wider transversely, and the proximal articular surface for the radius is relatively wider and more convex dorsopalmar.

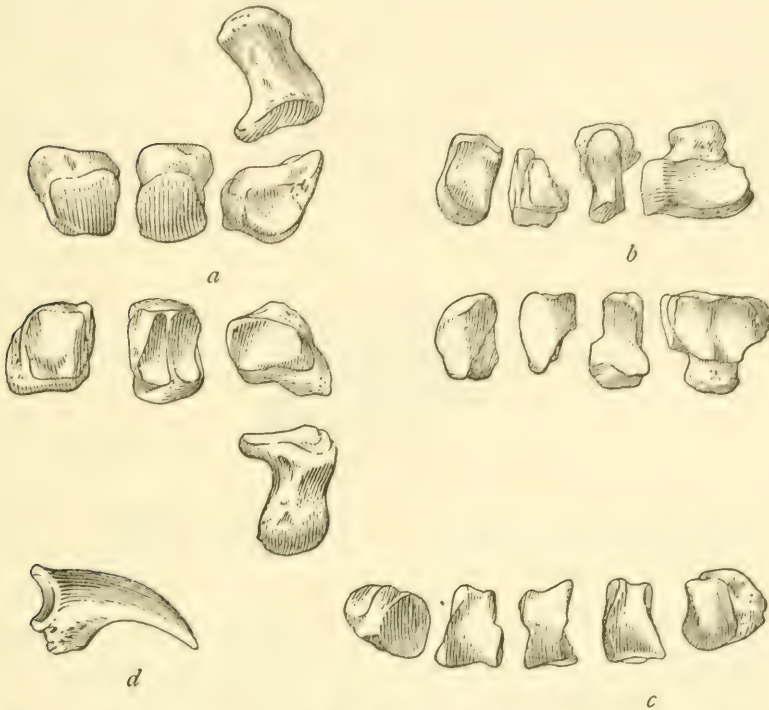


FIG. 33.—*Trogosus hyracoides* (Marsh): Left carpals, metacarpals, and distal phalanx (U.S.N.M. No. 17886); *a*, proximal (above) and distal (below) views of scaphoid, lunar, cuneiform, and pisiform; *b*, proximal (above) and distal (below) views of trapezium, trapezoid, centrale (proximal only), magnum, and unciform; *c*, proximal view of metacarpals I to V; *d*, medial view of distal phalanx of 2d digit;  $\times \frac{2}{3}$ . Bridger (B) middle Eocene, Wyoming.

*Lunar*.—The lunar of *Trogosus* is less wedgelike, as seen dorsally (fig. 33a), and more nearly rectangular, as seen in proximal and distal views, than the scaphoid. Its surface for articulation with the radius covers the dorsal two-thirds to three-quarters of the proximal surface (about half in the dorsopalmar elongate lunar of *Tillodon*) and is convex transversely as well as in a dorsopalmar direction. The lateral and medial surfaces are without facets for the cuneiform and scaphoid. Distally, the lunar shows three subequal dorsopalmar elongate surfaces

for the centrale, magnum, and unciform. The distomedially-facing facet for the centrale is more flattened than the others, broad dorsally, but pinches out toward the palmar extremity. The central facet for the magnum is narrow dorsally, widens in a palmar direction, and is distinctly concave both dorsopalmar and transversely. The distolaterally-facing facet for the unciform is broad dorsally, narrows slightly toward the palmar margin, and is concave only in the dorso-palmar direction. As in the scaphoid, the palmar portion of this bone is much expanded or inflated, evidently also supporting a ligamentous attachment.

The lunar belonging to the foot of the *Esthonyx* specimen is likewise very like that in *Trogosus*, but more arcuate as seen from the side, with a more convex dorsopalmar profile for the proximal surface and a more concave profile for the distal surface.

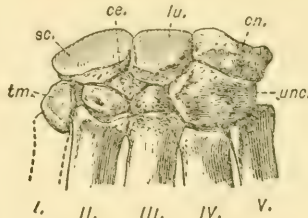


FIG. 34.—Cf. *Esthonyx bisulcatus* Cope: Left manus (associated with A.M. No. 4276), dorsal view (cuneiform drawn upside down),  $\times 1\frac{1}{2}$ . Gray Bull lower Eocene, Wyoming.

*Cuneiform.*—The *Trogosus* cuneiform is roughly triangular viewed proximally (fig. 33a), and has a broad anterior surface that sweeps widely around the lateral side to the palmar extremity. The facet for the ulna is slightly concave and nearly circular, truncated toward the palmar margin by the transversely elongate facet for the pisiform. A single facet for the unciform covers most of the distal surface, with the exception of a very small facet for the fifth metacarpal at its lateral extremity. The medial portion of the unciform facet has a greater dorsopalmar extent and is slightly concave, whereas the more constricted lateral portion is convex. Medially this bone is moderately deep, dorsoventrally, and shows no facet for articulation with the lunar. Laterally it tapers nearly to a point at its palmar extremity. The palmar portion does not show the expansion noted in the scaphoid and lunar, this area being surmounted by the pisiform.

The *Esthonyx* cuneiform lacks the tip of the bone at the palmar extremity of the lateral portion, but otherwise resembles that in *Tro-*

*gusus*. In detail, however, the facet for the ulna is more elongate transversely and that for the pisiform more generally concave. Also, the distal surface for the unciform shows somewhat more flexure. It should be noted, moreover, that this bone in figure 34 was drawn upside down.

*Pisiform*.—The pisiform (fig. 33a) is large and sturdy as represented in the *Trogosus* material. The head is well expanded and transversely oval-shaped, offering a substantial area for insertion of a part of the *flexor carpi ulnaris*. The forward extremity is widely extended medially and has transversely broad articular surfaces for the ulna and cuneiform. The proximal facet for the ulna is transversely concave, wide at its lateral extremity and tapering medially. The distal of the two surfaces is likewise broad laterally and narrower medially, but is more nearly flat.

The pisiform is not represented in the *Esthonyx* specimen, but on the other hand it is included in the type material of *Tillodon fodiens*. The *Tillodon* pisiform is strikingly larger, particularly in the diameter of the extremities, also the facet for the ulna would appear to be larger relative to that for the cuneiform. The length of the pisiform, however, though actually a little longer than that in the *Trogosus* specimen, is relatively shorter.

*Centrale*.—The centrale (fig. 33b) is the smallest of the carpal elements although it presents dorsally a surface as large as, or perhaps larger than, that of the magnum. It is a thin tabular bone, nearly triangular in the outline of its proximal surface for articulation with the lunar. Along its medial edge it articulates with the scaphoid and laterally with the magnum. Its surface for the magnum is slightly concave and extended laterally along a part of the distal margin, so that the distal surface for the trapezoid is somewhat larger and more nearly trapeziform than the proximal.

Little can be said of the *Esthonyx* centrale other than that as exposed in the articulated manus (fig. 34) it appears distinct and rectangular in outline dorsally. It is noticeably less flattened, proximodistally, than in *Trogosus*.

*Trapezium*.—The trapezium is by no means the smallest bone in the *Trogosus* carpus. It presents a comparatively broad and deep face dorsally (fig. 32), but is much reduced in the palmar aspect. The proximal articular facet (fig. 33b) for the scaphoid covers almost the entire proximal surface and except for the rounded dorsomedial portion would be nearly rectangular. In a dorsopalmar profile the dorsal portion of the proximal surface is gently convex and the palmar portion concave. Moreover, the proximal surface is noticeably deflected

distally in its palmar-medial portion. The distal surface for the first metacarpal is approximately triangular in outline with the smallest angle directed palmad. The surface is concave fore and aft, convex from side to side, and in general inclined decidedly proximad in a palmar-medial direction, so that the proximal and distal facets almost meet at the palmar extremity of the medial margin. The lateral surface of the trapezium shows an elongate facet extending the length of the proximal margin for articulation with the trapezoid, and at the dorsal and palmar extremities it is extended distally for articulation with the second metacarpal. The more palmar of these two facets for the second metacarpal is deflected sharply medial so that the trapezium slightly overrides the metacarpal.

So far as can be determined in the manus (fig. 34) with the *Esthonyx* material, the trapezium is relatively wider transversely across the dorsal surface, in comparison with its proximodistal extent, than in *Trogosus*, and may not be relatively so deep in a dorsopalmar direction. Also, so far as exposed, the proximal and distal surfaces are only convex.

*Trapezoid*.—The *Trogosus* trapezoid is a little larger than the centrale and more distinctly wedgelike with its thin edge directed laterally. Its proximal surface (fig. 33b) articulates with the centrale and is deeply notched at the palmar-lateral portion of its margin. The compressed lateral margin of the trapezoid may make a line contact with the magnum but is largely eliminated from this articulation by the centrale. Medially, the rectangular face of the trapezoid articulates with the trapezium, and along the slightly rounded angle between the proximal and medial surfaces it makes a line contact with the scaphoid. The distal surface of the trapezoid is convex from side to side and covers the proximal extremity of the second metacarpal, except where the latter has a small facet at the palmar extremity of the medial margin for the trapezium.

Only the dorsal surface of this bone can be seen in the articulated Gray Bull manus but it is almost identical in outline to that of *Trogosus*.

*Magnum*.—The magnum (fig. 33b) is beyond doubt the most peculiarly shaped bone in the *Trogosus* manus. It has something of the form of a narrow-soled shoe, inverted and with the toe directed dorsally and distally. It presents an irregularly oval face dorsally, and proximally it rises keel-like toward the "heel" beneath the lunar. The sides of the elongate proximal portion articulate medially with the centrale and laterally with the unciform. The very large knoblike distopalmar portion articulates on its medial side with a facet on the

lateral side of the proximal extremity of the second metacarpal. The saddle-shaped distal surface of the magnum is widely expanded in its palmar portion and its articulation there extends somewhat beyond the third metacarpal onto the second. The bulbous palmar expansion of this bone is evidently for ligamentous attachment.

In *Esthonyx* the magnum would appear likewise to be of limited dorsal exposure and to rise high and keel-like in a proximopalmar direction beneath the lunar.

*Unciform.*—The tillo dont unciform (fig. 33b) is a very large segment of the manus, rivaling the pisiform in size. Its form resembles somewhat that of a hammer head with the large bulbous palmar projection corresponding to the direction of the handle. The dorsal exposure of the bone (fig. 32) is broad and deep, with two liplike prominences lapping dorsally over the median portions of the heads of the fourth and fifth metacarpals. The proximal articular portion of the unciform is deep and very broad transversely. It consists of two principal parts, a wide segment for articulation with the cuneiform and a transversely, much narrower, and somewhat medially turned segment for the lunar. The surface for the cuneiform is convex medially but the lateral portion is transversely concave, sloping distally toward the palmar-lateral margin. Medially, and at about a 90° angle with the surface for the lunar, the unciform articulates with the magnum, and somewhat lower with the lateral side of a proximally directed lip of the third metacarpal. Distally the surface is concave in a dorsopalmar direction and the medial portion is slightly convex transversely, corresponding to the transverse concavity in the head of the fourth metacarpal. The lateral portion of the distal surface articulates with the fifth metacarpal and at the palmar extremity of the lateral margin comes to a thin edge with the proximal surface for the cuneiform, permitting contact between the cuneiform and fifth metacarpal. The palmar projection is much like that of the magnum and about equally developed, evidently also for ligamentous attachment.

An unciform is also included in the type material of *Tillodon fodiens*, which is appreciably larger than that in the *Trogosus* manus. It appears also to be relatively a little deeper medially and to have a relatively broader surface for the lunar. Distally the surface for the fourth metacarpal and that for the third and for the magnum grade into one another more smoothly, and the surface for the fifth metacarpal extends more palmar onto the relatively less-produced palmar process.

The unciform in the *Esthonyx* material (fig. 34) is relatively deeper proximodistally than in *Trogosus*, and like the magnum shows a rela-

tively broad palmar process. The proximal and distal surfaces of the unciform converge laterally, but may not permit contact between the fifth metacarpal and cuneiform as it does in both *Trogosus* and *Tillodon*.

*Metacarpals.*—The *Trogosus* metacarpals (fig. 32) are moderately short and sturdy, increasing in length from the first to the third and decreasing again to the fifth. The first and fifth, however, show no appreciable tendency toward reduction from a fully functional pentadactyl foot. The transverse profile across the dorsal surface of the articulated metacarpals is but gently curved and the divergence between the metacarpals is moderate with perhaps somewhat greater divergence between the first and second, although this appears compensated, at least in part, by the curvature of the first metacarpal. The proximal extremity of the first metacarpal is set distinctly distal to that of the second metacarpal, whereas the second and third are even. The fourth and fifth together are located slightly distal to the proximal extremity of the third. The dorsal surface of each in longitudinal profile shows but slight deviation from a straight line. The palmar surfaces, however, are strongly concave longitudinally, with both the extremities much expanded in a palmar direction. The distal extremities, in articulation with the proximal phalanges, are smoothly convex dorsally in all, and strongly keeled on the palmar surface. Also the distal extremities, at the widest points, are more expanded transversely than the proximal extremities, except in the first and fifth.

Considering the metacarpals in more detail, the first (fig. 33c) is seen to have a broadly expanded proximal extremity with the broad and transversely concave facet for the trapezium tilted decidedly distolateral, directing the metacarpal distally rather than medially from the trapezium. There is no facet, however, for articulation between the first and second metacarpals. Medially the proximal portion of the first is expanded and noticeably roughened. The distal articular surface is relatively narrow transversely, and is twisted slightly with respect to the proximal extremity, so that the phalanges are oriented similarly to those of the other digits.

The second metacarpal has its proximal articulating surface (fig. 33c) almost perpendicular to the long axis of the bone, and although this surface shows practically no dorsopalmar convexity, it is somewhat concave transversely. The dorsal portion is broad with the lateral margin projecting proximally more than the medial, but the palmar portion is narrower and has facets on either side inclined slightly away from the principal facet for the trapezoid. The medial of these is for an overlap of the trapezium which also articulates with a small facet



at the dorsal extremity of the medial surface of the second metacarpal, and the lateral is for the expanded side of the magnum. The medial surface of the second metacarpal does not articulate with the first, but the lateral surface has a small oval facet at the dorsoproximal angle for the third metacarpal.

A scarred process for the *extensor carpi radialis longior* is prominently displayed about a third of the way distally on the medial side of the dorsal surface of the second metacarpal, and for the *extensor carpi radialis brevior* in about the same position on the third metacarpal of *Trogosus grangeri*. These processes are relatively more proximal, and that on the second metacarpal is more centrally placed on the dorsal surface in A.M. No. 18982 of *Trogosus hyracoides*. In U.S.N.M. No. 17886 of *T. hyracoides* the processes are scarcely evident.

The nearly rectangular surface for the magnum on the third metacarpal (fig. 33c) is decidedly convex in its dorsopalmar profile, and slightly concave transversely near the dorsal margin, but tilted so that the lateral margin is extended noticeably more proximad than the medial. The medial side of the third metacarpal articulates with the second metacarpal only at its dorsoproximal angle. The lateral side, however, articulates with the fourth throughout the dorsopalmar extent of the head. The facet for the fourth metacarpal is strongly arcuate, as determined by the convexity of the surface for the magnum, and exhibits a marked dorsopalmar concavity. The upturned lip of the lateral margin of the surface for the magnum permits articulation for a short distance along its outer surface with the unciform, proximal to that for the fourth metacarpal.

The proximal extremity of the fourth metacarpal (fig. 33c) is broad dorsally, but somewhat narrower in its palmar portion. The proximal surface for the unciform is gently concave transversely, and the dorsopalmar profile convex, although the convexity is distinctly less than that of the surface for the magnum on the third metacarpal. The medial surface shows an arcuate facet for the third metacarpal throughout the dorsopalmar portion of this surface, and facing more nearly proximal is a small lenticular facet for the transversely expanded palmar portion of the magnum, noticeably constricting the palmar portion of the facet for the unciform. This facet for the magnum is less well defined in the *T. grangeri* foot than in the U.S.N.M. foot of *T. hyracoides*. Laterally, the proximal extremity of the fourth metacarpal is markedly excavated, with an arcuate facet for the fifth metacarpal, resembling that on the lateral side of the third, but under-

cut dorsally so that the fourth metacarpal rides over a small knoblike prominence on the medial side of the fifth.

The proximal extremity of the fifth metacarpal (fig. 33c) is widely expanded transversely, with the strongly convex articular surface confined to the medial half of the head. The very large lateral expansion of the head probably includes the insertion for the tendon of the *extensor carpi ulnaris*. Transversely, the facet for the unciform is of uniform width and has a straight to slightly convex profile. At its palmar-lateral extremity it articulates with the cuneiform, when the metacarpal is extended, as a slight flexure of the proximal surface at this point would so indicate. The crescentic medial facet for the fourth metacarpal is proximodistally wide and its dorsal portion is extended medially and distally to occupy the concavity of the opposing surface on the fourth metacarpal.

The few metacarpals found associated with the type material of *Tillodon fodiens* are essentially similar to those in *Trogosus*; however, the extremities, particularly the proximal, are noticeably enlarged, although the length of each is only a little greater than in *Trogosus*.

Of the metacarpals in the manus considered to be *Esthonyx*, only the proximal portions of the second to the fifth are preserved. The heads of those are obscured in articulation with the carpus and partly by matrix so that no significant details are evident. It is noted, however, that the shafts of the metacarpals extend from the proximal extremities in uniform and full width, not so noticeably constricted a short distance from the head as in *Trogosus*. In all probability the *Esthonyx* metacarpals were relatively longer than in *Trogosus*.

*Phalanges*.—The proximal and intermediate phalanges (fig. 32) are, like the metacarpals, moderately short and sturdy. The articulations are developed to permit extensive flexure as in clawing, digging, or grasping. Moreover, the distal phalanges are transversely compressed, markedly curved, uncleft, birdlike claws.

The proximal extremities of the proximal phalanges are deeply cupped and much expanded, both transversely and in dorsopalmar depth. The palmar margin of the cup is deeply notched to accommodate the keel of the metacarpal. Moreover, the wings to either side of the notch are roundly faceted above for contact with the elongate sesamoids articulating with the palmar surface of the distal extremity in each metacarpal.

The distal extremity of the proximal phalanges is distinctly narrower and shallower than that proximally, and the distal articular surface is a well-rounded trochlea with the median groove deeply im-

pressed. In the first digit the distal articular surface is appreciably narrower than in the others, articulating directly with the claw.

The intermediate phalanges are progressively narrower than those proximally and between two-thirds and three-quarters as long. Their proximal surface is deeply concave and divided. The ridge between the concavities meets the dorsal margin in a lip for extensor muscles, which projects well up on the dorsal surface of the trochlea articulating with it. The distal surface, articulating with the distal phalanx or claw, is narrower than that of the proximal phalanx, but distinctly deeper in a dorsopalmar direction, with the expansion dorsal to the shaft as well as palmar. Moreover, the condyles of the distal trochlea are more nearly parallel, affecting a more perfect pulley than on the proximal phalanx.

The proximal extremity of each of the claws is transversely expanded to cover the lobes of the distal articular surface of the intermediate phalanx, and much recurved in a dorsopalmar plane. The claw is transversely very flattened, longitudinally curved (fig. 33d), and distally pointed. Also, as noted above, it shows no evidence of a median cleft or fissure distally. On the palmar margin near the proximal surface there is a broad, rugged process for the tendon of the *flexor profundus digitorum*. Between this rugosity and the palmar margin of the articular surface on either side is a small nutrient foramen penetrating the bony claw.

#### PELVIS

Of the pelvic girdle in *Trogosus* only the ilium is known; however, a portion of an innominate bone associated with *Esthonyx*, A.M. No. 4276, from the Gray Bull, includes the acetabulum and adjacent parts of the ilium and ischium. The *Trogosus* ilium, found associated with the *T. hillsii* material, is strikingly trihedral in form in its posterior portion, recalling the Rodentia. However, a relationship to this order is not implied, inasmuch as a three-sided ilium with the iliac surface rather well developed would appear to be a primitive mammalian condition, noted in monotremes, didelphid marsupials, and certain insectivores, creodonts, and edentates as well. The form in *Trogosus* may be compared to that in *Solenodon* or limnocyonid creodonts, but with important differences from both.

The sacral surface is relatively narrow posteriorly where it makes a nearly 90° angle with the iliac surface at the pubic border; however, it becomes wider forward and more nearly confluent with the iliac surface toward the suprailiac border. The gluteal surface is much the

widest; it is gently concave forward and makes a very acute angle with the iliac surface at the acetabular border, more acute than in *Solenodon*, almost as in *Castor*. Toward the acetabulum the acetabular border exhibits a rather rugged longitudinal prominence for the *rectus* muscle of the leg.

Of the three innominate portions associated with *Esthonyx*, A.M. No. 4272, one may be *Esthonyx*, the other two (one of which was figured by Cope, 1884a, pl. 24c, figs. 10, 10a; 1884b, fig. 24c) are surely creodont. The particular fragment regarded as *Esthonyx* exhibits, as in *Trogosus*, an acute acetabular border between the gluteal and iliac surfaces, but the sacral surface is relatively wider posteriorly and the iliac surface narrower. The iliac surface is turned more nearly inward than, for example, in *Solenodon* and some of the creodonts, with a tendency toward confluence with the sacral surface forward. This would appear to be a tillodont peculiarity.

#### FEMUR

Remains of six or more femora of *Trogosus* are known, two of these, Y.P.M. No. 11088 (fig. 35) and A.M. No. 17011, from the Bridger and Huerfano, respectively, are nearly or quite complete though showing evidence of limited crushing and distortion. There are in addition several femoral portions associated with the *T. hillsii* skull, but representing more than one individual.

Characteristic of the *Trogosus* femur is its sturdy, almost straight shaft with no appreciable curvature fore and aft. The proximal extremity is broad with a prominent greater trochanter well separated from the head. At its outer margin the greater trochanter is directed posteriorly over a deep and longitudinally elongate digital fossa with the intertrochanteric crest not continuous with the lesser trochanter. Beneath the head the lesser trochanter is prominent and extends flange-like a noticeable distance along the posteromedial margin of the shaft. A third trochanter is present well over a third of the way down the lateral margin of the shaft. It is longitudinally extended and almost as much expanded as the lesser trochanter, apparently more so than the third trochanter in larger creodonts. The lesser and third trochanter are relatively more elongate, extending more distally than in *Solenodon*. The prominence of the lateral trochanters is in keeping with the relative importance of the gluteal surface of the ilium in the expected development of the gluteal muscles for extension of the femur, such as in running and other motions of the hind limb. The rather unusually expanded lesser trochanter would suggest a powerful *psoas magnus* which acts in flexing the hip.

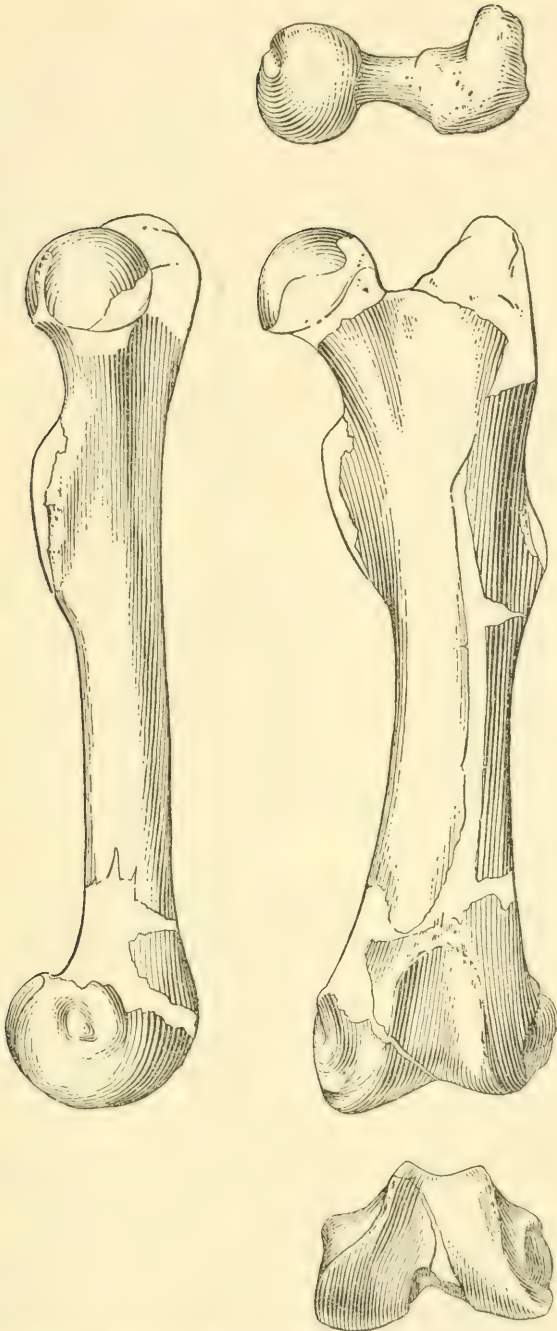


FIG. 35.—Cf. *Trogosus*, species: Left femur (Y.P.M. No. 11088, restored from A.M. No. 17011 and material associated with type of *T. hillsii*, U.S.N.M. No. 17157), proximal, medial, anterior, and distal views,  $\times \frac{1}{2}$ . Bridger and Huerfano (B) middle Eocene, Wyoming and Colorado.

The distal portion of the femur would appear to be characterized by its fore and aft shortness, in which the condyles do not project posteriorly so markedly as observed, for example, in various carnivores. The medial condyle, as customary, extends posteriorly somewhat more than the lateral condyle. The patellar surface extends broadly well up the anterior surface of the bone.

The femur of a Gray Bull *Esthonyx* in its proximal portion is much like that of *Trogosus*. It shows the same relative transverse width and the longitudinally elongate digital fossa. The distal portion of a femur of another individual, believed associated with teeth of a Clark Fork *Esthonyx*, may be somewhat crushed but appears rather narrow transversely across the condyles and across the patellar surface, as well as anteroposteriorly deep, as in certain creodonts. There is no certainty, however, that this fragment of a femur is *Esthonyx*.

#### TIBIA

A complete tillodont tibia is not known; however, there are at least 10 tibiae represented by proximal or distal extremities, or both. These are included among materials representing *Esthonyx* as well as *Trogosus* and *Tillodon*. In one individual of *Trogosus*, Y.P.M. No. 11088 (fig. 36), the entire shaft of a fibula is preserved, associated with the proximal and distal extremities of the tibia from the same side, making it possible to determine closely the length of the latter bone. Undoubtedly the most striking feature of the tibia is its shortness. Its length is but two-thirds that of the femur, measured in the same individual.

The tibia of *Trogosus* has strong, rugged articular portions and the proximal extremity is markedly excavated posterolaterally beneath the lateral condyle. The articular surface of the medial condyle is the larger of the two and slightly concave, whereas the lateral articular surface would appear to be slightly higher, smaller, and more convex. The shaft, though strong, is somewhat flattened anteromedial-posterolaterally and rounded distally. The cnemial crest is rugged and broad proximally but rapidly loses its ruggedness distally as it blends smoothly with the shaft. The distal extremity of the tibia exhibits an anteroposteriorly deep and medially expanded internal malleolus, projecting bluntly downward below the internal surface for the astragalus. On its posterior surface the internal malleolus shows a prominent groove apparently for both the *tibialis posticus* and *flexor longus digitorum*. The articular surface for the astragalus is composed of two shallow concavities, the outer of which is somewhat more flattened

and abbreviated, and is bounded high externally by the lower margin of the small, posteroexternally-facing facet for the fibula.

The fragments of tibiae representing *Tillodon fodiens* do not appear

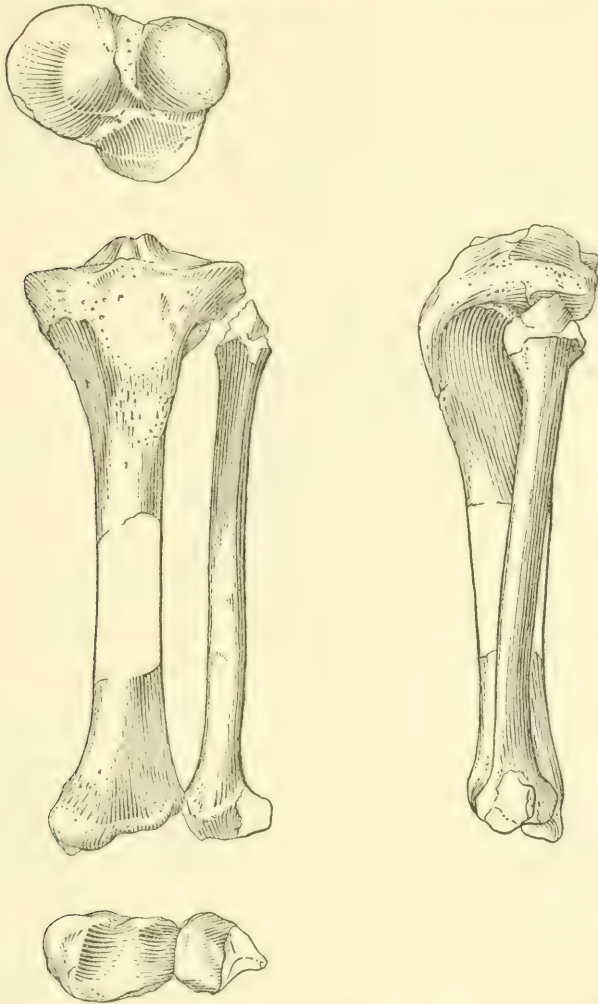


FIG. 36.—Cf. *Trogosus*, species: Left tibia and fibula (Y.P.M. No. 11088), proximal, anterior, lateral, and distal views,  $\times \frac{1}{2}$ . Bridger middle Eocene, Wyoming.

to differ significantly from those of *Trogosus* other than being of a little greater size. The proximal extremity is deeper through the cnemial crest and the distal extremity is a little heavier throughout. The *Esthonyx* tibia, if correctly associated, would appear to be relatively longer and more slender, with the external condyle of the

proximal extremity supported below by a more prominent, though compressed, ridge extending upward from the posterolateral wall of the shaft. The internal malleolus is less expanded medially and the external portion is slightly more compressed anteroposteriorly.

#### FIBULA

The fibula belonging to Y.P.M. No. 11088 (fig. 36) of *Trogosus* is nearly complete, though damaged somewhat at the proximal extremity where contact is made with lower surface of the external condyle of the tibia, and the posterolateral flange on the external malleolus is missing. The proximal extremity, as seen in A.M. No. 17008 of *Trogosus grangeri*, has a nearly horizontal, slightly concave articulating surface on an abruptly expanded head, the forward margin of which is proximodistally much compressed. The anteromedial margin of the shaft shows a thinly compressed interosseous crest only on the proximal portion. The greater part of the shaft is nearly circular but distally, as seen in Y.P.M. No. 11088 and more prominently in A.M. No. 2692, a crest is developed on the external margin which expands abruptly posterolaterally from the external malleolus. The wide notch posterior to this flattened process carries the tendon of the *peroneus brevis*. The distal articular surface for the outer wall of the astragalus is large and inclined at an angle of about  $45^\circ$  with the long axis of the fibula. At its medial upper limit the surface is joined by the small marginal facet for the tibia.

A proximal portion of a fibula, found associated with Gray Bull *Esthonyx*, A.M. No. 4276, is relatively more flattened transversely than in *Trogosus*, but shows a compressed and low interosseous crest for approximately three centimeters down the median surface. This fibula was figured by Cope (1884a, pl. 24c, figs. 9, 9a) but he was uncertain as to whether the bone represented was a fibula or the radius.

#### PES

Representation of the tillodont hind foot is very scant, and in only one specimen of *Trogosus*, Y.P.M. No. 11088 (figs. 37(part) and 38c), are there as many as three elements which can be articulated: the astragalus, calcaneum, and cuboid. In U.S.N.M. No. 17886 of *Trogosus hyracoides*, the cuboid and ectocuneiform (figs. 37(part) and 38e) are preserved and in the material associated with *Trogosus hillsii* incomplete calcanea and a partial astragalus are included. Certain other specimens include single elements of the hind foot. Associated with the type of *Tillodon fodiens* are an incomplete calcaneum, cuboid,



mesocuneiform (figs. 37(part) and 38d), and the proximal extremities of the third and fourth metatarsals (figs. 37(part) and 38h and i). Calcanea and astragali are included in materials associated with jaws or teeth of *Esthonyx*, but the identity of these is uncertain.

The composite hind foot here illustrated (fig. 37) is made up of elements from four different individuals, representing two genera. The navicular, cuneiforms, and metatarsals are poorly matched to the



FIG. 37.—*Trogosus*, and *Tillodon*, new genus: Composite left pes (astragalus, calcaneum, and cuboid, Y.P.M. No. 11086) of Cf. *Trogosus*; navicular, Y.P.M. No. 11086 of Cf. *Trogosus*; left external cuneiform, U.S.N.M. No. 17886 (reversed in error) of *Trogosus hyracoides*; and middle cuneiform and metatarsals III and IV (metacarpals reversed from right side) of *Tillodon fodiens*, new genus (internal cuneiform and 1st, 2d, and 5th digits not represented), dorsal view,  $\times \frac{2}{3}$ . Bridger middle Eocene, Wyoming.

remaining elements in size so that distortion as to direction and relative position is inevitable. The composite does, however, show the general arrangement of the elements and, in particular, suggests marked divergence of the medial digits.

The tillodont tarsus does not particularly resemble that in either insectivores or creodonts. It does, however, show a resemblance to the structure seen in such forms as *Periptychus* and *Pantolambda*, as Matthew (1937) has illustrated their pes. These Paleocene genera are currently regarded as representing the orders Condylarthra and

Pantodonta, respectively, although Matthew regarded them as belonging to the same order, the Taligrada. His description of the "taligrade" astragalus corresponds well with that in *Trogosus*. It should be noted, however, that *Trogosus* is not subungulate but distinctly unguiculate.

*Astragalus*.—The astragalus of *Trogosus* is in general flattened,



FIG. 38.—*Trogosus*, and *Tillodon*, new genus: Tarsals and metatarsals; a, *Trogosus*, species, left calcaneum (A.M. No. 17011), dorsal view; b, Cf. *Trogosus*, species, left navicular (Y.P.M. No. 11086), proximal view; c, Cf. *Trogosus*, species, left cuboid (Y.P.M. No. 11088), proximal view; d, *Tillodon fodicens*, new genus, right middle cuneiform (Y.P.M. No. 11087), type specimen, distal view; e, *Trogosus hyracoides*, left (reversed in error) external cuneiform (U.S.N.M. No. 17886), distal view; f, Cf. *Trogosus*, species, left cuboid (Y.P.M. No. 11088), distal view; g, *Trogosus hyracoides*, left astragalus (A.M. No. 18982), plantar view; h and i, *Tillodon fodicens*, new genus, left (reversed from right side) 3d and 4th metatarsals (Y.P.M. No. 11087), type specimen, proximal view;  $\times \frac{2}{3}$ . a, Huerfano (B) middle Eocene, Colorado; b-i, Bridger middle Eocene, Wyoming.

short-necked, and with a transversely broad articular surface on the head. It is noticeably like that figured for *Periptychus* but in detail the articulation for the tibia is somewhat more trochlear in form, with the medial ridge approaching the head more closely than in *Periptychus*. The amount of rotation between the astragalus on the one hand and tibia and fibula on the other was decidedly limited, however, in comparison with modern carnivores and ungulates. In poste-

rior view the medial portion of the surface for the tibia extends rather more plantad than the outer half, and between these two portions, just dorsal to the groove for the tendon of the *flexor longus hallucis*, is a prominent astragal foramen. Anteriorly, the articular surface on the head, though not complete in any specimen at hand, is transversely more broad than deep. A slight deflection of this surface posteriorly in its lateral part denotes the separation of the portion articulating with the cuboid from that which articulates with the navicular. The medial surface of the astragalus extends broadly inward in its plantar portion and shows a rather limited area of articulation above for the internal malleolus of the tibia. The external surface extends laterally in a more nearly conical form with its apex at the plantar margin. The external malleolus articulates broadly with this surface and at a nearly 90° angle from that for the tibia. In the plantar view (fig. 38g) the elongate-oval and decidedly concave ectal facet for the calcaneum is marginally placed with its long diameter anterolaterally directed. Somewhat medial to the center of the plantar surface, the less elongate, more nearly circular sustentacular facet is gently convex, anteroposteriorly, and may or may not extend completely to the portion of the anterior facet for the cuboid. Posteriorly, the sustentacular facet turns abruptly plantad beneath the median tubercle on the posterior extremity.

*Calcaneum*.—The calcaneum of *Trogosus* has an elongate heel which is somewhat flattened. The posterior extremity or tuberosity is enlarged and rounded, but showing a division into an upper and lower prominence, and near the extremity on the dorsomedial surface there is a rather large process. This process is missing on the lower Eocene calcanea and the shaft for the tuberosity is flattened more nearly transversely. The anterior portion of the *Trogosus* calcaneum (fig. 38a) has a relatively widely extended sustentacular process which projects noticeably inward and forward beyond the sustentacular facet, giving a large rugged surface for the attachment of ligaments and a part of the *tibialis posticus*. The sustentacular process shows a smooth groove below and posteriorly, extending toward the posterior margin of the ectal facet, for the *flexor hallucis longus*. The sustentacular facet for the astragalus is irregular in shape, slightly concave and extends forward to the facet for cuboid with which it makes a sharp angle. Posteriorly the sustentacular facet curves abruptly for a very short distance onto the posterior margin of the sustentacular process. The ectal facet is obliquely elongate, convex, and separated from the sustentacular facet by a deep and broad groove into which is attached the interosseous ligament to the astragalus. The outer surface of the calcaneum

exhibits a very prominent and widely extended peroneal process which is grooved longitudinally for the *peroneus longus*. Immediately dorsal to the peroneal process and close to the lateral margin of the ectal facet are two noticeable grooves, one of which may be for the *peroneus brevis* if this occupies a separate channel. The anterior extremity of the calcaneum has a large, slightly concave surface for the cuboid. The surface for the cuboid, rather than being perpendicular to the long axis of the heel, is decidedly oblique, with its long axis directed posteromedially toward the sustentacular process.

The calcanea presumed to be of *Esthonyx* are characterized by much less expanded sustentacular processes and apparently smaller peroneal processes. Moreover, the facet for the cuboid is more nearly transverse and is well separated from the sustentacular facet so that there is no continuity between the two as there is in *Trogosus*.

*Navicular*.—Only two tillodont naviculars are known: one, Y.P.M. No. 11086 from the Bridger, and the other included in material associated with *Esthonyx* teeth, obtained by Princeton University in Paleocene beds of the Big Horn Basin. The navicular belonging to Y.P.M. No. 11086 (fig. 38b), which is believed to represent *Trogosus*, but may possibly be *Tillodon*, is a much-flattened bone, slightly arcuate in outline, as viewed proximally, and exhibits a strong posteroexternal process. This process is undoubtedly for a part of the *tibialis posticus*, although in many widely divergent groups of mammals the process for this muscle is located on the medial side of the plantar surface. The proximal facet for the head of the astragalus is concave, and laterally, through a rather slender line of contact with the cuboid, it joins the distal external facet for the external cuneiform. The distal surface of the navicular is gently convex from side to side and the facets for articulation with the three cuneiforms are nearly confluent so that their limits between are not easily discerned, except near the dorsal and plantar margins. Medially, the facet for the entocuneiform turns inward rather markedly.

The navicular associated with *Esthonyx* material is relatively thicker proximodistally, has a deeper, cup-shaped proximal surface for the astragalus, and the distal surface is not so convex as in the Bridger specimen. Also, the facet for the entocuneiform is relatively very small.

*Cuneiforms*.—The internal cuneiform was not found or recognized in any of the tillodont materials examined; however, an incomplete mesocuneiform (fig. 38d) is apparently included in the type material of *Tillodon fodiens*. This element is a dorsoplantad elongate bone, transversely compressed in its posterior or plantar portion, so that

scarcely more than the process for a part of the *tibialis posticus* is exposed. The proximal and distal surfaces are both dorsoplantad elongate, gently concave surfaces for the navicular and second metatarsal, respectively. Articulation with the external cuneiform is indicated by a facet along the proximal margin of the lateral surface.

The external cuneiform (fig. 38e) is included in the skeletal material, U.S.N.M. No. 17886, belonging with the skull of *Trogosus hyracoides*. As noted for the mesocuneiform, the ectocuneiform is an elongate bone very narrow at its plantar extremity. The process for a part of the *tibialis posticus* is high and more clearly set off from the lower portion, which is notched transversely for the *peroneus longus* tendon. Proximally, the surface for the navicular is joined by a narrow margin of articulating surface on both the medial and external surfaces, for the middle cuneiform and cuboid, respectively. The distal articulation is L-shaped, or almost T-shaped, for the proximal extremity of the third metatarsal. The distal surface is distinctly notched externally and but slightly so internally, dividing the facets on the distal portion of the lateral and medial surfaces into dorsal and plantar portions.

*Cuboid*.—The tillodont cuboid (fig. 38c, f) is scarcely cubical in form, as a result of the very oblique angle in which the calcaneum articulates with it. The dorsal face is large and nearly pentagonal in outline. The proximal surface of the cuboid has a gablelike crest separating the concave facet for the astragalus from the larger convex and proximolateral surface for the calcaneum. Externally, the facet for the calcaneum almost meets the distal surface, leaving only a slender gap between. Medially, the facet for the navicular is a narrow dorsoplantar band adjacent to that for the astragalus but joined smoothly below by the facet for the ectocuneiform, which does not quite reach the distal surface. Distally, on the medial surface, small dorsal and plantar facets, adjacent to the distal surface of the cuboid, articulate with the distal margin of the external face of the ectocuneiform. The plantar surface of the cuboid is more nearly triangular, characterized at its broad distal portion by a rugged, transversely broad process or tuberosity, apparently for attachment of the ligament to the calcaneum. On the distal surface of the cuboid, between the broad, gently concave surface for the fourth and fifth metatarsals and the lower margin of the enlarged posterior tuberosity, is a smooth, well-defined transverse groove for the tendon of the *peroneus longus*.

*Metatarsals*.—The only metatarsals that can be identified and recognized as to position are the proximal portions of the third and fourth (figs. 37 and 38h and i) belonging to *Tillodon fodiens*, and possibly

a second in material associated with the skull of *Trogosus hyracoides*. There are other metatarsals in the *Trogosus* specimen but these are mostly distal portions and not certainly determined as to position.

The tillodont metatarsals are clearly more slender and in all probability longer than the metacarpals. The second metatarsal (not illustrated), whose proximal portion is preserved, exhibits only the dorsal portion of the articulating surface for the mesocuneiform. This surface is relatively flat and inclined slightly toward the medial side. No facets for articulation show on the medial side, but a single small facet is preserved, proximodorsally, on the lateral side. I cannot determine from the material at hand whether this small facet articulated externally with the lower margin of the ectocuneiform or with the third metatarsal. The absence of an equivalent facet on the *Tillodon* third metatarsal suggests that the second may well have had articulation with the outer cuneiform.

The proximal extremity of the third metatarsal has a slightly convex articular surface for the external cuneiform which is inclined distally to the dorsal and medial sides. The surface is approximately quadrilateral but transversely constricted across its middle portion. There do not appear to be articular facets on the somewhat roughened medial surface of the extremity, but the lateral surface shows two well-defined facets for the fourth metatarsal. The plantar and more proximal of the two is plane and triangular in outline, whereas the larger, more dorsal surface, also triangular, is noticeably concave, partially enveloping its counterpart on the fourth metatarsal.

The proximal extremity of the fourth metatarsal lacks the plantar portion, but it is sufficiently complete to determine its correct position in the series. As in the third, the proximal articular surface, which in this case articulates with the cuboid, is gently convex and inclined distally toward the dorsal and lateral sides. On the medial side is shown the convex, proximodistally elongate facet for the concavity on the third, but the more plantar facet is broken away. The external surface shows an arcuate, concave facet entirely across the preserved portion adjacent to the cuboid facet.

*Phalanges*.—None of the preserved phalanges belonging to the hind foot of the *Trogosus* specimen, U.S.N.M. No. 17886, are determined as to digit represented, but these elements, presumably in contrast to the metatarsals, are clearly shorter than in the forefoot and, moreover, the proximal phalanges appear somewhat more compressed dorsoventrally.

## RELATIONSHIPS OF ORDER AND CONCLUSIONS

One might expect, after having examined nearly all the known tillodont material and made extensive comparisons with various forms in other orders, to have arrived at well-founded conclusions regarding the origin and affinities of the group, but this is not the case. Resemblances of one kind or another were noted to several of the orders of mammals represented in the early Tertiary. Some would appear to be fundamental in nature and surely significant, but the best that can be said of these in most such cases is that their significance is basic or fundamental to perhaps several early groups of mammals. Other characters, largely adaptive in significance, are strikingly like those in representatives of other orders but can be regarded only as samples of parallelism, or perhaps convergence.

Perhaps the most misleading resemblance is to the remarkable development of the anterior teeth in the Taeniodonta. This early led to their being included in the same order; however, the specialization was reached independently in different geologic periods and, still more noteworthy, the principal teeth involved in the two groups are not homologous. The anteroposteriorly shortened basicranial area, known only in the latest stage of tillodonts, is unlike the elongate basicranial area observed in Paleocene taeniodonts, and the rostral portion, though robust, is relatively attenuated in comparison with the shortened and anteriorly deepened taeniodont snout. There is no particular resemblance between upper molar teeth in the earlier forms of each group; however, the conoryctid-type lower molars with their somewhat higher trigonid and hypsodont outer walls approximate the esthonychid type, although the structure of the talonid is distinctly different. Moreover, the foot structures in the two groups, though in part largely adaptive in importance, have early evolved in entirely different directions.

The rodentlike incisors of the later tillodonts led A. S. Woodward to regard them as rodents, and indeed the teeth so modified may well be homologous, although there is no proof for this. However, as Weber and Gregory have shown, there is no justification for this assignment and the fossil record itself shows the development of rodentlike incisors to be obviously a case of convergence. The peculiar trihedral ilium of the tillodonts might be regarded as rodentlike, but I regard this as basically primitive among mammals, noted in monotremes, didelphid marsupials, and certain insectivores, pantodonts, creodonts, and edentates as well.

Insectivore resemblance is probably in a large measure due to the almost "prototypal" character of this order with respect to several groups of mammals, and also undoubtedly to the very wide range of

characters represented by the various families. Cope regarded *Esthonyx*, though not the later tillodonts, as an insectivore, this because of certain resemblances to *Erinaceus*. It should be noted, however, as has been mentioned in a foregoing section, that the enlarged upper incisor in the two may not be homologous. It is I<sup>1</sup> in *Erinaceus*. Moreover, the basicranial region in *Erinaceus* bears little or no resemblance to that of the tillodonts. There are, of course, many points of similarity between tillodonts and insectivores, and likewise between tillodonts and creodonts, but whether the correspondence is closer to one or to the other or whether, as Gregory (1910, p. 293) has postulated, derivation was from an earlier insectivore-creodont stock is not clearly evident.

A general structure of the tillodont teeth somewhat resembling those of the primate *Pelycodus* was observed by Cope, and what I believe to be an even greater similarity was observed in comparison with arctocyonic teeth of the chriacine type, i.e., *Chriacus* and *Deltatherium*. On the other hand, much may be said in favor of the *Pantolambda* type of dentition. I do not mean to imply a derivation of *Esthonyx* teeth from *Pantolambda* itself, but feel there is a basic cheek-tooth pattern suggesting relationships through a pre-Torrejonian ancestry (possibly within the Arctocyonicidae?). *Pantolambda* has already become too specialized with distinctly crescentic cusps in both the upper and lower teeth. The styler development of the upper cheek teeth, except for the presence of a small mesostyle, is comparable to that in *Trogosus*; however, *Pantolambda* lacks the sweeping hypoconal ridge seen in both *Trogosus* and *Esthonyx*. The correspondence of the lower molars to those of *Trogosus* is rather striking, even to the metastylid; however, the external walls are distinctly less hypsodont and more compressed anteroposteriorly. Much of the resemblance is undoubtedly due to parallelism, evolving at different geologic times, but possibly from basically similar patterns. The anterior teeth, of course, are quite different in their relative development, but this is a later modification in the tillodont line, but weakly shown in *Esthonyx*, so probably not significant in earlier Paleocene time.

The basicranial region of *Pantolambda* is not preserved or exposed in the American Museum specimens figured by Matthew (1937) so that many of the more conservative skull characters are not evident; however, comparison is permitted with other skeletal portions and many points of resemblance noted. The gross form of most limb elements is largely adaptive in significance. Modification in one way or another to methods of locomotion and food getting and similar habits will be correlated with similar-appearing structures. Nevertheless,



there is much to be said for the basic character of the shapes, arrangement, and relative proportions of the elements of the carpus and tarsus. In consideration of these, I am much impressed by the striking similarity noted between the tillodonts and *Pantolambda* in both the carpus and tarsus, in spite of the quite different modification of the distal portions of the feet, with *Pantolambda* decidedly more ungulate. I do not know what foot structure *Deltatherium* or *Chriacus* may have possessed. It is likely that the manus would be similar, but I suspect that the more creodont tarsus would prevail. The tillodont tarsus, as has been noted in its description, is most like that in *Pantolambda* and *Periptychus*, or of a taligrade type according to Matthew's arrangement of the orders.

So much for the supposed earlier history of the order. During Eocene time it has been generally assumed, and I know of no evidence against it, that *Trogosus* and *Tillodon* were derived from *Esthonyx*; however, the species from which they were derived is not clearly evident. It may well have been from *E. acutidens*, but in that case there appears to have been a remarkable transition, apparently in Green River time, not all recorded in the Wyoming and Colorado fluviatile equivalents. One is tempted to postulate derivation of the middle Eocene forms from some larger and earlier *Esthonyx*, such as *E. grangeri*, with the absent intervening stages not recorded in the Rocky Mountain region. On the other hand, *E. grangeri* itself has no particular characteristics to recommend it, other than its size, and possibly the less-developed state of the posterior lobe of  $P_4$ , as the upper teeth of this species are less likely looking than those of *E. acutidens*. The situation with regard to *Trogosus* and *Tillodon* would, however, not appear to be unique; perhaps no more so than that with regard to the immediate ancestry of such genera as *Hyrachyus* and *Palaeosyops*.

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TILLODONT SKULL FROM THE BRIDGER MIDDLE EOCENE

*Trogosus hyracoides* (Marsh) : Skull (U.S.N.M. No. 17886), dorsal view.  
Approximately one-half natural size.



TILLODONT SKULL AND JAWS FROM THE BRIDGER MIDDLE EOCENE

*Trogosus hyrcanoides* (Marsh): Skull and mandible (U.S.N.M. No. 17880), lateral view. Approximately one-half natural size.





**TILLODONT SKULL FROM THE BRIDGER MIDDLE EOCENE**

*Trogosus hyracoides* (Marsh) : Skull (U.S.N.M. No. 17886), ventral view.  
Approximately one-half natural size.



**TILLODONT MANDIBLE FROM THE BRIDGER MIDDLE EOCENE**

*Trogosus hyracoides* (Marsh): Mandible (U.S.N.M. No. 17886), dorsal view.  
Approximately one-half natural size.



TILLODONT SKULL FROM THE HUERFANO MIDDLE EOCENE

*Trogosus grangeri*, new species: Skull (A.M. No. 17008), type specimen, dorsal view. Approximately one-half natural size.



TILLODONT SKULL AND JAWS FROM THE HUERFANO MIDDLE EOCENE

*Trogosus gramaci*, new species: Skull and mandible (A.M. No. 17008), type specimen, lateral view. Approximately one-half natural size.



TILLODONT SKULL FROM THE HUERFANO MIDDLE EOCENE

*Trogosus grangeri*, new species: Skull (A.M. No. 17008), type specimen, ventral view. Approximately one-half natural size.



TILLODONT MANDIBLE FROM THE HUERFANO MIDDLE EOCENE

*Trogosus grangeri*, new species: Mandible (A.M. No. 17008), type specimen, dorsal view. Approximately one-half natural size.



**TILLODONT SKULL FROM THE HUERFANO MIDDLE EOCENE**

*Trogosus hillsii*, new species: Skull (U.S.N.M. No. 17157), type specimen, dorsal view. Approximately one-half natural size.



TILLODONT SKULL AND JAWS FROM THE HUERFANO MIDDLE EOCENE  
*Trogosus hillsii*, new species: Skull and mandible (U.S.N.M. No. 17157), type  
specimen, lateral view. Approximately one half natural size.





TILLODONT SKULL FROM THE HUERFANO MIDDLE EOCENE

*Trogosus hillsii*, new species: Skull (U.S.N.M. No. 17157), type specimen, ventral view. Approximately one-half natural size.



**TILLODONT MANDIBLE FROM THE HUERFANO MIDDLE EOCENE**

*Trogosus hillsii*, new species: Mandible (U.S.N.M. No. 17157), type specimen, dorsal view. Approximately one-half natural size.



TILLODONT SKULL FROM THE BRIDGER MIDDLE EOCENE

*Tillodon fodiens* (Marsh), new genus: Skull (Y.P.M. No. 11087), type specimen, dorsal view. Approximately one-half natural size.



TILLODONT SKULL AND JAWS FROM THE BRIDGER MIDDLE EOCENE

*Tillodon fodiens* (Marsh), new genus: Skull and mandible (Y.P.M., No. 11087), type specimen, lateral view. Approximately one-half natural size.



**TILLODONT SKULL FROM THE BRIDGER MIDDLE EOCENE**

*Tillodon fodiens* (Marsh), new genus: Skull (Y.P.M. No. 11087), type specimen, ventral view. Approximately one-half natural size.



**TILLODONT MANDIBLE FROM THE BRIDGER MIDDLE EOCENE**

*Tillodon jodiens* (Marsh), new genus: Mandible (Y.P.M. No. 11087), type specimen, dorsal view. Approximately one-half natural size.







SMITHSONIAN MISCELLANEOUS COLLECTIONS  
VOLUME 121, NUMBER 11

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Charles D. and Mary Vaux Walcott  
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GEOLOGICAL BACKGROUND OF THE  
IYATAYET ARCHEOLOGICAL SITE,  
CAPE DENBIGH, ALASKA

(WITH FOUR PLATES)

BY

D. M. HOPKINS

U. S. Geological Survey

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(PUBLICATION 4110)

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INTRODUCTION

Iyatayet, a stratified archeological site at Cape Denbigh, Alaska (fig. 1), offers an exceptional opportunity to examine a sequence of human occupations against a background of fluctuating climate. Iyatayet is the discovery site and the type locality of the Denbigh flint complex, the oldest large assemblage of cultural remains thus far found in Alaska. The site was excavated by Giddings during 1948, 1949, and 1950. Hopkins visited the site for three days in August 1950.

The discovery and excavation of the Iyatayet site were important steps forward during the past 15 years in the study of early human history in Alaska. Detailed geologic investigations during the same period have clarified many aspects of the late Quaternary geomorphic and climatic history of the region. Until recently, however, little progress has been made in relating archeological sequences to a geologic and climatic chronology. The younger archeological sites have been occupied too recently to record notable geologic changes, and most of the older sites have lacked distinctive features upon which to base a chronology.

Many problems in the archeology and Quaternary geology of Alaska await the accumulation of additional evidence. A better understanding of the time relationship between archeological and geological events will assist in their solution. The precise dating of these events, the

nature of the Alaskan environment during early periods of human history, and the nature and availability of routes for the spread of population at various times are among the problems whose solutions depend upon evidence to be gathered from both geological and archeological investigations.

Three culture layers at Iyatayet separated by sterile zones or sharp physical discontinuities record three distinct periods of occupation separated by long periods during which the site was abandoned (table 1). The deeper layers indicate by their character that they have been subject to soil movements and to soil-forming processes that are no longer active at Iyatayet. These layers record a sequence of climatic changes similar to known sequences in other regions in Alaska. Converging lines of evidence indicate that the earliest dwellers at Iyatayet lived during a warm period in Alaska more than 8,000 years ago and perhaps more than 12,000 years ago. The later dwellers lived during two periods in the past 2,000 years, and their deposits reflect minor climatic fluctuations in the Bering Sea region.

#### GEOGRAPHIC SETTING

Iyatayet is located on the west face of the Reindeer Hills, a few miles north of Cape Denbigh, Alaska (fig. 2). The Reindeer Hills are isolated bedrock hills, ranging in altitude from 700 to 1,000 feet, which form the western extremity of a peninsula jutting from the east coast of Norton Bay near the village of Shaktolik. On the landward side the hills slope gently eastward and merge into a poorly drained coastal plain which composes most of the peninsula. On the seaward side the hills terminate abruptly in rugged sea cliffs, 100 to 300 feet high, extending with only minor embayments from Cape Denbigh to Point Dexter.

The hills are drained by several straight, shallow valleys that enter Norton Bay between Cape Denbigh and Point Dexter. Most of these valleys have been truncated by the retreat of the sea cliffs, and the streams descend to the sea in cascades at the valley mouths. The largest stream, Iyatayet Creek, has excavated its valley apace with the retreat of the cliffs, and its valley floor is graded to present sea level (pl. 1). The Iyatayet site is at the mouth of Iyatayet Valley.

Bedrock of the Reindeer Hills consists of coarsely crystalline, banded, reddish-brown and light-gray marble.<sup>1</sup> The marble is tightly

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<sup>1</sup> The Reindeer Hills are shown erroneously as basalt on Smith and Eakin's geologic map (1911, pl. 6) of southeastern Seward Peninsula. Small bodies of basalt possibly may be present, but none were seen by the writers.

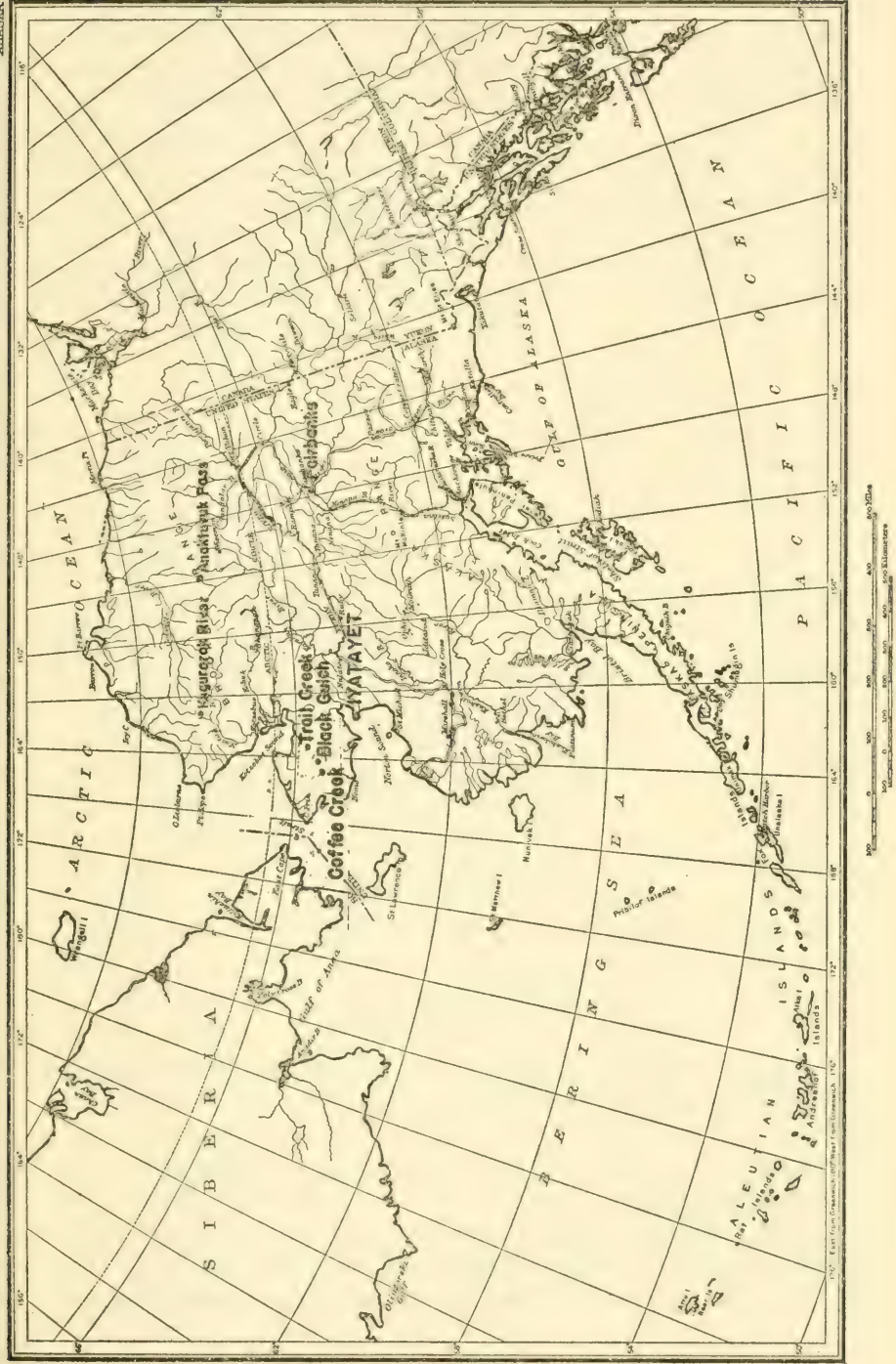


FIG. 1.—Index map of Alaska.

folded and is cut locally by large dikes of dense, dark, igneous rock largely altered to serpentine. Silt and peat 10 to 20 feet thick underlie the coastal plain to the east of the Reindeer Hills. At least 100 feet of sand and gravel is believed present beneath the silt and peat.

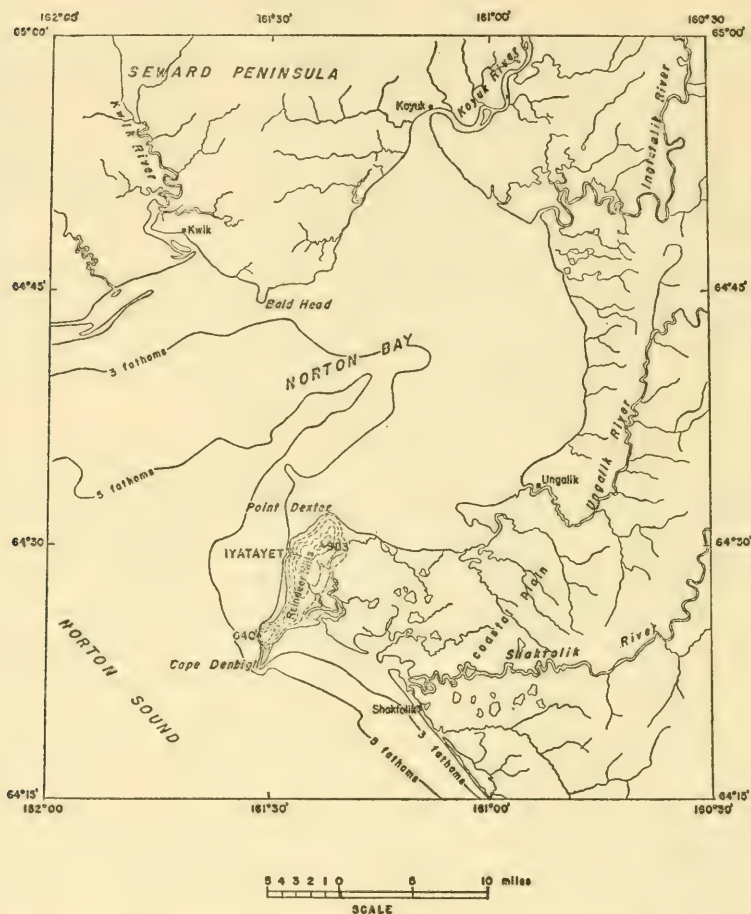


FIG. 2.—Map of Norton Bay area showing location of Iyatayet. After Norton Bay quadrangle, Alaska Reconnaissance 1:250,000 series, U. S. Geological Survey, 1951.

There is no evidence of glaciation in or near the Reindeer Hills during any part of the Quaternary.

Perennially frozen ground is present throughout the coastal plain east of the Reindeer Hills, except beneath lakes and streams. In the Reindeer Hills, perennially frozen ground probably is present beneath



areas that slope less than  $5^{\circ}$  and that are mantled by more than 2 feet of turf, peat, or silty soil. It is lacking, however, beneath slopes as steep as the walls of Iyatayet Creek and beneath areas of exposed bedrock or rubble.

No weather records are available for the Reindeer Hills or for Shaktolik. Interpolation from weather records at Nome, St. Michael, and Nulato (U. S. Weather Bureau, 1943) indicates that the Reindeer Hills have a mean annual temperature of about  $25^{\circ}$  F. The mean precipitation is about 14 inches, of which about half falls during a well-defined rainy period from July through September. More than a third of the annual precipitation falls as snow.

#### GENERAL FEATURES OF IYATAYET VALLEY

Iyatayet Creek is a small, perennial stream about a mile long. The creek flows on bedrock in a sharply cut valley, the walls of which slope  $10^{\circ}$  to  $15^{\circ}$ . A narrow terrace 40 feet above the valley floor can be traced 1,000 feet upstream from the mouth of the valley (fig. 3). Farther upstream on the northeast valley wall is an area of irregular topography at approximately the same altitude as the terrace surface. The irregularities consist of semicircular benches 10 to 30 feet wide, separated from one another by steep fronts about 10 feet high. These features, termed lobate soil terraces or soil lobes (Sigafoos and Hopkins, 1952), formed at a time when the climate was colder. At present they are not active.

A dense stand of alders, 6 to 10 feet tall, covers most of the lower walls of Iyatayet Valley (pl. 1). The alder thickets are interrupted locally by small parklike areas in which there are dense stands of tall bunchgrass or open stands of dwarf birch, Alaska tea, blueberry, cranberry, and spirea. Sedges, *Equisetum*, and scattered small alders, arranged in stripes parallel to the slope, grow on poorly drained, gently sloping areas on the higher parts of the valley walls (upper left, pl. 1). Scattered spruce may grow elsewhere in the Reindeer Hills, but there are none in Iyatayet Valley.

The steep slopes of Iyatayet Valley are stable and free of solifluction or other types of mass movement today and have been for many centuries, as indicated by the lack of active soil lobes or other active frost features, by the wide distribution of an undisturbed soil profile at the surface, and by the continuous cover of large, healthy, undeformed alders. Solifluction probably is active, however, on higher, gentler slopes where drainage is poorer.

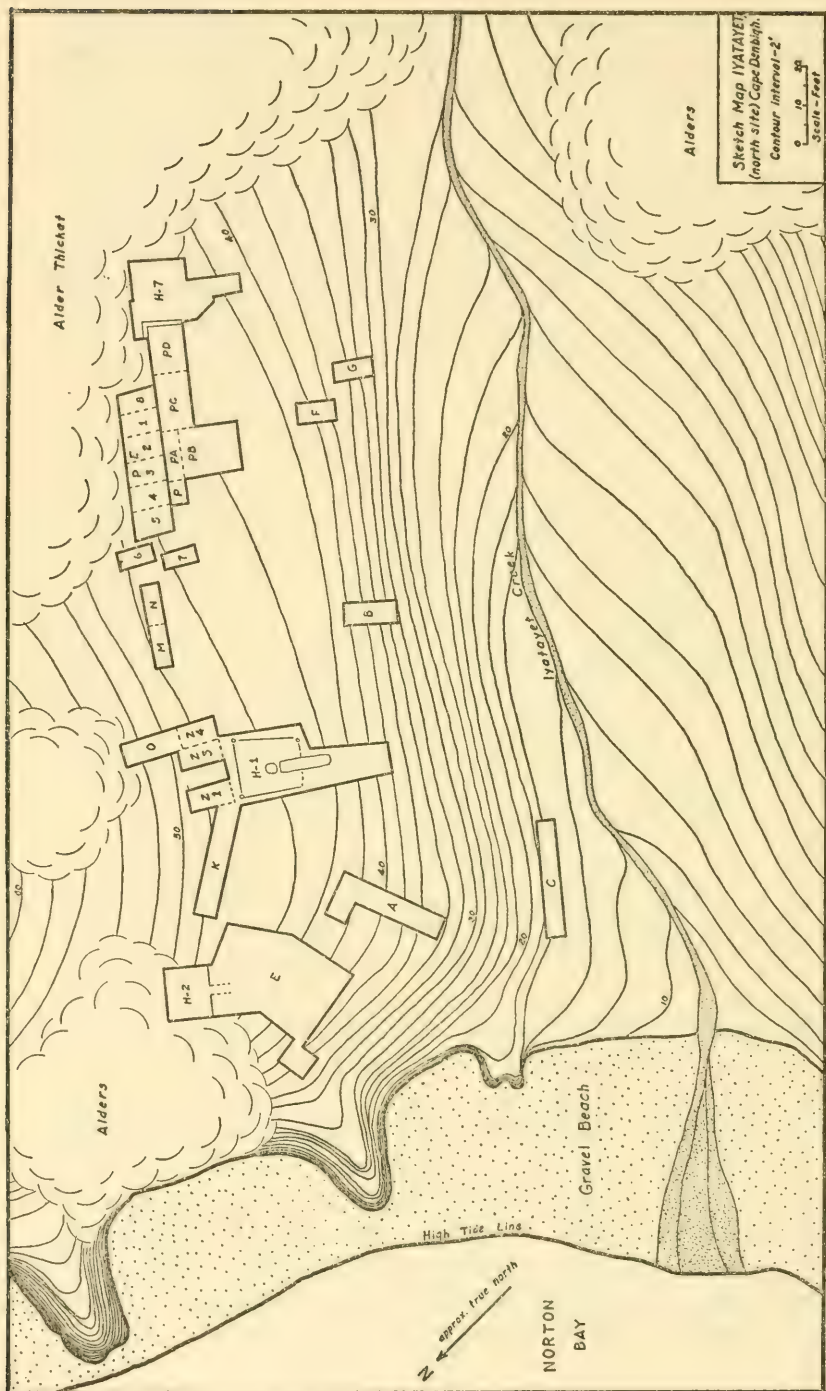


FIG. 3.—Sketch map of Iyatayet Valley. Mapped in 1950 and 1951 by J. L. Giddings. Datum is mean high tide. Numbered rectangles are excavations. H-1, H-2, and H-7 are recognizable Paleo-Eskimo houses. Widely spaced stipples are beach gravel, and closely spaced stipples are creek gravel.

## GEOLOGY AND SOILS OF IYATAYET VALLEY

Bedrock of marble lies a few feet beneath the hill slopes above the terraces. It is mantled by residual weathered material consisting of angular fragments of marble in a matrix of sandy silt. The fine-grained matrix consists chiefly of the least-soluble minerals in the marble. Feldspars and unidentified alteration minerals predominate in samples examined by Hopkins; fine-grained muscovite is abundant; and quartz, apatite, tremolite, and diopside are present in small quantities. Calcite constitutes more than 95 percent of the bedrock but is scarce or lacking in the fine-grained matrix of the weathered mantle.

The 40-foot terraces on each side of the mouth of Iyatayet Creek are composed of similar weathered marble debris. The terrace fill is vaguely stratified and poorly sorted; individual fragments generally are subangular. The deposit shows little evidence of water or wave handling. It consists chiefly of material introduced into the valley bottom from the neighboring slopes by mudflow or solifluction during a past cold period, and thus may be termed *congeliturbate* (Bryan, 1946, p. 640). The apparent absence of turf or peat layers within the terrace fill suggests that accumulation was rapid and continuous.

The top of the *congeliturbate* in the terrace represents approximately the level of the bottom of Iyatayet Valley after the accumulation of the fill and before the present era of stream cutting (fig. 4). A layer of sandy silt up to 18 inches thick overlies the *congeliturbate* on the surface of the terrace and at many places higher on the valley slopes. An ancient soil profile is preserved at the top of the *congeliturbate*, beneath the sandy silt, but has been removed or masked by later soil-forming processes where the sandy silt is lacking (fig. 5).

The top of the buried soil is marked by a 1-inch layer of sticky, ashy-gray silt in which sand and rocks are lacking. The upper 2 or 3 inches of *congeliturbate* beneath the silt are stained yellow-brown, grading downward into pale yellow or light olive-gray. Marble fragments increase in abundance and freshness with increasing depth in the *congeliturbate*.

The ashy-gray silt superficially resembles volcanic ash. A sample examined by Theodore Woodward, U. S. Geological Survey Petrographic Laboratory, consists chiefly of unidentified alteration minerals. Muscovite and orthoclase feldspar are common; a few grains of quartz and hypersthene or enstatite were recognized. No volcanic glass or fragments of obvious volcanic origin were observed. All minerals present are present also in the underlying *congeliturbate*. The ashy-

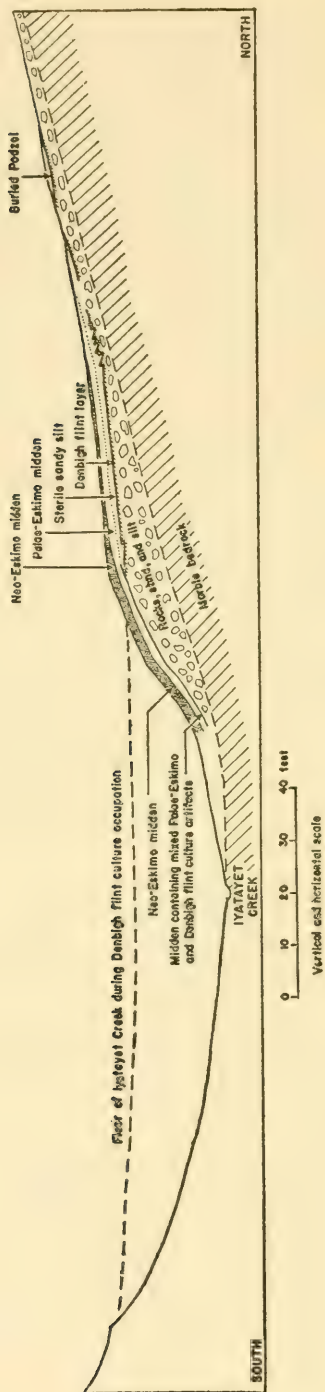


Fig. 4.—Diagrammatic cross section across Iyatayet Valley.

gray silt, therefore, is believed to be derived by weathering from the underlying congeliturbate.

The ashy-gray silt resembles the characteristic  $A_2$  horizon of an ancient podzol. The underlying 2 or 3 inches of stained congeliturbate represent the B horizon. Kellogg and Nygard (1951, pp. 49-58) report similar but much thicker and better-developed podzol profiles at a few localities elsewhere in Alaska. A thick turf layer forms the  $A_1$  horizon of modern podzols but has not been preserved in the buried

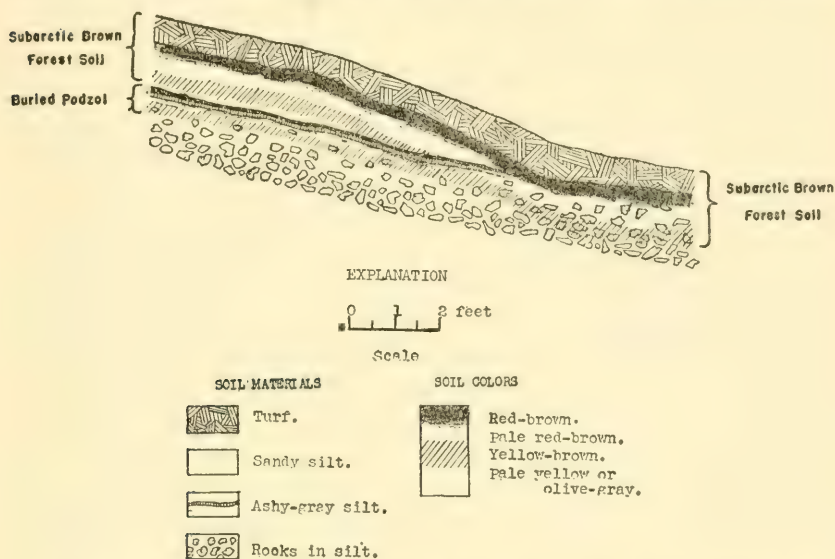


FIG. 5.—Diagrammatic sketch showing distribution and arrangement of soil layers in Iyatayet Valley. Ancient podzol is preserved in areas where it was later covered with a layer of silt (left) but has been destroyed by later soil-forming processes elsewhere (right). Left side of section is approximately 4 feet high.

soil at Iyatayet. The buried soil profile records a period of relatively warm climate and soil stability after the filling of the valley with the underlying congeliturbate and preceding the deposition of the overlying sandy silt during cold periods.

The sandy silt that overlies the buried podzol is similar in size grade and mineral composition to the matrix of the congeliturbate, but it is free of large rock fragments. Locally it is laminated; the laminae are contorted and range from one-eighth to one-half inch in thickness. A 2-inch layer of peat appears within the lower part of the silt in one of the archeological excavations (pl. 2), and a Subarctic Brown Forest soil profile appears beneath the peat.

The sandy silt consists mostly of material washed from the fronts of active soil lobes higher on the slopes of the valley during a cold period. Small fans of similar material appear below soil lobes active on Seward Peninsula at the present time. Upon thawing in spring the upper soil layers within the lobes become saturated with water. Underlying, still-frozen soil prevents excess moisture from percolating deeper, and a stout turf mat retards lateral drainage. Part of the excess water eventually escapes through open, fibrous parts of the turf, carrying with it a load of silt and fine sand. Rocks are retained within the lobe by the turf. The sand and silt then are deposited on lower, gentler slopes (fig. 7).

Wind-blown sand and silt, derived from beaches and coastal dunes at a time when sea level was lower and the strand line lay at least several miles from the Reindeer Hills, may be included in the sandy silt layers, as well as in the underlying congeliturbate.

A well-developed soil profile similar to the widespread Subarctic Brown Forest soil in interior Alaska described by Kellogg and Nygard (1951, pp. 49-58) appears beneath the surface turf throughout most of Iyatayet Valley. The profile is developed in sandy silt, congeliturbate, or earthy midden, wherever these materials are near the surface. Similar soil profiles are found beneath ground levels buried by midden and beneath the peat layer enclosed in the sandy silt (pl. 2).

The soil profile generally consists of a layer of turf 4 to 8 inches thick, underlain by 5 to 8 inches of rocky mineral soil deeply stained reddish brown and containing a considerable admixture of organic material. At greater depth the mineral soil grades in color through yellow-brown into pale yellow or light olive-gray. Marble fragments are scarce and deeply weathered in the upper reddish-brown zone, where the profile is developed in congeliturbate, but rocks increase in abundance and freshness at greater depth (fig. 5, right side).

Kellogg and Nygard's schematic soil association map of Alaska (1951) indicates that tundra soils predominate on the east coast of Norton Bay. Tundra soils undoubtedly are present in less well-drained sites, but the surface soils in Iyatayet Valley resemble more closely the Subarctic Brown Forest soil.

The Subarctic Brown Forest soil profile at the surface has developed since active soil movements ceased on the slopes of Iyatayet Valley. The similar buried soil profile near the base of the sandy silt in pit Z-4 (pl. 2) may record another period of warm climate and soil stability that interrupted the accumulation of sandy silt after the buried podzol was developed.

## THE IYATAYET ARCHEOLOGICAL SITE

Iyatayet Valley has been occupied by human beings during three distinct periods (table 1). Evidence of occupation is found on the surface and slopes of the terrace remnants on each side of the valley. Cultural remains of the earliest period have been termed the Denbigh flint complex (Giddings, 1951) and include a few artifacts similar to those found at several sites of seemingly great age in the interior of Alaska (Giddings, 1950; Irving, 1951; Solecki, 1951). The Denbigh culture layer is overlain by a sterile layer of sandy silt, and then by

TABLE 1.—*Summary of archeological and geological features of Iyatayet Valley*

I Archeological sequence	II Geological sequence	III Assumed climate
	Grass turf, alder roots, and Subarctic Brown Forest soil profile in underlying material	Like present
Neo-Eskimo occupation	Midden with well-preserved organic material	Like present
Paleo-Eskimo occupation	Midden with poorly preserved organic material and Subarctic Brown Forest soil profile in underlying material	Warmer than present
	Sandy silt	Cold
	Peat and Subarctic Brown Forest soil profile in underlying material	Like present
	Sandy silt and folds in Denbigh flint layer	Cold
Denbigh flint culture	Podzol soil profile. Almost no recognizable organic material	Warmer than present
	Rocky congeliturbate	Cold

a layer containing objects characteristic of the widespread Paleo-Eskimo culture (Ipiutak of Larsen and Rainey, 1948; Bristol Bay of Larsen, 1950) of the Bering and Arctic coasts of Alaska. This is overlain in turn by a layer containing Neo-Eskimo material. Grass turf 4 to 18 inches thick covers the youngest, Neo-Eskimo part of the site; the remainder is covered by large alders.

## THE DENBIGH CULTURE LAYER

The Denbigh flint complex is found in place on the terrace on the northeast side of Iyatayet Creek. The culture layer lies above the ash-gray layer of the buried podzol and is overlain by sandy silt.

Gaps in the layer caused by soil movements are found near the inner edge of the terrace. Filled excavations and house sites of the Paleo-Eskimos interrupt the continuity of the layer elsewhere on the terrace surface. The flint layer ends abruptly near the front edge of the terrace and is replaced on the steep foreslope by a diffuse zone of mixed Denbigh flint and Paleo-Eskimo material (fig. 4). The Denbigh flint material in the mixed zone probably consists of material encountered in house excavations and thrown over the terrace scarp with other refuse by Paleo-Eskimos.

Cultural material of the Denbigh flint complex consists of sparsely distributed flint flakes and artifacts (chert, obsidian, and chalcedony, in order of their abundance) pressed flush against the buried podzol. Neither these nor the small beach pebbles and angular marble fragments found in some parts of the layer are intruded into or below the underlying ashy-gray silt. Recognizable organic remains are extremely scarce and consist of tiny fragments of charcoal and decomposed bone. No house floors or tent rings have been recognized, but a series of five hearths, roughly in line, have been uncovered at the upslope edge of the terrace. Four of the hearths are shown on figure 6.

The distribution of cultural material in the Denbigh culture layer, pressed flush against the surface of the buried soil, is open to two interpretations. The site may have been occupied only during winter, when the ground was frozen to the surface and was too hard to allow stones or wood to penetrate under the pressure of human feet. If this were the case, however, it is difficult to understand why the stones of hearths and the ground around these obviously fire-exposed areas also should be limited by the underlying dense soil. A more appealing interpretation would be that the campers at Iyatayet left their hearths and flinty materials on top of a sod cover, the organic parts of which have long since decomposed and disappeared. Occupation would then be limited to no particular season, but probably would be limited to rather brief visits. Under continuous occupation the protecting turf layer should have been broken, permitting penetration of artifacts into the soil, as occurred during the later Paleo-Eskimo occupation.

Nearly 1,500 artifacts have been found in the Denbigh culture layer. The collection is characterized by tools and techniques that, with few exceptions, bear little resemblance to cultural materials generally recognized as Eskimo (Giddings, 1951).

Burins, or "gravers" in the European sense, and their spalls discarded in sharpening comprise about a quarter of the Denbigh flint collection (Giddings, 1951, figs. 59a, 60a). Burins apparently had not been recognized elsewhere in America before the excavation of Iyata-



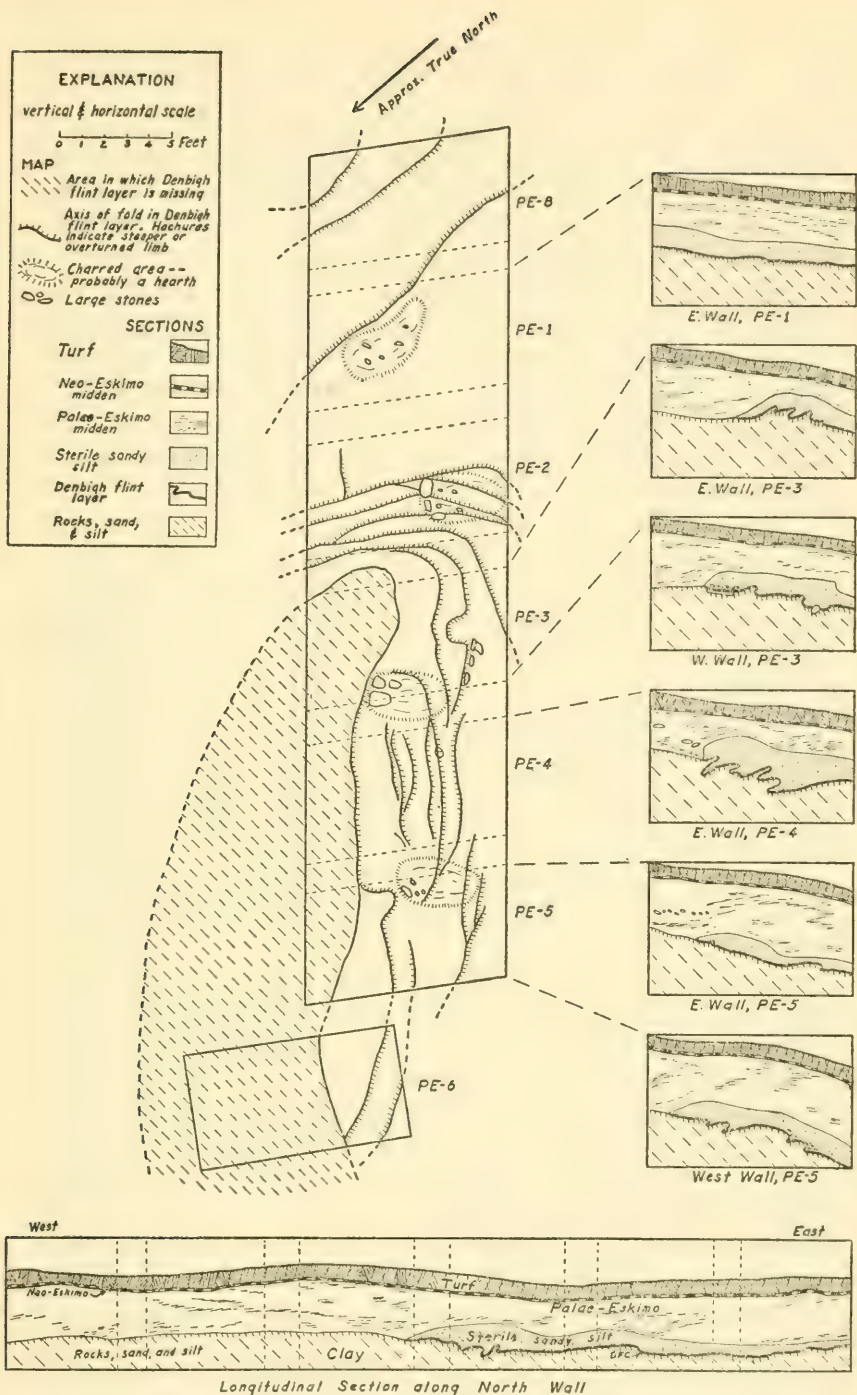


FIG. 6.—Map and cross sections showing folds in the Denbigh culture layer in pits PE-1 through PE-8. Note large gaps where Denbigh culture layer is missing upslope from folds (lower left part of map). A well-defined turf layer separates the Paleo-Eskimo and Neo-Eskimo middens in many parts of the site but is lacking in the area shown here.

yet. A variety of forms are present, several of which fall into types known from the Aurignacian and later periods of European pre-history. Referable to the same periods and places are a few other special forms found at Iyatayet, including keeled scrapers, flake knives, and gravette-like blades (op. cit., fig. 59b).

Lamelles and cores—microlithic blade developments known as early as the late Paleolithic, and with a geographic spread that includes large parts of Eurasia and Africa—comprise more than half of the collection (Giddings, 1951, fig. 61b). These have been reported previously from a few other sites in America. Many of the small blades at Iyatayet have been carefully pressure-flaked diagonally to produce the most delicate and elaborate microlithic forms known to the authors.

Several points or blades (Giddings, 1951, fig. 60), a form of “channeled” scraper (op. cit., fig. 62), and a single graver (op. cit., fig. 59b) resemble forms found in “Yuma”<sup>2</sup> and Folsom sites of southwestern United States so closely that there can be little doubt of technological relationship.

A few other blades and scrapers are unique at Iyatayet, and still others are of a generalized nature that renders them presently unclassifiable. Short, wide, and thin blades with concave bases (Giddings, 1951, fig. 64) closely resemble specimens found hafted as sealing harpoon blades at Ipiutak (Larsen and Rainey, 1948). A bit of birch bark that appears to have been part of a lashed or sewn vessel constitutes the only recognizable organic artifact recovered in the Denbigh flint layer.

Assemblages of artifacts in the Denbigh flint complex tradition have been found in the Kugurorok River Valley (fig. 1) in the eastern part of the Brooks Range (Solecki, 1951), in Anaktuvuk Pass in the central part of the range (Irving, 1951), and near the Anaktuvuk River at the north front of the range (Solecki and Hackman, 1951). The Kugurorok River site occupies glaciated bedrock knolls, and the Anaktuvuk River site occupies unconsolidated deposits of glacial origin. The Anaktuvuk Pass site undoubtedly also lies within a glaciated area. These sites were not necessarily covered with ice, however, during the latest glacial advance in the Brooks Range. At least four distinct Pleistocene ice advances, each less extensive than its predecessor, are

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<sup>2</sup> This term is used here in the sense generally understood by archeologists to include several forms and techniques of early-man flint work. Although “Yuma” is in current disfavor, it has not been replaced by a similarly comprehensive term.

recognized farther east by R. F. Detterman, of the U. S. Geological Survey (personal communication).

Hopkins examined air photos of the Anaktuvuk River site. The morainal ridges upon which the site is found appear similar in degree of modification and dissection to morainal ridges deposited during the second of the three glacial advances recognized by Detterman. The other two sites at which Denbigh cultural material is found may also be in areas that remained ice-free during the latest glacial advance in the Brooks Range. Solecki (1951) states that "the fact that these early manifestations were found in glaciated areas conclusively points out that these sites were occupied within post-glacial times." On the basis of present knowledge, however, it can only be said that the sites are younger than an early glacial advance; they are not necessarily younger than the latest Pleistocene glacial advance.

Cultural material comparable with, but believed by the writers to be younger than, the Denbigh flint complex characterizes the lower levels of stratified cave deposits excavated by Helge Larsen at Trail Creek, Seward Peninsula (fig. 1). Mesolithic and early American traits, including core and microblade, diagonal flaking, and "Yuma"-like points, are common to the lower levels at Trail Creek and to the Denbigh flint complex at Iyatayet. The Paleolithic traits of the Denbigh flint complex, including burins and spalls, are completely lacking, however, at Trail Creek. These relationships suggest that no part of the Trail Creek sequence known at present is as old as the Denbigh flint complex at Iyatayet.

A carbon-14 analysis of willow stems collected in one of these lower levels at Trail Creek, but not definitely associated with cultural material, gives an age of  $5,993 \pm 280$  years (Johnson, 1951, p. 16).<sup>3</sup> Because of the abundant sources of sample error in carbon-14 analyses, data obtained from single samples must be treated with extreme caution (see discussion of sample error in Flint and Deevey, 1951, pp. 259-260; and Bartlett, 1951). If, however, future analyses confirm the age of the lower part of the Trail Creek sequence, one may assume that the Denbigh flint complex at Iyatayet is older than 6,000 years.

The so-called "Siberian Neolithic," a widespread cultural horizon known from the Ural Mountains to the Lena River, contains flint

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<sup>3</sup> A sample of charcoal from the Denbigh flint layer was submitted for age analysis at the end of the 1951 field season. When this sample was found too small for reliable use, a special trip to Iyatayet was scheduled for the 1952 field season. Aided by Alex Ricciardelli, Giddings obtained charcoal enough for more than one analysis from the Denbigh flint layer, from which carbon-14 dates are anticipated in the near future.

traditions strongly suggestive of connectives both with the Denbigh flint complex and with later Paleo-Eskimo flint developments in Alaska. Briefly, the Siberian Neolithic includes microblade and core industry, diagonal flaking, pottery in abundance and variety, and well-preserved bone and other organic material. Microburins are reported at the Kullata site near Yakutsk (Okladnikov, 1950) but are lacking at other sites. According to Grigoriev (1950, p. 177), Okladnikov believes that the Kullata site was occupied during a warm, dry period 4,000 to 6,000 years ago; other Siberian Neolithic sites are assigned dates by Okladnikov and others of 6,000 to 3,000 years ago.

Full discussion of the relationships between the Siberian Neolithic and cultural horizons represented at Iyatayet is reserved for a later paper by Giddings. For the present it may be said that the Siberian material appears to the authors transitional between the Denbigh flint complex and the Paleo-Eskimo culture and that the Siberian Neolithic is believed to represent a later culture than the Denbigh flint complex.<sup>4</sup>

The several lines of archeological evidence described above indicate a considerable antiquity for the Denbigh flint complex. With the exception of the probable harpoon blades, none of the artifacts can be considered characteristically Eskimo, and thus a profound separation from later, Eskimo cultures is indicated. Many of the tools and techniques of the Denbigh flint complex are found typically in United States and Old World sites occupied prior to the "postglacial" thermal maximum; some of these distant sites were occupied still earlier in the last (Wisconsin or Würm) glacial stage. The traits common to the Denbigh flint complex and to ancient sites in the Old World or the United States are so distinctive and so unlikely to have been invented twice that one must assume that the Denbigh flint complex is in a direct line of heritage with these far-distant sites. The archeological evidence argues strongly for an age greater than that of the thermal maximum as recognized in the United States, believed to have begun about 6,000 years ago (Flint and Deevey, 1951, p. 258), and may permit an age greater than that of the Mankato substage of glaciation, believed to have reached its climax between 8,500 and 11,000 years ago (*op. cit.*, pp. 261-267; Schultz, Lueninghoener, and Frankforter, 1951, pp. 34-36). Geological evidence, summarized in

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<sup>4</sup> The authors acknowledge with full respect the views expressed in writing and in conversations by Profs. H. L. Movius, Jr., and Lauriston Ward that more resemblances to the Denbigh flint complex appear in the Siberian Neolithic horizons than in known sites of the east Asiatic upper Paleolithic, and recognize in these views a difficulty of correlation with the dating herein proposed.

a later section, indicates that the Denbigh culture layer at Iyatayet was deposited during a warm period at least 8,000 years ago and possibly more than 12,000 years ago.

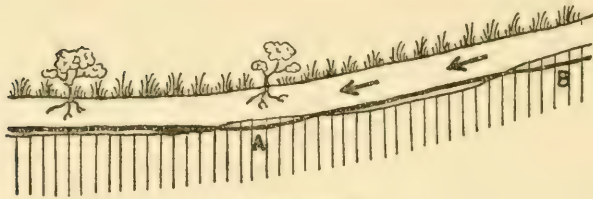
#### FOLDS IN THE DENBIGH CULTURE LAYER

Complex folds with axes approximately parallel to the surface contours disturb the Denbigh flint layer in several parts of the site (pls. 2 and 3). The folds are best developed near the base of the steep bedrock slope at the inner edge of the terrace, but gentler folds are noted elsewhere (fig. 4). Involved in the folds are the upper part of the congeliturbate, the ashy-gray silt, the Denbigh culture layer, and at least part of the sterile sandy silt. The folds are not reflected at the surface or in any part of the Paleo-Eskimo layer.

Axes of the folds are broadly arcuate and convex downslope. Individual folds decrease in amplitude laterally and fade out a few tens of feet from the point where they are best developed. A younger set of folds in one part of the site appears superimposed upon an older fold (pit PE-2 in figure 6).

The folds are asymmetric or overturned, with the steeper or overturned limb on the downslope side. Thin beds retain their continuity unbroken within the folds, but upslope from each set of folds are found gaps several feet wide in which both the Denbigh culture layer and the ashy-gray silt are missing. Flint chips and stones pressed flush against the lower surface of the Denbigh layer faithfully reflect the attitude of the layer, being horizontal and above the ashy-gray silt on the upslope limbs, vertical at the crests of the folds, and tilted beneath the ashy-gray silt on the overturned limbs.

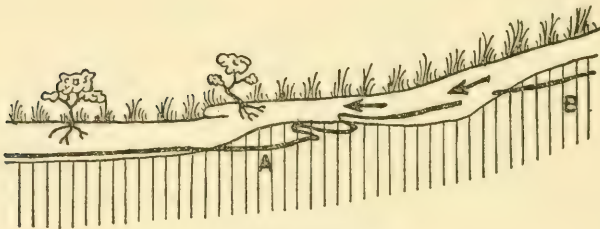
The folds in the Denbigh culture layer formed in the course of development of soil lobes in the overlying sandy silt (fig. 7) during a cold period long after the early occupation ended. Active soil lobes studied by Sigafos and Hopkins (1952) creep downslope during late spring, when the thawed soil near the surface is saturated with meltwater. At deeper levels the soil remains frozen in position and cannot partake of the surface movements. Differential heaving during the fall freezing season results in similar differential movements (*op. cit.*, fig. 1). Shear resulting from frictional drag between mobile, saturated, sandy silt above and immobile, frozen, rocky debris below produced the intricate folds in the Denbigh culture layer. The remarkable continuity of distinctive zones throughout the folds indicates that the movements were slow, perhaps totaling a few inches each year. During the folding, the total downslope length of the area occupied by



STAGE I



STAGE II



STAGE III

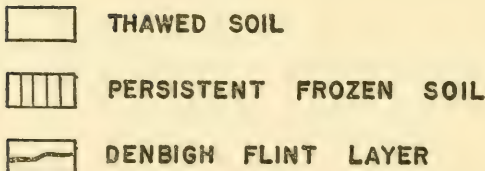


FIG. 7.—Development of folds in the Denbigh culture layer by creep and solifluction. *Stage 1:* Ground thaws during late spring but frozen ground is still present below the surface. Denbigh culture layer is thawed in most places but locally is anchored firmly in frozen ground (A). *Stage 2:* Saturated surface layer creeps downslope, forming soil lobe. Thawed part of Denbigh culture layer overrides part of layer still anchored in frozen ground (A). Gap forms upslope from fold, downslope from another area where Denbigh culture layer is frozen (B). *Stage 3:* Front of soil lobe advances, overriding surface turf, during spring in a later year. Additional folds are formed in Denbigh culture layer and gap widens where layer is missing. Note tilted shrub with roots trailing upslope.

the Denbigh flint layer was shortened. This shortening was compensated by the formation of gaps in the layer upslope from the folds. The peat layer found within the sandy silt in one pit probably is a remnant of the strong turf cover that retained the soil lobes.

#### THE PALEO-ESKIMO LAYER

Remains of the Paleo-Eskimo culture are found in a layer 18 to 36 inches thick on the top and steep foreslope of the terrace on the northeast side of Iyatayet Creek. The Paleo-Eskimo layer fades imperceptibly at its lower boundary into the sterile sandy silt that covers the Denbigh flint layer. A layer of grass sod locally separates the Paleo-Eskimo zone from the overlying Neo-Eskimo layer, but in some places the two layers are in direct contact. They are distinguished easily, however, by a sharp break in the degree of preservation of organic matter.

The Paleo-Eskimo layer generally consists of a rich, red-brown or light yellow-brown mixture of humic material and silty soil, but in some places it consists of soft, friable, black, peaty material. In many parts of the site, one or more former ground levels can be distinguished. Paleo-Eskimo artifacts are found in the sandy silt beneath the buried ground levels in attitudes suggesting that they have been thrust or tramped into the ground. Cross-bedded middens are found above the buried ground levels. One house and several charred areas have been recognized. Many filled excavations are present (pl. 2); some of these extend below the Denbigh culture layer.

The Paleo-Eskimo cultural material consists of stone tools, pottery, beach pebbles, angular marble fragments, charcoal, and abundant but poorly preserved organic material. Hard, firm bone, antler, and ivory are rare; generally these materials are preserved as small, friable fragments of about the same consistency as the enclosing sandy silt. Shells are abundant, but only the papery, chitinous cover of the limy valves can be recovered. Wood generally is represented by a few limp fibers or by a humic stain in the enclosing silt and sand. Rarely a recoverable log is found.

In striking contrast with the Denbigh flint complex, the Paleo-Eskimo layer contains the sorts of household equipment, tools, and weapons commonly associated with Eskimo developments locally and Neolithic developments in other parts of the world. Stone lamps of a triangular, "sadiron" shape, as well as of irregular forms, have been pecked out of igneous or metamorphic rock in relatively large numbers. Smaller stone vessels of teacup and soap-dish size and shape may

have been mortars and paint dishes rather than lamps. Thick pottery vessels were occasionally made in crude imitation of stone lamps, but the great bulk of potsherds collected were those of thin, well-fired cooking pots. The pots had been either round or conical-based or flat-based, and had been imprinted over all the outer surface with striations or small check-stamps. Cord markings appear on a few sherds, and two or three vessels represented in the collection were treated on the outer surface only by smoothing. All in all, the methods of treating this pottery are in keeping with upper Neolithic practices in Asia and with Woodland and other traditions of earliest pottery making in the eastern United States.

The grinding and polishing of slate to be seen on blade fragments are in no case as refined as are these techniques on Neo-Eskimo artifacts. Heavy scratches characterize the semilunar and other knife blades of the Paleo-Eskimos. A finer polishing distinguishes the tongue-shaped, partly chipped adz blades and the long, medial labrets of stone and jet that also are found in the Paleo-Eskimo deposits. A polished form of small, hard stone implement appears to be a cutter or groover to be used in the manner of a burin: it is fairly numerous, and is characterized by the meeting of two planes at nearly right angles at one narrow edge. Adz blades, labrets, and burinlike instruments are made of highly silicified slate or other materials that could be prepared by conchoidal flaking. Whetstones of several shapes and grain sizes as well as fragments of larger grinding stones appear in both Paleo-Eskimo and Neo-Eskimo deposits, but are lacking in the Denbigh flint complex.

The flinty materials chosen by the Paleo-Eskimo were mainly basalts and silicified slates—materials almost totally lacking in the Denbigh flint complex. They were skillfully handled, however, and furnished a base for most of the weapon points and other blades. Some use was made of chert and obsidian, but it is often difficult to determine which of the objects made of these materials belong to the middle levels and which were displaced from underlying disturbed sections of the Denbigh flint layer.

The few objects of organic materials obtained from these levels are, in almost all cases, relatable to pieces from the Near Ipiutak<sup>5</sup> houses and middens at Point Hope. These include harpoon heads of two types, arrowheads slotted for side blades and for end blades, bone

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<sup>5</sup> Larsen and Rainey (1948) recognized the contents of a few isolated house and midden deposits in Point Hope as distinct from Ipiutak culture materials, though closely related. They named this aspect "Near Ipiutak" but were unable to say with certainty whether it represented an earlier or a later stage of culture.



and ivory awls or marlinespikes, ice picks, flaking hammers, and an engraving tool. Engraved decoration is lacking. A single crude, armless "doll" of ivory has a long trunk and an oval head, but lacks facial features.

All in all, the materials obtained from the Paleo-Eskimo levels at Iyatayet show close identity with those from Near Ipiutak at Point Hope, and much less similarity to those from Ipiutak proper.

No part of the Paleo-Eskimo site is perennially frozen, and the poor preservation of organic material indicates that it has not been perennially frozen during most of the time elapsed since the period of Paleo-Eskimo occupation. Small-scale plications in charcoal lenses characterize the deeper parts of the Paleo-Eskimo layer, below old ground levels. Some of these were produced by the formation and destruction of clear ice lenses during annual cycles of freezing and thawing; others were formed by local slumping as wood and other organic material in the soil rotted away. Still others probably resulted from the pressure of tramping feet when the ground was wet and soft each spring. Large-scale folds, comparable with those involving the Denbigh culture layer, are lacking. A Subarctic Brown Forest soil appears to have developed beneath Paleo-Eskimo ground levels, indicating that the soil was relatively stable and immobile. Additional quantities of sandy silt, however, were washed into some parts of the site. Some of the silt may have been introduced during brief cool periods when soil lobes formed higher on the slope, but most of the added sediment probably was derived from paths, dog holes, and other artificial bare areas. Intrusion of Paleo-Eskimo artifacts below the surface on which they lived indicates that occupation continued for long periods, through summers as well as winters. Carbon-14 analysis of a charcoal sample indicates that an older part of the Paleo-Eskimo zone at Iyatayet is  $2,016 \pm 250$  years old; a younger phase is  $1,460 \pm 200$  years old (samples 563 and 506—Johnson, 1951, pp. 15-16).

#### THE NEO-ESKIMO LAYER

Deposits of the Neo-Eskimo culture are found on both sides of Iyatayet Creek, on the steep slopes as well as the surfaces of the terraces. The culture layer is found immediately below the surface sod. A well-defined sod layer underlies much of the Neo-Eskimo midden and separates it from the deeper Paleo-Eskimo layer. The culture layer ranges from a few inches to 6 feet in thickness and consists of peaty, dark-brown to black midden material. Parts of the midden are perennially frozen, although underlying Paleo-Eskimo midden

is thawed. The midden shows no evidence, however, of disturbance by frost action.

Organic materials, including bone, antler, ivory, and bivalve shells, are abundant and well preserved. Wood is abundant but is generally soft and friable. Some logs are fresh enough, however, to permit cutting sections for tree-ring study.

All the later deposits at Iyatayet contain sparse cultural materials displaced from older levels. This is to be expected in any village or camp site that lies above another, not only because of the Eskimo practice of digging house and cache pits, but also because of a curiosity and archeological bent of many individuals such as may be seen among Eskimos living in the area today. No doubt the Paleo-Eskimos were as keenly interested in the microlithic work of the earliest inhabitants of the site as are the Neo-Eskimos of the present day in all the curious early workmanship. The earlier artifacts are readily distinguished, however, in the deposits of the Neo-Eskimos. This is partly because of a difference in tradition of style and workmanship between the two periods. A more definitive aid in separating the later deposits at Iyatayet, however, is Giddings's excavation of a pure Neo-Eskimo site, Nukleet, on the south side of Cape Denbigh (Giddings, 1949). Several thousand artifacts from the Nukleet site delineate a sequence of stylistic changes that affords a rather complete picture of the Neo-Eskimo in the Cape Denbigh region during their period of occupation. Dendrochronological studies indicate that occupation extended from about A.D. 1100 to 1600 (op. cit., p. 86).

The Neo-Eskimos were a fishing, sealing, caribou-hunting people whose dependence on the inland, forested regions nearby is attested by their extensive use of beaver teeth as knives, their use of birch bark as containers, and their extensive use of antler. An enumeration of their other artifacts is in preparation; we may note, however, that their cultural balance seems much like that of present-day Eskimos living at points along the northeastern Bering Sea.

## LATE QUATERNARY HISTORY OF IYATAYET VALLEY

### CLIMATIC SIGNIFICANCE OF FEATURES OF IYATAYET VALLEY

A series of changes in climate and in the position of sea level may be inferred from the geologic and archeologic deposits in Iyatayet Valley (table 1). The recognized history begins with the carving of the bedrock valley. Because the bedrock valley is graded approximately to present sea level, one must assume that sea level stood near its present position at that time. The climate probably was not colder than at present.

A subsequent period of valley filling during an interval with cold climate is recorded by the 40-foot terrace. Lack of rounding and the unsorted character of the debris indicate, in this region, that the fill consists of congeliturbate introduced from neighboring slopes by solifluction during a period of intense frost action. The lack of wave-handled material in the terrace fill and the absence of elevated wave-cut rock terraces elsewhere along the rugged coast between Cape Denbigh and Point Riley indicate that sea level stood no higher during the deposition of the congeliturbate than it does at present. Instead, sea level is believed to have been lower. The shore line probably shifted several miles—perhaps several hundred miles—across the flat floor of Bering Sea away from the Reindeer Hills.

Iyatayet Creek was unable to transport all the load furnished by solifluction on the valley walls, and the valley was filled to a depth of 40 feet. The fill probably extended as an alluvial fan beyond the mouth of the valley across the dry floor of Iyatayet Cove.

Valleys draining the hills between the Koyuk and Kwik Rivers, 40 miles north of Cape Denbigh (fig. 2), resemble Iyatayet Creek after its valley was filled with congeliturbate. Minor streams within the hills in the Koyuk-Kwik area meander across flat, debris-choked valley bottoms (pl. 4). Longitudinal profiles of the valleys are steep. The streams debouch onto adjoining coastal lowlands across broad debris fans similar to that inferred at the mouth of Iyatayet Creek. A small rise in sea level in the Koyuk-Kwik area would subject the unconsolidated fans to erosion by waves and longshore currents, and the fans would be removed rapidly to the edges of the bedrock hills. Stream gradients at the mouths of the valleys would be steepened, and the streams then would re-excavate the valleys, leaving remnants of the valley fill as terraces like those in Iyatayet Valley.

The podzol soil profile, developed in the congeliturbate during a warm interval while Iyatayet Valley was occupied intermittently by people of the Denbigh flint culture, records a brief but important interruption in the filling of the valley. The profile indicates a period of soil stability during which soil movements ceased on the adjoining slopes, to be resumed when the podzol with its included artifacts was buried and folded beneath sandy silt washed in from the walls. The precise climatic significance of the podzol is uncertain. Podzols are most widely distributed in Alaska in areas with a warmer summer temperature than that in the Norton Bay region, but Subarctic Brown Forest soils are abundant in the same areas (Kellogg and Nygard, 1951, pp. 51-83). It seems certain that the climate of the interval during which podzol formed at Iyatayet was at least as warm as, and

possibly slightly warmer than, the present climate. The shallow depth of profile development suggests that the warm period was brief compared with later intervals during which Subarctic Brown Forest soils were formed.

The sandy silt that covers the Denbigh culture layer marks the return of a cold climate that terminated the development of the podzol. Renewed intense frost action reactivated soil lobes higher on the valley slopes. Silt washed from the advancing soil lobe fronts was deposited lower on the slopes and on the terrace surface, which at that time still formed the valley bottom. The buried podzol, the Denbigh culture layer, and part of the sandy silt were tightly folded as soil movement progressed.

The thin peat and underlying Subarctic Brown Forest soil exposed in pit Z-4 probably record a warm interval that interrupted the pre-viously cold period during which the sandy silt was deposited. Because this buried profile appears in only one of the many good exposures of the full thickness of the sandy silt layer, it could be considered to have formed in a local area of stable soil at a time when solifluction was active in adjoining areas. Poorly drained silt, however, is particularly subject to frost heaving. Stirring due to frost heaving prevents the formation of a stratified soil profile in silt underlain at a depth of 2 or 3 feet by perennially frozen ground on Seward Peninsula (Hopkins and Sigafos, 1951, pp. 61, 63). The sandy silt in which the buried Subarctic Brown Forest soil appears lies at the base of a slope in a position where, if perennially frozen ground were present, it would maintain a high water content throughout most of the year. It is extremely unlikely that any part of the sandy silt on the old valley floor of Iyatayet Creek would have remained sufficiently stable to permit formation of a well-developed Subarctic Brown Forest soil profile during a period when frost action was intense a few feet away. Consequently, the buried soil exposed in pit Z-4 is believed to have formed during a warm interval, when soil movements ceased throughout Iyatayet Valley. The profile probably developed in the sandy silt throughout the valley but was obscured by frost stirring during the ensuing cold period except in areas where it was later buried by an exceptionally large thickness of sandy silt.

Deposition of the sandy silt was terminated finally by the period of warmer climate that has extended with only minor fluctuations to the present. Sea level rose and the shore line approached its present position. The alluvial fan assumed to have covered the floor of Iyatayet Cove was removed by waves and longshore currents. Iyatayet Creek re-excavated its valley to bedrock, leaving remnants of the valley

fill as terraces. Well-developed soil profiles beneath Paleo-Eskimo ground levels indicate that soil movements had ceased and that a warm climate had prevailed for a long time prior to Paleo-Eskimo occupation.

A minor climatic fluctuation during the past 2,000 years is suggested by the difference in preservation of organic material in Paleo-Eskimo and Neo-Eskimo middens. The Paleo-Eskimo midden is earthy, but friable fragments of bone and antler and soft fibers of wood testify to a former abundance of organic material now largely rotted away. The Neo-Eskimo midden, on the other hand, is peaty in character; organic material is well preserved and makes up much of the bulk of the deposit. The contrast in preservation of organic material indicates a climate slightly warmer than at present during and after Paleo-Eskimo occupation and a return to slightly cooler conditions during and after Neo-Eskimo occupation.

#### LATE QUATERNARY CLIMATIC FLUCTUATIONS ON SEWARD PENINSULA AND IN THE FAIRBANKS DISTRICT

The climatic fluctuations recorded at Iyatayet undoubtedly were common to other parts of Alaska. Glacial sediments mapped by Hopkins in the Kigluaik Mountains of Seward Peninsula (field notes, 1949, 1950) may have been deposited during one or more of the cold periods recorded at Iyatayet. Unfortunately, the glacial deposits of Seward Peninsula at present can be neither dated nor correlated with certainty with glacial deposits of known age elsewhere in Alaska.

Sequences of silt and muck (silt rich in organic material) exposed in placer mine excavations record climatic fluctuations in unglaciated areas of Seward Peninsula and central Alaska. Hopkins has studied silt and muck stratigraphy in some unglaciated valleys in central and northern Seward Peninsula. Muck layers present in many valleys have been dated by carbon-14 analyses of wood specimens from three localities. Péwé (1952) has studied more thoroughly the stratigraphy of unconsolidated sediments in upland valleys in the Fairbanks district. Carbon-14 analyses of wood from several different muck layers provide data by which several climatic fluctuations during the past 20,000 years can be dated.

Silt layers in upland valleys in the Fairbanks district consist of loess deposited on valley slopes and ridge tops and carried into valley bottoms during glacial episodes in the nearby Alaska Range (Péwé, 1950). Muck layers consist of stream and mudflow deposits and residual peat and forest beds that accumulated in stream valleys during

periods when glaciers in the Alaska Range were less extensive and when the climate was at least as warm as at present. Péwé recognizes three muck layers separated by two silt layers which record three warm intervals and two glacial intervals.

The oldest muck layer rests on auriferous gravel in valley bottoms and is at least 20,000 years old. A thick layer of slightly reworked loess overlying the oldest muck is more than 16,000 years old. Overlying the loess is a second muck layer from which samples of organic material 12,000 to 16,000 years old have been collected. A second loess layer less than 12,000 and more than 4,200 years old overlies the second muck layer and is overlain in turn by a third muck deposit from which samples of organic material 3,500 to 4,200 years old have been collected. The cold period represented by the second, upper loess deposit probably is equivalent in age to the Mankato substage of glaciation in north-central United States considered by Flint and Deevey (1951, pp. 261-267) to have occurred about 11,000 years ago.<sup>6</sup> At least part of the middle muck layer of the Fairbanks district was deposited during the interstadial interval between the Cary and Mankato substages as recognized in north-central United States.

Two muck units of different ages are tentatively distinguished by Hopkins in unglaciated creek valleys of central and northern Seward Peninsula. Specimens collected at Claim No. 4 above Discovery on Coffee Creek, a tributary of the Kougarok River 60 miles north-northeast of Nome, at the head of Black Gulch, a tributary of the Noxapaga River 80 miles north-northeast of Nome, and in the valley of Mud Creek near the southeast shore of Kotzebue Sound (fig. 1) have been dated by carbon-14 analysis by J. L. Kulp, Lamont Geological Observatory, Columbia University. Wood collected at Coffee Creek in the older muck unit is  $8,350 \pm 200$  years old; wood collected at Black Gulch in the older muck is  $8,800 \pm 200$  years old; and wood collected at Mud Creek in the younger muck is  $3,600 \pm 200$  years old.

The dated specimen from Coffee Creek was collected from frozen muck free of large ice masses that overlies blue-gray silt containing ice wedges arranged in a polygonal pattern. The blue-gray silt contains little or no organic material and is thought to consist either of wind-blown silt or of silt derived from frost-rived bedrock farther

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<sup>6</sup> A different opinion is offered by Schultz, Lueninghoener, and Frankforter (1951, pp. 34-36), who argue that the "Mankato climax may have been as recent as eight or even seven thousand years ago." Pollen sequences indicate, however, that Mankato ice had retreated in Minnesota and that spruce and fir grew in the glaciated area as early as 8,000 years ago (Flint and Deevey, 1951, pp. 272-273).

upslope, at a time when the climate was colder than at present. The overlying muck contains abundant willow wood, a few sticks of poplar (R. S. Sigafoos, botanist, U. S. Geological Survey, oral communication), and a log chewed by a beaver whose incisors were no larger than the incisors of *Castor canadensis*, the modern beaver in Alaska (H. W. Setzer, zoologist, United States National Museum, oral communication).

The dated specimen from Black Gulch was collected in muck generally similar to, but less well exposed than, the muck at Coffee Creek. Ice wedges are present in the muck at Black Gulch. Wood in the muck includes a few logs as large as 6 inches in diameter. The dated specimen was identified by Sigafoos as poplar wood.

The dated specimen from Mud Creek was collected near the inner edge of a rolling coastal plain at the southeast corner of Kotzebue Sound, 2 miles west of Candle, Alaska. The specimen consists of wood from a buried beaver dam at the base of a deposit about 30 feet thick of interbedded muck and fibrous peat. The organic sediments are underlain by Quaternary gravel many tens of feet thick. Mining operations in 1949 exposed the surface of an ancient floodplain upon which the beaver dam was built. Sedge turf, willow or alder thickets, and a birch stump 6 inches in diameter were seen rooted in place in the vicinity of the beaver dam. Sticks in the beaver dam had been carved by beavers whose incisors were comparable in size with those of *Castor canadensis*.

Sparse willow shrubs grow today in the valleys of Coffee Creek, Black Gulch, and Mud Creek, but poplar and birch trees do not. Willows are much less abundant on the modern surface of the valley of Mud Creek than on the exhumed flood plain on which the dated wood was collected. The western limit of beaver during the past 50 years has been 100 miles to the east of Coffee Creek and Black Gulch and more than 50 miles to the east of Mud Creek. The older muck, represented by the muck at Coffee Creek and Black Gulch, and the younger muck, represented by the muck at Mud Creek, must have accumulated at times when the climate was warmer than at present, and when trees and large shrubs grew in areas that now support tundra vegetation, with only a few dwarf shrubs.

The dated muck of Seward Peninsula and the youngest muck in the Fairbanks area may have accumulated during a single, long, post-Mankato warm interval that extended from about 9,000 to about 3,500 years ago. Alternately, the muck at Coffee Creek and Black Gulch may have accumulated during a brief, early post-Mankato warm interval 8,000 to 9,000 years ago, and the muck at Mud Creek and the

youngest muck in the Fairbanks district may have accumulated during a separate, much later warm interval 3,500 to 4,500 years ago.

CORRELATION BETWEEN LATE QUATERNARY EVENTS AT IYATAYET AND  
IN NEARBY PARTS OF ALASKA

Forty feet of congeliturbate accumulated in Iyatayet Valley during a period when the climate was cold and frost action and solifluction were intense. Sea level stood much lower than at present, suggesting that a major, world-wide, glacial event is represented. The lack of a recognized break in deposition suggests that accumulation was not interrupted by a period of stability and thus that the congeliturbate accumulated during a single, late Wisconsin substage of glaciation. Exposures are poor, however, and it is entirely possible that more than one substage is represented by the congeliturbate.

The podzol beneath the Denbigh culture layer formed during a brief warm interval that interrupted the prevailing cold climate and marked the end of deposition of the rocky congeliturbate. The distribution of the buried soil and culture layer suggests that the surface of the 40-foot terrace still formed the floor of Iyatayet Valley during the warm interval. This lack of dissection of the terrace suggests that sea level had not yet risen to its present position. The later cold interval during which the Denbigh culture layer was covered and folded appears to have been briefer and less intense than the cold interval during which the rocky congeliturbate was deposited, because the layer of sandy silt that was added to the surface is thin and is different in character from the rocky congeliturbate. Accumulation of the sandy silt probably was interrupted briefly by another warm period during which the peat and Subarctic Brown Forest soil exposed in pit Z-4 were formed.

Comparison of the Denbigh flint complex at Iyatayet with flints in the oldest culture layer recognized in the Trail Creek caves suggests that the Denbigh culture layer is more than 6,000 years old. Evidence that Iyatayet Valley had not yet been dissected, and thus that sea level had not yet risen to its present position, also suggests that the Denbigh culture layer and the associated podzol are older than 6,000 years. Sea level is believed to have been a few feet higher than at present in most unglaciated areas at the beginning of the post-Mankato thermal maximum as recognized in the United States and Europe. Flint and Deevey (1951, p. 258) estimate that the thermal maximum in the United States began about 6,000 years ago.

Two possible correlations must be considered for the deposits of the pre-Christian era in Iyatayet Valley (table 2). The rocky conge-



TABLE 2.—Suggested correlations between features of Iyatayet Valley and late Quaternary deposits elsewhere in Alaska

Features of Fairbanks area (F) and Seward Peninsula (SP)			Features of Iyatayet Valley		
Name	Age in years		Name	Age and date in years	
			Neo-Eskimo midden	350-850* (A.D. 1100-1600)	
			Paleo-Eskimo midden	1,500-2,000† (A.D. 1-500)	
			Sandy silt	2,000-3,500 (1500-1 B.C.)	
Youngest muck (F)	3,500-4,200		Subarctic Brown Forest soil in pit Z-4	3,500-4,200 (2200-1500 B.C.)	
Older muck (SP)	8,500		Sandy silt and folds in Denbigh culture layer	4,200-8,500 (6500-2200 B.C.)	
Younger loess (F)	16,000		Denbigh culture layer and podzol	8,500 (6500 B.C.)	
			Rocky congeliturbate	More than 8,500 (Earlier than 6500 B.C.)	

Features of Fairbanks area (F) and Seward Peninsula (SP)			Features of Iyatayet Valley		
Name	Age in years		Name	Age and date in years	
			Neo-Eskimo midden	350-850* (A.D. 1100-1600)	
			Paleo-Eskimo midden	1,500-2,000† (A.D. 1-500)	
			Sandy silt	2,000-3,500 (1500-1 B.C.)	
Youngest muck (F)	3,500-4,200		Subarctic Brown Forest soil in pit Z-4	3,500-4,200 (2200-1500 B.C.)	
Older muck (SP)	8,500		Sandy silt and folds in Denbigh culture layer	4,200-8,500 (6500-2200 B.C.)	
Younger loess (F)	16,000		Denbigh culture layer and podzol	8,500 (6500 B.C.)	
			Rocky congeliturbate	More than 8,500 (Earlier than 6500 B.C.)	

## B. Alternate correlation

\* Age determined by typological correlation with Kobuk River sites.

† Age determined by carbon-14 samples collected at Iyatayet.

turbate may have been deposited more than 16,000 years ago during the cold interval represented by the lower, pre-Mankato loess in the Fairbanks area (correlation B, table 2). The buried podzol may have formed and the Denbigh culture layer may have been deposited about 12,000 years ago, during part of the warm interval recorded by the middle muck in the Fairbanks area. The culture layer then would have been covered and folded during the Mankato substage at the same time that part of the upper loess of the Fairbanks area was deposited. The buried peat layer and Subarctic Brown Forest soil layer exposed in pit Z-4 would have formed during a single, long, warm interval 9,000 to 3,500 years ago represented by the dated mucks of Seward Peninsula and by the youngest muck in the Fairbanks area.

It is alternately possible that part or all of the rocky congeliturbate was deposited during the Mankato substage while the upper loess was being deposited in the Fairbanks area (correlation A, table 2). The podzol and the Denbigh flint layer may have formed during a brief warm interval about 8,000 to 9,000 years ago that is represented by the dated muck at Coffee Creek and Black Gulch, Seward Peninsula. The culture layer then would have been covered and folded during a minor cold interval between 8,000 and 4,200 years ago, and the peat and Subarctic Brown Forest soil exposed in pit Z-4 would have formed during a later warm interval 4,200 to 3,500 years ago, represented by the dated muck at Mud Creek and the youngest muck of the Fairbanks area.

The writers favor correlation of the podzol and the Denbigh culture layer with the older muck of Seward Peninsula, deposited 8,000 to 9,000 years ago, because the thinness of the podzol at Iyatayet suggests that the warm period during which it formed was very brief. The middle muck layer in the Fairbanks area, with which the podzol and culture layer instead may be correlative, represents a warm period that lasted at least 4,000 years. Moreover, the sandy silt which overlies the Denbigh culture layer appears to represent a relatively minor cold interval compared with the cold interval during which the congeliturbate was deposited. The thickness of the upper loess of the Fairbanks area suggests that the Mankato substage was a major cold interval in Alaska. The archeological relationships are more readily explained if the Denbigh flint complex at Iyatayet is assumed to be about 8,500 years old, but they do not rule out the alternate assumption that the culture layer is more than 12,000 years old. The possibility cannot be eliminated that Iyatayet was occupied by people of the Denbigh flint complex during an interstadial interval earlier than the Mankato substage.

Evidence that the climate at Iyatayet was warmer than at present during and after Paleo-Eskimo occupation from A.D. 1 to 500 is matched by evidence for a warm or dry climate near this time in Greenland (Brooks, 1949, pp. 342-343), southwestern United States (op. cit., pp. 356-357), Ohio, and the Valley of Mexico (Sears, 1951). The cooler period during and since the Neo-Eskimo occupation from about A.D. 1100 to 1600 corresponds broadly to the "little ice age" (Matthes, 1942), recognized in several places in Alaska (Lawrence, 1950; Péwé, 1951; Sharp, 1951) and in nearly every glaciated mountain range in the Northern Hemisphere (Manley, 1951).

#### ACKNOWLEDGMENTS

Archeological investigations at Cape Denbigh were supported in 1948 and 1949 by grants from the Arctic Institute of North America in cooperation with the Office of Naval Research, U. S. Department of the Navy. The field work was continued in 1950 as a part of the Bering Strait Expedition—a joint enterprise financed by the Wenner-Gren Foundation for Anthropological Research, the University of Alaska, the University of Pennsylvania, and the Danish National Museum. Giddings was aided in these studies by a contract between the Office of Naval Research and the University of Pennsylvania (NR 160-903). S. J. Newcomb, Wendell Oswalt, G. M. Henderson, and J. W. Van Stone assisted in the excavations. Hopkins's visit was made possible by the cooperation of the U. S. Geological Survey.

The writers gratefully acknowledge the assistance of H. N. Michael, who translated pertinent passages of Okladnikov (1950), and R. J. Hackman, who assisted in locating air photos of the Anaktuvuk River site.

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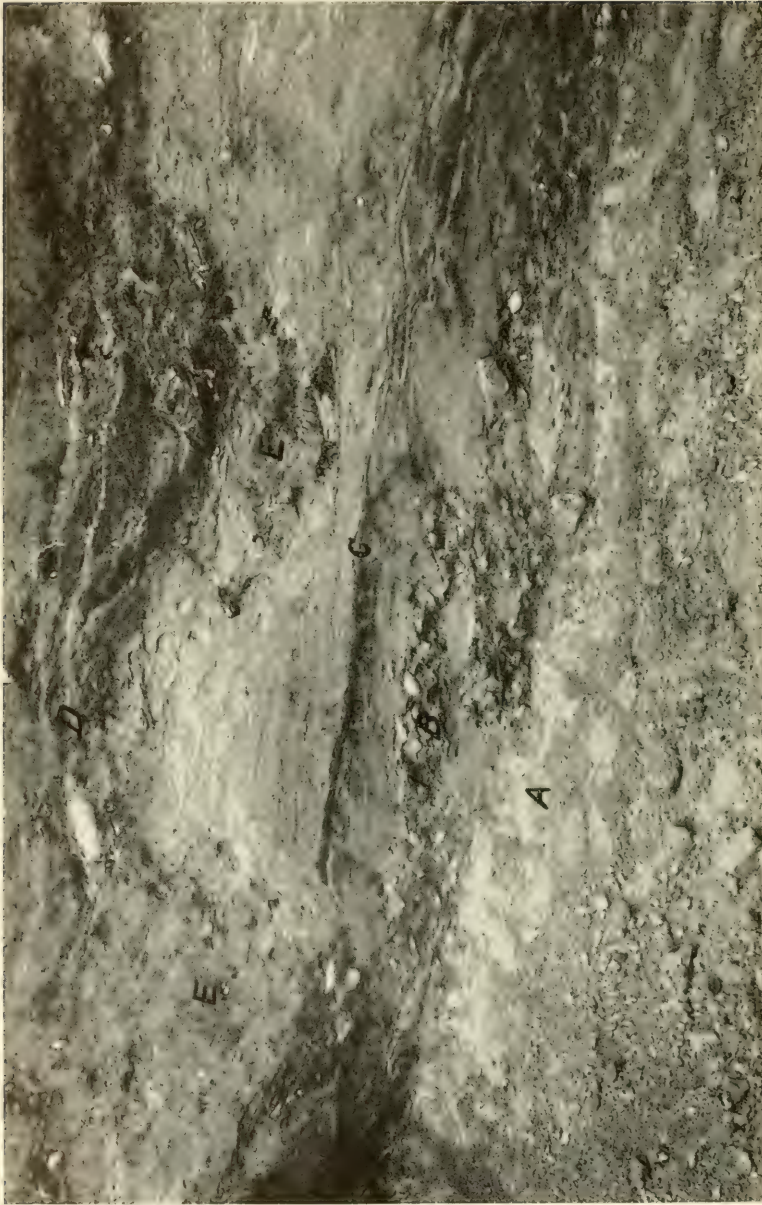
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## IYATAYET COVE AND IYATAYET VALLEY

Denhigh culture layer was found on 40-foot terrace at left side of valley mouth just above tents. Lower valley walls are covered with dense stand of tall alders. Upper slopes (near skyline at left) are covered with sedges, *Equisetum*, and small alder shrubs arranged in stripes. Lower slopes are free of soil movements, but upper slopes probably are subject to active solifluction.



FLOOR AND EAST WALL OF PIT Z-4

*A*, Congeliturbate in floor of pit. *B*, Denbigh culture layer, unusually thick at this locality. Note recumbent fold just left of *B*. *C*, Buried turf layer, enclosed in sterile sandy silt. *D*, Buried Paleo-Eskimo ground level. *E*, Filled Paleo-Eskimo excavations. Portion of wall shown here is about 2 feet high. Location of pit is shown on figure 3.





**SURFACE OF DENBIGH CULTURE LAYER EXPOSED ON FLOOR OF PIT PE-4**

Ridges near hammer are anticlinal folds in the Denbigh culture layer; "caves" are undersides of folds from which infolded sterile silt has been removed.



**SMALL VALLEY DRAINING HILLS BETWEEN BALD HEAD AND KOYUK RIVER VALLEY**

Note wide, swampy valley floor and gently sloping alluvial fan at mouth of valley. Beach at left is shore of Norton Bay. Before bottom of Iyatayet Valley was dissected to form 40-foot terrace, it resembled this valley.





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(WITH ONE PLATE)

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*U. S. Department of Agriculture*

(WITH ONE PLATE)

The most important Pleistocene locality in Maryland is Wailes Bluff, near Cornfield Harbor, on the eastern bank of the Potomac River about 3 miles above its mouth, in St. Marys County. In the Pliocene-Pleistocene volume of the Maryland Geological Survey (Shattuck et al., 1906) it was referred, like all the other fossiliferous localities of marine origin in Maryland, to the Talbot formation, at that time regarded as the youngest of the Pleistocene formations found in the State. Since that time a younger formation, the Pamlico, defined by a terrace 25 feet above sea level (that of the restricted Talbot formation being at 42 feet), has been recognized on the Atlantic coast, and some writers have referred to it the marine Pleistocene deposits of Maryland. This course was followed, at least as regards the Wailes Bluff deposit, in the Guidebook to the Chesapeake Bay Region prepared by Stephenson, Cooke, and Mansfield for the 16th International Geological Congress in 1933 (Guidebook 5, Excursion A-5), and for all the marine Pleistocene of Maryland by Richards in 1936 (pp. 1612-1618, with references to earlier papers). Richards, whose publication summarized present knowledge of the marine deposits of the southern Atlantic Coastal Plain, considered that all the fossiliferous marine Pleistocene beds from Delaware to Florida, which are all at elevations of 25 feet or less, belong to the Pamlico formation. The late Dr. E. W. Berry, however, informed me not long before his death that he still regarded all the marine Pleistocene of Maryland as referable to the Talbot.

Dr. C. Wythe Cooke, after a trip to the Wailes Bluff and Langleys Bluff localities with Dr. R. W. Brown and the writer in the autumn of 1951, has come to the conclusion that the beds in question are considerably older than had been supposed, probably of Aftonian and

Kansan age, and therefore near the base of the Pleistocene. He has kindly prepared a statement of his views which is given in the immediately following paragraphs. Since the primary purpose of the present paper is to present a record of the known fauna, the determination of the precise age of the deposits may be left to the future. For practical purposes, it seems as well to continue for the present the nominal reference of the beds to the Talbot formation.

#### AGE OF THE DEPOSITS AT LANGLEYS AND WAILES BLUFF<sup>1</sup>

At Langleys the marine Miocene St. Marys formation is overlain unconformably by a marine shell-bearing Pleistocene clay. This merges upward into nonmarine cross-bedded Pleistocene sand. At Wailes Bluff the Miocene deposits are not exposed. The lowest bed there is a marine shell-bearing clay similar to that at Langleys. It passes upward through an oyster reef into fresh-water sand.

Pleistocene time is divided into four glacial stages alternating with three interglacial stages, as follows:

- Wisconsin glacial stage.
- Sangamon interglacial stage.
- Illinoian glacial stage.
- Yarmouth interglacial stage.
- Kansan glacial stage.
- Aftonian interglacial stage.
- Nebraskan glacial stage.

The glacial stages were times of low sea level. In the present coastal region they were characterized by running streams and fresh-water deposits. The succeeding interglacial stages were times of higher sea level because melt water from the ice filled the oceanic basins to overflowing. In the coastal region they were characterized by drowned valleys and marine or brackish-water deposits. So the marine bed at Langleys and Wailes Bluff presumably represents an interglacial stage, and the conformable nonmarine sand represents the immediately succeeding glacial stage.

The oyster bed probably accumulated in shallow brackish water. The overlying sand may have been deposited in an estuary of about the same depth but containing water too fresh for oysters. The fact that there was no erosion of the oyster reef appears to indicate that sea level did not fall quite as low as its present location during the deposition of the fresh-water sand.

If that is true, the marine bed and the fresh-water bed cannot repre-

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<sup>1</sup> Contributed by C. Wythe Cooke.

sent the Sangamon and the Wisconsin stages, for sea level during the Wisconsin stage stood at least 25 feet lower than now. Moreover, the surface of the ground at Langleys and Wailes Bluff may have stood above water level during the Sangamon stage; for sea level then is supposed to have been only 25 feet higher than now, and the present rolling topography indicates that some erosion has occurred since the sea withdrew from that region. The surface around Langleys is little, if any, lower than 25 feet.

The Pleistocene beds at Wailes Bluff and Langleys presumably are not Yarmouth and Illinoian, for the shell bed lies directly on the eroded surface of the Miocene St. Marys formation. This would have been the condition if the marine bed were Aftonian, for sea level during the Nebraskan stage was lower than during the Aftonian, and the region must have stood above the water then and probably also during the Pliocene. So the evidence seems to point to an Aftonian age for the shell bed and a Kansan age for the nonmarine sand.

We can speculate as to the depth of the sea in which the shell bed accumulated. The maximum height of sea level during the Aftonian stage was probably 215 feet (in Coharie time); later in the same stage it dropped to 170 feet (in Sunderland time). So, if the shell bed is Aftonian, the depth of the water at Langleys and Wailes Bluff may have been originally as much as 215 feet. From this maximum depth it shallowed to 10 feet, more or less, near the close of the epoch, when the oyster reef grew. The gradual emergence of a land barrier or the growth of a bar presumably caused the water behind it to become brackish and then to freshen, first favoring the growth of oysters and then killing them.

#### HISTORY OF WAILES BLUFF

Wailes Bluff has been known to paleontologists for more than a century. Its first scientific visitor, apparently, was Timothy A. Conrad (1830), who on May 20 and June 15, 1830, read before the Academy of Natural Sciences of Philadelphia a paper embodying the results of a visit he had "lately" <sup>2</sup> made, "at the request of several members of the Academy," to the peninsula of Maryland. He collected at Fort Washington, Piscataway, Charlotte Hall, St. Marys River, and the present Wailes Bluff, which he referred to merely as a locality "about three miles north of the low sandy point [Point Lookout] which

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<sup>2</sup> His later reference to this expedition—"Since I discovered the Eocene formation in Maryland in 1830 . . ." (Amer. Journ. Sci., ser. 2, vol. 1, p. 209, 1846)—makes it clear that this trip was made early in 1830.

forms the southern extremity of the peninsula." Conrad's description of the exposure is quoted in large part by Smith (1920, p. 85), and his list of 29 mollusks is reproduced by Richards (1936, p. 1622), with one species, "*Solen ensis* Lin." (= *Ensis directus* (Conrad)), accidentally omitted.

A few years later Conrad (1835, p. 110) published a revised list of Wailes Bluff mollusks, also totaling 29 species, under the heading "List of Fossil Shells of the Newer Pliocene on the Potomac." *Actacon melanoides* and *Venus* sp. of the first list were omitted, *Turritella alternata* Say and *Ostrea virginica* were added, and some corrections were made in nomenclature. *Bittium alternatum* (Say), the present designation for *Turritella alternata*, has been omitted from the Wailes Bluff lists of all later authors. It does not appear in Conrad's final list of 1842.

Still later, in a general paper on the Tertiary deposits of the Atlantic coast, Conrad (1842) gave a section of the Wailes Bluff deposit with an excellent description, both quoted in full by Mansfield (1928, pp. 129-130), and a third list of species. *Natica interna* Say and the unnamed *Scalaria* and *Venus* of the first list were omitted, *Actacon melanoides* was restored, and some further changes in nomenclature were made. This list includes only 26 species and, like the first list, omits the *Ostrea*. In his discussion of Conrad's work, Richards (1936) compares the first and third lists, but in citing the latter gives the reference belonging to the second list.

Altogether, Conrad recorded in his three Wailes Bluff lists a total of 31 mollusks, two of which, a *Scalaria* and a *Venus*, were not identified specifically. Five species of *Epitonium* (*Scalaria*) are now recorded from Wailes Bluff, so that the identity of his single species of this genus cannot be ascertained, and as he recorded *Venus mercenaria*, the identity of his unnamed *Venus* is also uncertain. It seems likely that it was merely a form of *V. mercenaria* rather than the rare *V. campechiensis*, which has been found there (in young specimens only) by Richards alone. *Crepidula glauca* is now considered a form of *C. convexa*, and in the Maryland Geological Survey the latter, as to Maryland specimens, was referred to *C. fornicata*. *Natica interna* is a Miocene species, and Conrad's specimens, if really from Wailes Bluff, must have been *Polinices duplicata*, which he also listed. His *Actacon melanoides* of the first and third lists and *Turritella alternata* of the second list are dubious; both names possibly refer to the same species. Omitting all these from consideration, we find that Conrad recorded 25 identifiable mollusks from Wailes Bluff against 39 in the Maryland Geological Survey volume (Shattuck et al., 1906), which omitted two

of Conrad's species that are now definitely known to occur. Several of the species first recorded in the Maryland Geological Survey are rare, and two (*Aligena elevata* and *Macoma calcarea*) have not been found by any subsequent collector, but it is surprising that Conrad did not mention *Fulgur carica*, *F. canaliculatum*, *Crepidula plana*, and *Actaeocina canaliculata*, all of which are common and the two first conspicuous. Possibly his *Crepidula glauca* was really *C. plana*, which is much more distinct in appearance from *C. convexa* and *C. fornicata* than they are from each other.

The Maryland Geological Survey (Shattuck et al., 1906) reported 1 arthropod (*Balanus crenatus*) as well as indeterminate crab claws, 39 mollusks, 3 Bryozoa, 1 sponge, and 4 Foraminifera from Wailes Bluff; *Pandora trilineata* (= *P. gouldiana*) and *Cytherea sayana* (= *Callocardia morrhua*) of Conrad's 1842 list were omitted, presumably because they had not been found by collectors for the Survey, as was also the problematical *Actaeon melanoides*. Aside from the vertebrates, every animal species definitely listed in that volume from the Maryland Pleistocene was recorded from Wailes Bluff except *Callinectes sapidus* and *Odostomia impressa*, both of which are now known to occur there.

The next important contribution was by Ernest R. Smith (1920), who gave an account of the locality with a section and bibliography and a table showing the Recent and Pleistocene distribution, geological range, and depth range of the mollusks known from Wailes Bluff. He added 10 species to the known fauna. Canu and Bassler (1923) added 1 bryozoan, Mansfield (1928) 3 crustaceans, Rathbun (1935) 2 more crustaceans, and Richards (1936) 1 mollusk and 1 bryozoan. Some years ago I (1939) reported a single vertebrate, *Tursiops* sp., of the Delphinidae, which was apparently the first definite record for a member of this family from the Atlantic coast Pleistocene. In his 1928 paper, Mansfield (pp. 129-132) gave sections of the Wailes Bluff and Langleys Bluff localities, with a list of the species known from each arranged by the beds in which they occurred, and an analysis of the faunas. Unfortunately he overlooked Smith's 1920 paper.

Richards (1936, pp. 1622-1624) gave a historical sketch of the work done on the Wailes Bluff fauna, with lists of the species reported by previous writers, and in his table showing the distribution of Pamlico species recorded altogether 57 species from this spot; he omitted the Foraminifera. However, three Mollusca (*Rochefortia planulata*, *Callocardia morrhua*, and *Fulgur canaliculatum*) that were reported from Wailes Bluff in his text were omitted from his table, as were the three Bryozoa listed in the Maryland Geological Survey volume, and the two Crustacea added by Miss Rathbun.

In the Maryland Geological Survey (Shattuck et al., 1906), four Foraminifera were reported from Wailes Bluff. Cushman and Cole (1930), in their account of the Foraminifera known from the Maryland Pleistocene, listed 11 species (and 2 additional varieties) from Wailes Bluff and Langleys Bluff, only one of which was known from Langleys Bluff but not from Wailes Bluff. One of the species reported by Bagg in the Maryland Geological Survey was mentioned but not identified, one was omitted, and a third was doubtfully synonymized with one of the species they reported. Dr. Charles T. Berry several years ago sent the two Foraminifera from Wailes Bluff now remaining in the Maryland Geological Survey collection to Dr. Cushman for examination, and the information thus obtained has been utilized in the list that follows, together with Dr. Cushman's notes on the other species reported by Bagg.

On the basis of these publications, the recorded fauna of Wailes Bluff contains 78 species<sup>9</sup> (and 2 additional varieties), distributed as follows: Protozoa (Foraminifera) 12, Porifera 1, Bryozoa 5, Mollusca 53 (Pelecypoda 28, Gastropoda 25), Arthropoda 6, Vertebrata 1. To this list are now to be added 36 species—Coelenterata 1, Echinodermata 1, Bryozoa 4, Mollusca 14 (Pelecypoda 6, Scaphopoda 1, Gastropoda 7), Arthropoda 8, Vertebrata 8—bringing the total to 114 species, divided among the following groups: Protozoa (Foraminifera) 12, Porifera 1, Coelenterata 1, Echinodermata 1, Bryozoa 9, Mollusca 67 (Pelecypoda 34, Scaphopoda 1, Gastropoda 32), Arthropoda 14, Vertebrata 9 (Pisces 8, Mammalia 1). With the exception of *Lyonsia hyalina* and *Odostomia impressa*, all these 36 species are new to the Pleistocene fauna of Maryland as well as to that of Wailes Bluff. The additions include representatives of the Coelenterata, Echinodermata, Scaphopoda, Ostracoda, and Pisces, all groups not previously reported.

#### HISTORY OF LANGLEYS BLUFF

The second most important Pleistocene exposure in Maryland, that at Langleys Bluff, about 5½ miles below Cedar Point on the western

<sup>9</sup> This figure and those that follow do not take into account the 63 species of Pyramidellidae, all but one of which were considered undescribed, mentioned by Smith in 1920 on the authority of Bartsch. As these have not been published, the species here listed to represent this family are only seven, namely the four in the Maryland Geological Survey, the single unnamed species of *Pyramidella* listed by Smith, and two additional species collected by the writer and identified by Dr. Rehder. The unidentified *Elliptio* reported by Richards and the unidentified *Epitonium* mentioned by Smith are also not considered in these figures.

shore of Chesapeake Bay in St. Marys County, below the mouth of the Patuxent River, has received less attention than the Wailes Bluff locality, although perhaps of more interest geologically because it shows the contact with the underlying St. Marys (Miocene) formation. In the Maryland Geological Survey volume only 6 species (all mollusks) were listed and some of the commonest and most conspicuous forms, such as *Ostrea virginica*, *Venus mercenaria*, *Mulinia lateralis*, and *Barnesia costata*, were not mentioned, although one of the rarest species (*Unio complanatus*) was reported. Mansfield (1928) added 16 mollusks and Richards (1936) 3 more mollusks. Cushman and Cole (1930) listed 5 species and 2 additional varieties of Foraminifera, all of which were new records. In the present paper 1 sponge, 2 echinoderms, 3 bryozoans, 25 mollusks, and 8 arthropods are added, bringing the total to 69 species (and 2 additional varieties), somewhat less than two-thirds the known total for Wailes Bluff. These 39 additions include 14 species not previously recorded from the Maryland Pleistocene, but 8 of these are also here reported from Wailes Bluff. Although the fauna is much poorer than that at Wailes Bluff there can be no doubt that it will be increased as further collecting is done, since I was able to add about 19 species on 10 visits in 1942. At the base of the section the Pleistocene fauna is often intermixed with the St. Marys, and occasional shells from the St. Marys deposit, particularly *Cardium laqueatum*, *Arca idonea*, and *Turritella*, are found in position fairly high up in the main Pleistocene bed.

In the Maryland Geological Survey (Shattuck et al., 1906, pp. 99, 102) it is stated that this locality, like that at Wailes Bluff, was well known to Conrad. I have been unable to find an indubitable reference to Langleys Bluff in Conrad's writings, but the locality he visited on Chesapeake Bay 5 miles south of the estate of Dr. Robert Neale, which, in turn, was "some miles south of Town Creek," and from which he (1842, p. 188) recorded *Mulinia lateralis*, *Pholas costata*, and *Arca transversa*, can be identified only with Langleys Bluff among Pleistocene localities known at present. The section he gave, however, does not agree at all well with the present exposure.

#### RECORDS FROM OTHER LOCALITIES

In his discussion and table, Richards included all the known records from marine fossiliferous localities in the Maryland Pleistocene except those for the Foraminifera, aside from a few accidental omissions. Of the 17 localities mentioned besides Wailes Bluff and Langleys Bluff, all but two are insignificant, their recorded faunas consisting of only one

to three species, all of which are found at Wailes Bluff. The same is true of the 15 species recorded from Federalsburg in Caroline County. The only species he reported from the Pleistocene of Maryland which are not known from Wailes Bluff or Langleys Bluff are 9 Mollusca out of a total of 24 which he obtained from fills from hydraulic dredgings from the bottom of Sinepuxent Bay at South Ocean City, about 2 miles south of Ocean City, on the Atlantic coast of the Delmarva Peninsula. The specimens were mixed with recent material and all, with two exceptions (*Modiolus demissus*, now known from Virginia southward, and *Thais floridana*, from North Carolina southward), are known in the living state both north and south of Maryland. These species as listed by Richards are: *Arca campechiensis* Say, *Pecten gibbus irradians* Lamarck, *Anomia simplex* Orbigny, *Modiolus demissus* Dillwyn, *Littorina irrorata* Say, *Thais floridana* Conrad, *Columbella avara* Say, *Nassa vibex* Say, *Melampus lineatus* Say.

The Maryland Geological Survey (Shattuck et al., 1906) recorded also the mastodon, *Mammuth americanum* (Kerr); the northern mammoth, *Elephas primigenius* Blumenbach; the southern mammoth, *Elephas columbi* Falconer; an extinct box turtle, *Terrapene eurypygia* (Cope); the snapping turtle, *Chelydra serpentina* (Linné); and some indeterminable fragments of Coleoptera, all from various non-marine Pleistocene localities in Maryland. Two other vertebrates, the elk, *Cervus canadensis* Erxleben, and the Virginia deer, *Cariacus* [= *Odocoileus*] *virginianus* (Boddaert), listed by Cope as occurring in company with the remains of *Cistudo* (= *Terrapene*) *eurypygia* at Oxford Neck, Talbot County, were omitted by F. A. Lucas from his treatment of the Mammalia in the Pliocene-Pleistocene volume of the Maryland Geological Survey, although incidentally mentioned by O. P. Hay in his account of the *Terrapene* in the same volume. The records of numerous other Pleistocene land vertebrates of Maryland, mostly found in caves or limestone fissures, are summarized in Hay's work (1923, pp. 344-351) on the Pleistocene of eastern North America. The most important recent contribution to this subject is Gidley and Gazin's (1938) monograph of the Pleistocene fauna from Cumberland Cave.

#### DESCRIPTION OF THE BEDS

In listing the species from Wailes Bluff I have followed Mansfield's (1928) nomenclature for the beds, although I regard his bed 2 as having no real existence. Bed 1 at the base of the cliff, of very compact and sticky greenish-blue clay, is exposed for 4 to 6 feet above the level of the beach and contains essentially the whole Wailes Bluff fauna for



which the details of occurrence are known. Of 114 recorded species, 92 are definitely known from this bed, 1 (*Crepidula fornicata*) is known to me only from bed 3, and the zone of 21 is not recorded. Bed 2, a layer of blue clay 1 foot thick or less, not clearly demarked from the lower bed and not present in all parts of the bluff, may well, as Mansfield suggests, "be considered a part of bed 1." In his paper, Mansfield combined his records from beds 1 and 2 into one list, but definitely reported from bed 2 *Rangia cuneata* and *Venus mercenaria*, both of which are also found in bed 1. Bed 3, the oyster bed, 1 to 2 feet thick, has 21 definitely recorded species, all of which, with the single apparent exception of *Crepidula fornicata*, are also found in bed 1. Bed 3 is capped by 6 to 8 feet of unfossiliferous sands and gravels (bed 4). The beds in which the 12 Foraminifera were found are not reported either in the Maryland Geological Survey or in Cushman and Cole's paper, but from the abundance of Foraminifera in bed 1 in the *Mulinia*-filled borings and inside clam shells, and their comparative rarity in bed 3, where they occur chiefly in *Cliona* borings in oyster shells, it is probable that most, if not all, of the 12 recorded species came from bed 1. The 2 Bryozoa and 7 Mollusca reported by previous authors without indication of bed and not found by me must likewise have occurred mostly, if not entirely, in bed 1.

The Wailes Bluff section given by Smith (1920) was somewhat more detailed than that of Mansfield. He recognized four fossiliferous beds and three nonfossiliferous layers of sand, gravel, and loam above them. His four fossiliferous beds were: the *Mulinia* bed, 6 feet deep or less, corresponding to Mansfield's bed 1; the *Rangia* bed, 1 foot deep to absent, corresponding apparently to Mansfield's bed 2; the *Venus* bed, 1 foot deep to absent, and the *Ostrea* bed, about 1 foot deep, the two latter together equivalent to bed 3 of Mansfield. In listing the fauna I have used Mansfield's system rather than Smith's because I regard the aggregation of *Venus* below the *Ostrea*, observable in parts of the bluff, as a local development rather than a distinct bed. If such local phenomena were to be distinguished with the title of beds, it might be necessary to recognize in addition two *Mya* beds, one below and one above the oyster bed, perhaps also a *Tagelus* bed toward the top of bed 1. On our visit to Wailes Bluff in the autumn of 1942, Dr. R. W. Brown and I made especial search for the *Rangia* bed of Smith and Mansfield and the *Venus* bed of Smith and satisfied ourselves that no such beds are now recognizable in the bluff.

GEOLOGICAL FEATURES OF WAILES BLUFF AND  
LANGLEYS BLUFF

The following summary of the geological features of Wailes Bluff and Langleys Bluff, with a generalized sketch (fig. 1) showing the sections at both localities, is contributed by Dr. Roland W. Brown, who accompanied the writer on a 2-day trip in the autumn of 1942 and on another visit in the spring of 1943, as well as on a third trip in the autumn of 1951, when Dr. C. W. Cooke was also present:

The Pleistocene sections at Wailes Bluff and Langleys Bluff are lithologically identical and apparently contemporaneous. That exposed at Langleys, 15 miles north of Wailes, is somewhat thicker and rests unconformably on the bluish, sandy, marine clay of the St. Marys formation (Miocene) which is not exposed at Wailes Bluff. The sections, beginning at the bottom, include the following recognizable zones:

A. This is a compact, sandy, greenish-blue, marine clay that shows little evidence of stratification except at a few spots in the uppermost layers at Wailes. On drying, exposures of this clay develop vertical cracks and columns. Scattered through it at both localities are small, quartzitic pebbles and some large boulders, but the boulders are more abundant at Langleys and are concentrated at the base among a few oysters. These boulders may have been ice-rafted or dropped from floating root clumps. This zone yields practically the whole Wailes Bluff fauna and also some fossil wood of *Taxodium distichum*. A singular feature of the zone is the common occurrence of burrows, one to several feet long and about two inches in diameter, more or less vertical and filled with *Mulinia* shells. The maker of the burrows has not been identified. It is conjectured that this clay was deposited rapidly in relatively shallow water that was not disturbed by strong currents.

B. Oyster-bed zone. The upper boundary of zone A is slightly uneven because an oyster bed rests upon it. Locally this bed is thickened and the weight of the oysters has pressed down the underlying clay as shown by the parallel down-bent curves of layers of *Mulinia* shells. At Wailes the oyster bed can be traced along the greater part of the bluff as irregular, discontinuous lenses, one of which is about 630 feet long and in spots 3 feet thick. The oyster bed may indicate greater agitation of the water than prevailed during the deposition of zone A. In places at Wailes the uppermost layers of zone A are conspicuously stratified, and these, together with the oyster bed, may indicate increased current action.

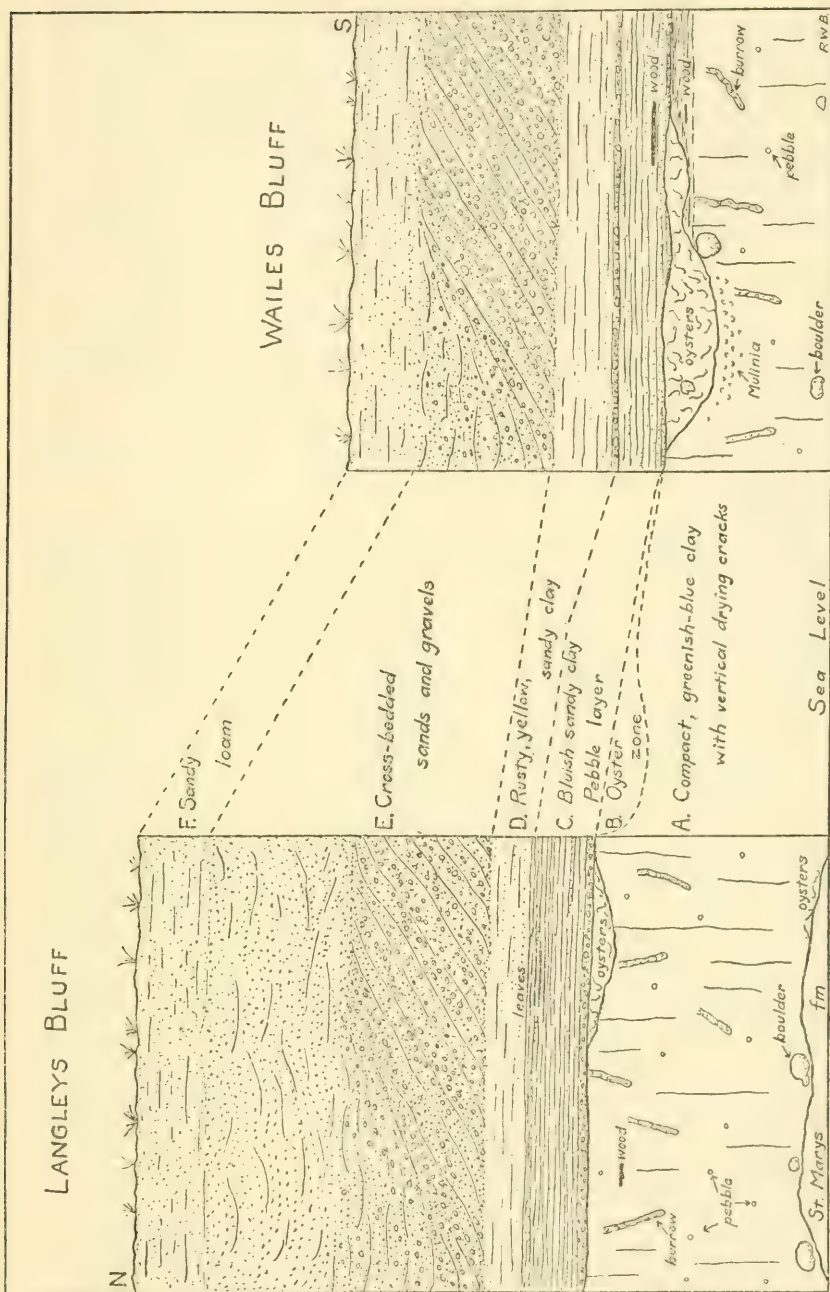


FIG. 1.—Pleistocene sections at Langleys Bluff and Wailes Bluff, Md. The Langleys Bluff section is shown as a mirror image of the actual section. Langleys Bluff is 15 miles north of Wailes Bluff. Vertical scale:  $\frac{1}{8}$  inch equals 1 foot.

C. A new phase of deposition, perhaps representing a change to fresher and shallower water, terminated the further development of the oyster bed, and it is possible that some erosion of the oyster bed and preceding strata occurred before the new deposits were laid down. At Langleys this zone begins with a relatively inconspicuous, thin, pebbly and sandy layer overlying the oyster bed and the compact clay at those spots where the oyster bed is not present. At Wailes this pebble layer was seen at only one place and in general is absent. Horizontal, thin-bedded, bluish, sandy clay succeeds the pebble layer. No fossils except pieces of wood have been found in this zone. Most of the wood is *Taxodium distichum*, but one log of *Fraxinus* sp., 2 feet long, was found in 1942 at the southern end of Wailes Bluff in the position marked in the section. The genus is not listed in the Maryland Survey Pleistocene volume, but E. W. Berry (Torreya, vol. 15, p. 208, 1915) has reported leaves of *Fraxinus americana* from the Pleistocene at Indian Head, Md.

D. Sharply separated in color, but of similar texture, is the horizontal, thin-bedded, rusty, sandy clay that overlies zone C. At Wailes this zone begins with a pebble layer and has occasional brownish carbonaceous streaks near the base. At Langleys it yields scattered leaf impressions, including *Juglans* sp., *Salix* sp., and *Pinus* sp. The sharp contrast in color may be a weathering effect, but the pebble layer at Wailes suggests a depositional change of some sort.

E. Overlying the horizontal layers of zone D are cross-bedded sands and gravels that grade upward into the sandy loam of zone F at the top of the terrace. Although the aspect of these sands and gravels seems normal throughout most of the exposures, their attitude locally is suggestive, although, so far as is known, no previous observers of these sections have called specific attention to it. As shown in the sketch (fig. 1), in portions of the outcrops at both localities the gravels dip steeply northward (see Shattuck et al., 1906, pl. 18, fig. 1) and thus indicate deposition by a current from the south, a condition which, unless whirling return currents are assumed, seems contrary to what should be expected if the Potomac and Patuxent Rivers were the responsible transporting agents. It may be that these gravels represent some kind of bar that advanced landward over a shallow lagoon (see Shattuck et al., 1906, pp. 127-134). However, no marine or other fossils have been found in them.

The strata of these sections represent phases of deposition, as pointed out in the description of each zone. If any division of the sections is contemplated it would seem that the appropriate place to draw a line is at the level of the oyster bed, either its base or top, the latter

probably being the better choice. This contact appears to mark a definite change from marine to brackish- or fresh-water deposits. However, this line may not represent any great lapse of time, and without further information should not be construed to mean a temporal or formational boundary.

As these bluffs are retreating rapidly, probably as much as 5 feet locally in some years, the sections present continually new faces. Thus, the features sketched now will likely not be quite the same as those that will be seen in subsequent years. [R. W. B.]

Mansfield distinguished five numbered beds at Langleys Bluff. The bank there is higher than at Wailes Bluff (about 25 feet at Langleys Bluff, 15 or less at Wailes Bluff), but the length of the fossiliferous area is considerably less (about 1,400 feet, as contrasted with about 2,100 at Wailes Bluff; both distances paced). His bed 1 is Miocene (St. Marys), 3 feet deep or less (so far as exposed) and highly fossiliferous, and separated by an unconformity from the four superposed Pleistocene beds. His bed 2, of compact bluish sandy clay 6 to 8 feet deep with a thin oyster zone at the base, contains the same fauna, so far as it goes, as bed 1 at Wailes Bluff and is in all probability (except for the basal oyster zone) equivalent to it. His bed 3, an oyster zone 1 foot thick or less, absent along much of the length of the bluff, is likewise clearly the equivalent of bed 3 at Wailes Bluff, although its species are much fewer. No bed corresponding to his bed 2 at Wailes Bluff was distinguished. The two remaining beds are both unfossiliferous. Bed 4, a layer of dark gray sandy clay 2 feet deep with a pebbly band at base, was not recognized by him at Wailes Bluff but is actually represented there. Bed 5, of cross-bedded sands and gravels 4 to 15 feet deep, corresponds to bed 4 at Wailes Bluff although usually deeper.

The thin oyster zone mentioned by Mansfield at the base of the deep layer of bluish sandy clay is well marked for practically the entire length of the bluff and should be recognized as a separate bed. It is a shallow layer of double valves of *Ostrea*, only 2 or 3 inches thick, in some places accompanied by a very thin layer of sand only half an inch thick and everywhere with abundant rounded pebbles and cobbles, the latter sometimes a foot in diameter. In places complete specimens of *Venus mercenaria* and *Mya arenaria* occur just below the oysters and thus actually in the uppermost part of the St. Marys bed, the *Mya* in its natural vertical position. The total known fauna of this bed is 10 species, of which 6 (*Cliona sulphurea*, *Acanthodesia oblongula*, *Ostrea virginica*, *Venus mercenaria*, *Mya arenaria*, and *Balanus crenatus*) are also known to occur rarely or casually in the *Mulinia* bed, and 5

(*Cliona sulphurca*, *Ostrea virginica*, *Mytilus recurvus*, *Venus mercenaria*, and *Mya arenaria*) occur also in the upper oyster bed. The close proximity to shore when this bed was laid down is indicated by the colony of *Elliptio complanatus* mentioned in the list that follows. I propose to designate this bed as the Basal *Ostrea* bed; the superposed bed of blue sandy clay 6 to 8 feet thick, forming the remainder of Mansfield's bed 2<sup>4</sup> as the *Mulinia* bed; and the oyster bed on top of it, 1 foot thick or less, Mansfield's bed 3, as the Upper *Ostrea* bed. From the Basal *Ostrea* bed are recorded 10 species, 6 of which, listed above, are also known from the *Mulinia* bed; from the *Mulinia* bed, 60 species, all, except the 6 species mentioned, confined to it; and from the Upper *Ostrea* bed, 5 species, all of which are also found in the Basal *Ostrea* bed, and all but one (*Mytilus recurvus*) in the *Mulinia* bed. The bed or beds in which the five known species of Foraminifera occurred are not recorded, but the abundance of specimens of this group in the *Mulinia*-filled borings, as at Wailes Bluff, makes it very probable that they all came from the *Mulinia* bed.

#### BORINGS AT WAILES BLUFF

The contact between the base of the Pleistocene at Wailes Bluff and the St. Marys Miocene that should underlie it has never been found. In July and August 1942, with the assistance of William E. Salter, of the U. S. National Museum, I made two attempts to reach it. Our first trial, made with a small spade, showed only that bed 1 was at least 10 feet 3 inches deep, including that part exposed in the bluff, at the point where we dug near the upper end of the fossiliferous part of the exposure. On the second occasion, working again toward the upper end of the bluff and using an auger borrowed from the Geological Survey, we penetrated to a depth of 21 feet without passing through the Pleistocene. As 5 feet of bed 1 were exposed in the bank above, the total depth of the Pleistocene deposit here is over 26 feet (although it is not certain that it all belongs to bed 1), whereas the corresponding *Mulinia* bed at Langleys Bluff is only 6 to 8 feet deep. The following description of the cores, prepared with the assistance of Dr. Julia A. Gardner, may be placed on record. The shell contents of the cores, after washing and sifting, are added in parentheses.

Depth below  
beach level

0-5 ft.

Tenacious greenish-blue clay like that exposed in the bluff above, with *Mulinia*, etc. (From our first digging.)

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<sup>4</sup> Mansfield's bed 1 was the St. Marys (Miocene) bed.

Depth below  
beach level

- 4-5 ft. Greenish-black finely micaceous silty clay with a few moderately large grains of quartz and a few shell fragments. (Many *Nuculana acuta*; one hinge of *Yoldia limatula*.)
- 5 ft. 8 in.-  
6 ft. 8 in. Similar, but with sandy pockets. (No shells.)
- 10 ft. Greenish clayey sand. (No shells; a little carbonaceous material.)
- 12 ft. Dark greenish silty clay, very finely micaceous and with some carbonaceous material. (One fragment of *Mulinia*, some small quartz pebbles.)
- 12 ft. 6 in. Similar, but more carbonaceous and with some shell fragments. (Several pieces of *Rangia*, showing the epidermis.)
- 13 ft. Dark greenish, very tenacious silty clay with small specimens of *Rangia cuneata* and *Mulinia lateralis*. (One fragment of *Nucula proxima*; numerous valves of *Rangia*, somewhat worn but still retaining some epidermis.)
- 14 ft. Dark greenish, less tenacious silty clay with small specimens of *Rangia* (fragmentary, somewhat worn, but still retaining some epidermis).
- 17 ft. Brownish-green silty clay, carbonaceous and slightly micaceous, not so heavy as preceding sample. (No shells.)
- 18 ft. Brownish-green sandy clay with occasional irregularly shaped pellets of light buffy sandy clay and large quartz pebbles, also considerable carbonaceous material and one much-worn fragment of *Venus*. (One valve of *Arca transversa*, one or two fragments of *Rangia* (?).)
- 19 ft. Brownish-green sandy clay somewhat mottled with clear green, with a few of the light buffy pellets, considerable carbonaceous material, a few small shell fragments, and one fragment of much worn *Ostrea*.
- 20-21 ft. Same as preceding but extremely tenacious, no carbonaceous material noted except a few well-preserved fine rootlets; one fragment of *Rangia* and an extremely worn and polished fragment of *Ostrea* (?). (One fragment of *Rangia*, two small and much-worn fragments of *Ostrea*, one fragment of *Barnea costata* (?).)
- 21 ft. Tenacious silty greenish clay with occasional rounded masses of clearer green clay of similar character, slightly micaceous and with a few quartz pebbles, with traces of sand pockets; no carbonaceous material noted; a few very much worn shell fragments (*Ostrea*?).

On October 31, 1942, Dr. Roland W. Brown and I made another boring toward the opposite extremity of the cliff, about 150 yards above the lower (southern) end of the fossiliferous part of the exposure. As the pipe came apart at a depth of 16 feet, it was not possible to penetrate as deeply as on the previous attempt, but the results in general were in fairly close agreement with earlier ones. The exposed part of bed 1 in the bank at this point was about 4 feet deep, so that

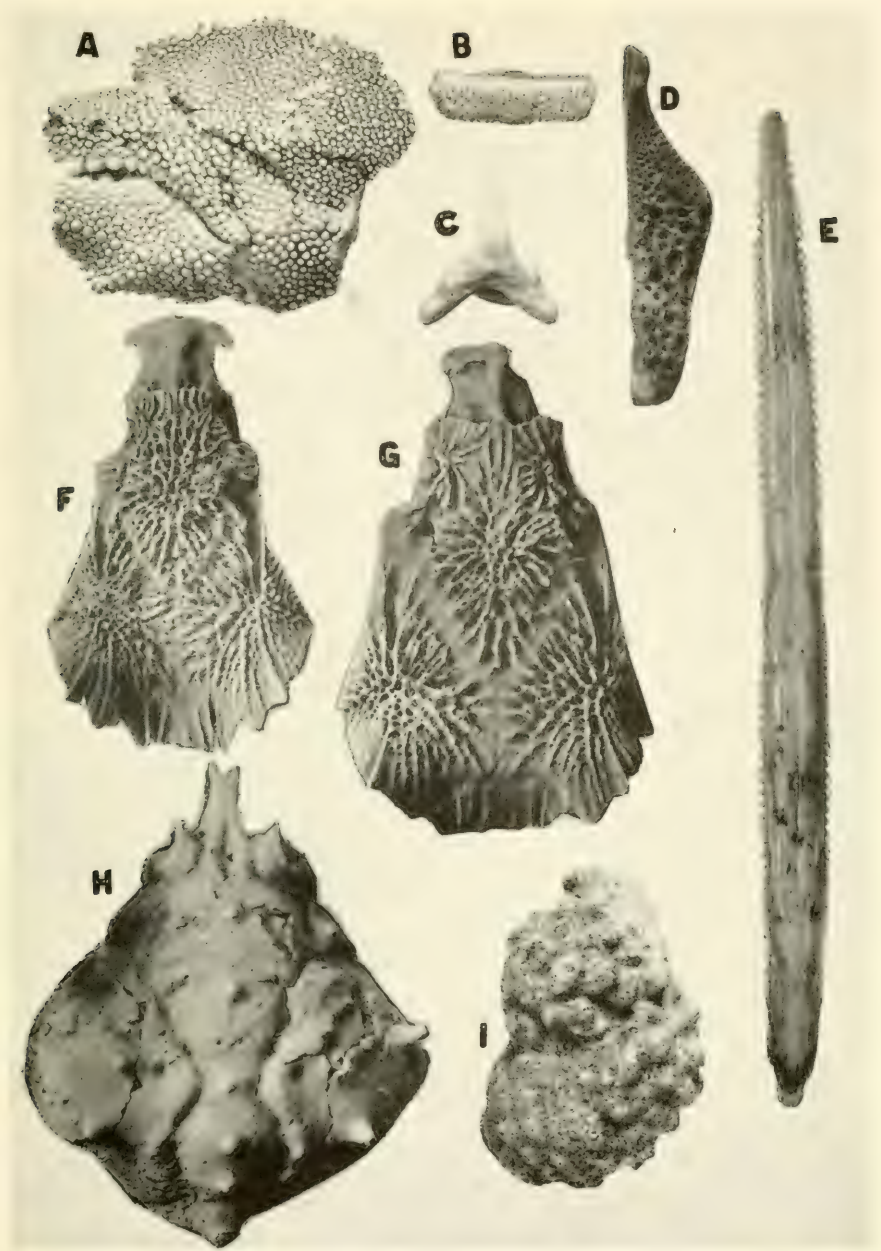
its total depth was 20 feet and an undetermined amount more. The following description of these cores was prepared with the assistance of Dr. Julia A. Gardner; the shell contents of the cores are given in parentheses.

Depth below  
beach level

- 4 ft. Grayish-green clay with a little mica and a few stringers of clear quartz sand. (Several *Actaeocina*, 2 *Nuculana*, 1 each *Arca transversa*, *Mulinia*, *Ostostomia disparilis*, *Nassarius trivittatus*, some shell fragments.)
- 6.5 ft. Similar, with a few shell fragments. (Several *Nuculana*, *Actaeocina*, and *Turbonilla interrupta*, 2 *Arca transversa*, 1 each *Nucula*, *Yoldia*, and *Mulinia*; some skeletal remains of *Asterias*.)
- 7 ft. Similar, with slightly more sand and a few more shell fragments. (Many *Nucula* and *Actaeocina*, very many *Nuculana*, more material of *Asterias*, fragments of *Barnea costata*, 1 each *Nassarius trivittatus* and *Crepidula plana*.)
- 8.5 ft. Similar to preceding. (Several *Nucula*, *Nuculana*, *Yoldia*, *Mulinia*, and *Actaeocina*, 1 *Arca transversa*, 1 fragment of *Balanus*.)
- 11 ft. Similar to preceding, but with fewer shell fragments and a few large quartz grains. (Few fragments of *Nucula*, *Nuculana*, and *Mulinia*, and a few *Actaeocina*.)
- 12 ft. Similar but with decidedly more sand. (A very few small shell fragments.)
- 14 ft. Stiff, grayish rather than greenish clay with some carbonaceous material, a few very small specks of mica and a very few clear quartz grains. (Two fragments of *Mulinia*.)
- 15 ft. Similar, but with more carbonaceous material which occurs in streaks. (Numerous fragments of *Rangia*, somewhat worn, and a few tiny fragments of small bivalves.)
- 16 ft. Similar, more greenish, with rather numerous specimens of *Rangia* (including some complete valves) and little or no carbonaceous material. (Several fairly complete valves and several fragments of *Rangia*, not badly worn and with some traces of epidermis remaining, 1 fragment of *Arca transversa*, 1 *Mulinia*, 1 worn *Actaeocina*, a few tiny shell fragments.)

The results of these two borings made toward the two extremities of the fossiliferous part of the cliff at Wailes Bluff are of considerable interest. They reveal, in the first place, the much greater depth of the Pleistocene deposit at Wailes Bluff than at Langleys Bluff—26 feet (plus an undetermined greater depth) as contrasted with 6 to 8 feet (omitting the overlying oyster bed). It has been suggested that our borings may have penetrated one or more of the older Pleistocene formations of Maryland—the Wicomico (if the exposed portion is Talbot) or possibly even the Sunderland. In both borings, at a depth varying from about 10 to 14 feet below beach level, considerable sand





A, *Pagurus pollicaris* (Say); B, tooth of *Myliobatis* cf. *fremovillii* Le Sueur, viewed from attached surface; C, *Odontaspis littoralis* (Mitchill); D, lower right pharyngeal of *Micropoqon undulatus* (Linné), oral surface; E, tail spine of *Dasyatis* cf. *centrourus* (Mitchill); F, G, skulls of *Prionotus* aff. *evolans* (Linné); H, *Libinia dubia* Milne Edwards; I, *Hippoqorida edax* (Busk). All  $\times 1\frac{1}{2}$ . All from Wailes Bluff, bed 1.



was encountered, accompanied by more or less carbonaceous material, both features suggesting shallow-water conditions; somewhat similar conditions were found again at about 18 to 19 feet in the deeper boring. However, except for a few small, badly worn, and nonsignificant fragments of *Ostrea* and *Venus*, no material of the species of shallower water such as *Mya arenaria*, *Venus mercenaria*, or *Ostrea virginica* was brought up from these depths, as would certainly have been the case had the auger passed through a bed of them. No marine fossils have been definitely reported from the Pleistocene of Maryland from any formation older than the Talbot and it would be unwarranted to regard those here recorded, in spite of their depth, as representing the older formations. The proper course at present appears to be to consider the 16 to 21 feet so far tapped below beach level, with the 4 or 5 feet exposed in the bank above, as constituting a single bed—bed 1 of Mansfield—unless the *Rangia* zone mentioned in the next paragraph is to be regarded as a separate bed.

The second significant fact revealed by these borings is the presence of abundant whole valves of *Rangia cuneata* at a depth of 12½ to 14 feet (at upper end of cliff) and 15 to 16 feet (at lower end) below beach level, corresponding respectively to depths of 17½ to 19 feet and 19 to 20 feet below the top of bed 1. No paired valves were found, but the comparatively unworn condition of the shells and the presence of epidermis upon them, as well as the occurrence of carbonaceous material in the cores just above those in which they were found, are all points to indicate that they were in or near the situation in which they had lived. Although *Rangia cuneata* is sometimes found, according to Dall, in the sea outside the lagoons, it is by preference an inhabitant of brackish water near the mouths of rivers and creeks at or near tidal level, favoring especially the muddy banks of creeks in brackish marshes. The presence of abundant specimens toward both ends of the cliff at a depth of 12½ to 16 feet below beach level, whether they represent two colonies or, as seems more likely, a continuous bed, definitely indicates a period during which shallow-water estuarine conditions prevailed—an indication reinforced by the occurrence of considerable carbonaceous material both above and below the *Rangia*.

#### TEMPERATURE OF THE WATER

With the exception of two species, *Vitrinella blakei* and *Rangia cuneata*, all the species definitely recorded from Wailes Bluff and Langleys Bluff are still living along the Atlantic coast.<sup>5</sup> The first of

<sup>5</sup> Curiously enough, in Clark's table (Shattuck et al., 1906, p. 147) showing

these, a tiny flattish gastropod little more than a millimeter in diameter, is known from only a single specimen and may well turn up later as a Recent species. The second, *Rangia cuneata*, is an abundant living species on the coast of the Gulf of Mexico. The evidence afforded by this fauna as to the climate at the time of its deposition has been discussed by Conrad, W. B. Clark, Smith, Mansfield, and Richards. Of the mollusks previously recorded from Wailes Bluff, only two have been regarded as indicating colder conditions, *Macoma calcarea* (Gmelin) and *Aligena elevata* (Stimpson). The *Macoma* now ranges from Greenland to New Jersey and has been found in the Cape May formation of New Jersey and the Pamlico of South Carolina, associated in both cases with a warm-water fauna. The *Aligena*, formerly supposed to range only from Massachusetts to New Jersey, is now known to occur as far south as North Carolina, so that its occurrence at Wailes Bluff is not of much significance. Both species, as Richards points out, must have been very rare, as they have not been found by any collector since the publication of the Maryland Survey volume. The specimen of *Aligena* in the Maryland Survey collection was reexamined by Mansfield, but the fragments of *Macoma* on which the original record was based were not found.

The evidence indicating a warmer climate than prevails at present is more impressive. The most significant species is *Rangia cuneata* (Gray), a colonial brackish-water species common on the Gulf Coast and not known living north of the (west) coast of Florida. It is fairly common at Wailes Bluff, usually in the form of single valves, but rare at Langleys Bluff, and was reported by Conrad (1842, p. 190) as forming a whole bed "on the land of Mr. Ebb, above the mouth of St. Mary's River." Another similar occurrence has been described to me by James E. Benedict, Jr. On July 16, 1933, he found a nearly or quite pure colony of this bivalve occupying the basal 3 or 4 feet of the bluff for a distance of perhaps 25 feet just below the mouth of Blake Creek (i.e., southeast of the mouth, not north of it as stated by Richards, 1936, p. 1625), about 7 miles downstream from Leonardtown, St. Marys County. The tropical cyclone of August 23, 1933, destroyed the bank at this point and wiped out the colony, and in 1935 I was able to find only scattered beach-worn shells. Several specimens of

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the geological range of the species known from the Maryland Pleistocene the only species indicated as not found in the Recent are *Callinectes sapidus* and *Ilyanassa obsoleta*. The former, the blue crab, is marketed in tremendous quantities each year from Chesapeake Bay, and the latter is one of the commonest mollusks on the eastern coast.

paired valves given me by Mr. Benedict are the largest and finest I have seen from this region, measuring up to 5 cm. in length by 4.5 cm. in height. The species occurs in the Pleistocene as far north as New Jersey. Several other species of southern range, but much less strikingly so than *Rangia*, are found at Wailes Bluff: *Arca ponderosa* Say, ranging from North Carolina to Mexico, in the Recent<sup>6</sup>; *Venus campechiensis* Gmelin, from Virginia to Texas; *Teinostoma cryptospirum* (Verrill), from North Carolina to Florida; *Epitonium denticulatum* (Sowerby), from North Carolina to West Indies; *Odotostomia acutidens* Dall, from North Carolina to Florida; and *Terebra dislocata* Say, from Virginia southward.

Cushman and Cole (1930, p. 94), in their paper on Foraminifera from Wailes Bluff and Langleys Bluff, suggested that possibly "different conditions of temperature prevailed during the deposition. Some of the species are now found in comparatively warm waters while others are now characteristic of very cold waters. A similar condition is shown in the Pleistocene beds of Sankoty Head, Nantucket." In a letter, Dr. Cushman listed *Quinqueloculina seminula*, *Elphidium incertum* and its var. *clavatum*, and *Eponides frigida* var. *calida* as indicative of colder waters, and *Triloculina rotunda*, *Nonion* (both species), *Elphidium discoideale*, and *Rotalia beccarii* (both varieties) as species of more definitely southern range, particularly the *Elphidium*.

Of the 40 species added to the Pleistocene fauna of Maryland in this paper, the only ones of significance in connection with the question of climate are all of southern affinity: *Stylopoma spongites* (Pallas), rare at Wailes Bluff, a bryozoan known in the Recent from the West Indies and the Gulf of Mexico, and in the Pleistocene north to South Carolina; *Hippoporidra edax* (Busk), a bryozoan not previously recorded in the fossil state and not known north of North Carolina in the Recent, which occurs sparingly at Wailes Bluff; *Lucina multilincata* Tuomey and Holmes, a bivalve known in the Recent from North Carolina southward; *Bankia gouldi* Bartsch, not previously recorded as a fossil and not known north of Virginia in the Recent, which is common at Wailes Bluff in pieces of cypress wood; and *Odotostomia disparilis* Verrill, known only as a Recent species from North Carolina.

#### SPECIES NEW TO THE PLEISTOCENE OF MARYLAND

The following 40 species reported in this paper have not previously been recorded from the Pleistocene of Maryland. Material of all these

<sup>6</sup> See F. S. MacNeil, U. S. Geol. Surv. Prof. Pap. 189, p. 24, 1938.

except *Schizoporella unicornis* and *Xestoleberis* sp. has been placed in the United States National Museum.

## COELENTERATA

*Astrangia danae* Agassiz. Wailes Bluff.

## ECHINODERMATA

*Asterias* cf. *forbesi* (Desor). Wailes Bluff, Langleys Bluff.

?*Moiria atropos* (Lamarck). Langleys Bluff.

## BRYOZOA

*Membranipora flabellata* Canu. Wailes Bluff.

*Stylopora spongites* (Pallas). Wailes Bluff.

*Schizoporella unicornis* (Johnston). Langleys Bluff.

*Palmicellaria convoluta* Ulrich and Bassler. Wailes Bluff.

*Hippoporidra edax* (Busk). Wailes Bluff.

## PELECYPODA

*Volsella modiolus* (Linné). Wailes Bluff.

*Lucina multilineata* Tuomey and Holmes. Langleys Bluff.

*Lucinoma filosa* (Stimpson). Langleys Bluff.

*Spisula solidissima* Dillwyn. Wailes Bluff.

*Barnea truncata* (Say). Wailes Bluff, Langleys Bluff.

*Martesia cuneiformis* (Say). Wailes Bluff.

*Bankia gouldi* Bartsch. Wailes Bluff.

## SCAPHOPODA

*Dentalium* cf. *entale stimpsoni* Henderson. Wailes Bluff.

## GASTROPODA

*Teinostoma* cf. *reclusum* Dall. Wailes Bluff.

*Vitrinella blakei* Rehder. Wailes Bluff.

*Epitonium angulatum* (Say). Langleys Bluff.

*Sayella* aff. *fusca* (C. B. Adams). Wailes Bluff, Langleys Bluff.

*Odotomia disparilis* Verrill. Wailes Bluff, Langleys Bluff.

*Odotomia* cf. *hendersoni* Bartsch. Wailes Bluff, Langleys Bluff.

*Seila adamsii* (H. C. Lea). Wailes Bluff.

*Haminoea solitaria* (Say). Langleys Bluff.

## OSTRACODA

*Cytheridea punctillata* Brady. Wailes Bluff, Langleys Bluff.

*Cythereis tuberculata* Sars. Wailes Bluff, Langleys Bluff.

*Loxoconcha impressa* Baird. Wailes Bluff, Langleys Bluff.

*Xestoleberis* sp. Wailes Bluff.

## DECAPODA

- Callianassa* cf. *matsoni* Rathbun. Wailes Bluff.  
*Pagurus pollicaris* (Say). Wailes Bluff.  
*Callinectes ornatus* (Ordway). Wailes Bluff.  
*Libinia dubia* Milne Edwards. Wailes Bluff.

## PISCES

- Odontaspis littoralis* (Mitchill). Wailes Bluff.  
*Dasyatis* cf. *centrourus* (Mitchill). Wailes Bluff.  
*Myliobatis* cf. *fremewillii* LeSueur. Wailes Bluff.  
*Brevoortia* cf. *tyrannus* (Latrobe). Wailes Bluff.  
*Roccus saxatilis* (Walbaum). Wailes Bluff.  
*Micropogon undulatus* (Linné). Wailes Bluff.  
*Pogonia* cf. *cromis* (Linné). Wailes Bluff.  
*Prionotus* aff. *evolans* (Linné). Wailes Bluff.

The revised complete list of the fauna of Wailes Bluff and Langleys Bluff here presented, amounting to 121 species and 2 additional varieties, includes the entire known marine Pleistocene fauna of Maryland except the 9 mollusks from dredgings at South Ocean City listed on p. 8. Of this total, 114 species and 2 varieties are known from Wailes Bluff, and 69 species and the same 2 varieties from Langleys Bluff. Seven species are known from Langleys Bluff but not from Wailes Bluff: a foraminifer, *Nomion sloanii* (?); an echinoderm, *?Moira atropos*; a bryozoan, *Schizoporella unicomis*; 2 bivalves, *Lucinoma filosa* and *Lucina multilincata*; and 2 gastropods, *Epitonium angulatum* and *Haminoca solitaria*. Fifty-two species are known from Wailes Bluff but not from Langleys Bluff; 62 species and 2 varieties are found at both localities.

In the list the asterisk marks species not previously recorded from Wailes Bluff; species not previously recorded from Langleys Bluff are so indicated in parentheses in the annotation. Names used in the Maryland Geological Survey volume have been given in parentheses when they differ from those here adopted. The treatment of Foraminifera is taken entirely from Cushman and Cole's paper (1930), supplemented by Dr. Cushman's notes referred to above. Except where otherwise indicated, the rest of the list is based on my own observations and collections made on 34 visits to Wailes Bluff and 21 to the Pleistocene locality at Langleys Bluff, but reference is made to the reports of other observers when they differ from my own.

My thanks are due to Dr. Paul Bartsch, Dr. R. S. Bassler, Austin H. Clark, Dr. Remington Kellogg, G. S. Miller, Dr. J. P. E. Morrison, Dr. G. S. Myers, the late Mary J. Rathbun, Dr. H. A. Rehder, E. D.

Reid, Dr. L. P. Schultz, Dr. W. L. Schmitt, Dr. W. L. Tressler, and Dr. J. W. Wells for the identification of specimens in their respective groups; to Dr. Arthur Koehler and Dr. W. C. Darrah for the identification of the only wood (*Taxodium* sp.) known from the lower beds at Wailes Bluff and Langleys Bluff; and to Dr. R. W. Brown, Dr. W. S. Cole, Dr. C. Wythe Cooke, the late Dr. J. A. Cushman, Dr. Julia A. Gardner, Dr. H. A. Pilsbry, Dr. H. G. Richards, William E. Salter, Dr. E. R. Smith, and Dr. Richard J. Taylor for information on their work at these localities or for assistance in other ways.

LIST OF THE PLEISTOCENE FAUNA OF WAILES BLUFF AND  
LANGLEYS BLUFF, MARYLAND

PROTOZOA  
FORAMINIFERA

(Based on Cushman and Cole's 1930 list, with some additional information supplied by Dr. Cushman.)

- Lenticulina rotulata* (Lamarck)? Dr. Cushman (in litt.) so refers Bagg's record of *Cristellaria rotulata* (Lamarck) from Wailes Bluff. The material on which Bagg's record was based could not be found by Dr. Charles T. Berry in the Maryland Geological Survey collection.
- Quinqueloculina flexuosa* d'Orbigny. Wailes Bluff, very rare.
- Quinqueloculina seminula* (Linnaeus). Wailes Bluff, very rare.
- Triloculina rotunda* d'Orbigny. Wailes Bluff, rare.
- Nonion pompilioides* (Fichtel and Moll). Wailes Bluff, rare.
- Nonion sloanii* (d'Orbigny) (?). Langleys Bluff, a single doubtful specimen.
- Elphidium advenum* (Cushman) var. *margaritaccum* Cushman. Wailes Bluff, a single specimen.
- Elphidium discoidale* (d'Orbigny). Wailes Bluff, "in some numbers."
- Elphidium incertum* (Williamson). Wailes Bluff and Langleys Bluff, much less abundant than the variety.—Var. *clavatum* Cushman. Wailes Bluff and Langleys Bluff, common. (Bagg's record of *Polystomella striatopunctata* (Fichtel and Moll) probably belongs to *Elphidium incertum*.)
- Entosolenia globosa* (Montagu). Dr. Cushman (in litt.) so refers Bagg's record of *Lagena globosa* from Wailes Bluff. The material on which the record was based could not be found by Dr. C. T. Berry in the Maryland Geological Survey collection.
- Entosolenia lucida* (Williamson). Wailes Bluff and Langleys Bluff.
- Eponides frigida* (Cushman) var. *calida* Cushman and Cole. Wailes Bluff and Langleys Bluff, fairly common; type from Wailes Bluff. Described as a warmer-water variety (identical with specimens living on the New England coast) of the Arctic *Eponides frigida*.
- Rotalia beccarii* (Linnaeus) var. *ornata* Cushman. Wailes Bluff and Langleys Bluff, common.—Var. *parkinsoniana* (d'Orbigny). Wailes Bluff and Langleys Bluff, common.



## PORIFERA

- Cliona sulphurea* (Desor). Wailes Bluff: Bed 1, scarce; bed 3, common. Langleys Bluff: Basal and Upper *Ostrea* beds, fairly common, 1942; *Mulinia* bed, casual (not previously recorded). A sponge, represented only by its borings in shells of *Venus* and *Ostrea*.

## COELENTERATA

- \**Astrangia danae* Agassiz. Wailes Bluff: Bed 1, on *Fulgur canaliculatum*, July 9, 1939, Harald A. Rehder and S. F. Blake; on a rock, 1940, R. J. Taylor; loose in the clay, 1943, S. F. Blake. Identified by Dr. J. W. Wells. New to the Maryland Pleistocene.

## ECHINODERMATA

- \**Asterias* cf. *forbesi* (Desor). (Asteriidae) Wailes Bluff: Bed 1, a few skeletal fragments found in siftings, 1938-42. Langleys Bluff: *Mulinia* bed, 1942-45, more or less complete skeletal specimens of at least 4 individuals, the best one showing much of the central skeleton in connection, including bases of all 5 arms, as well as a large section of the dorsal skeleton of 1 arm and additional fragments of the dorsal skeleton; also skeletal fragments in siftings, 1941-42 (not previously recorded). New to the Maryland Pleistocene. Identified by Austin H. Clark. The specimens were found separately on different occasions, and represented scattered individuals and not a colony.
- ?*Moira atropos* (Lamarck). (Hemiasteridae.) Langleys Bluff; single fragment, in *Mulinia*-filled boring, *Mulinia* bed, 1942 (not previously recorded). New to the Maryland Pleistocene. A tiny fragment of the test of a heart-urchin, measuring about 2 mm. square, has been identified by A. H. Clark as probably belonging to this species, which is known in the Recent from North Carolina southward.

## BRYOZOA

(All my specimens have been identified by Dr. R. S. Bassler.)

- Electra monostachys* (Busk). Wailes Bluff: Bed 1, rather common. Langleys Bluff: Basal *Ostrea* bed, scarce on *Ostrea*, 1941-42 (not previously recorded).
- \**Membranipora flabellata* Canu. Wailes Bluff: Bed 1, rare, 1935. Reported by Canu and Bassler from the Miocene but not from the Pleistocene.
- Conopceum germanum* (Ulrich and Bassler). Wailes Bluff; recorded by Ulrich in Maryland Geological Survey (as *Membranipora germana*).
- Acanthodesia oblongula* (Ulrich and Bassler). Wailes Bluff: Bed 1, rather common. Langleys Bluff: Basal *Ostrea* bed, scarce on *Ostrea*, 1941-42; *Mulinia* bed, on a *Mulinia* shell, 1942 (not previously recorded).
- Acanthodesia savartii* (Savigny). Wailes Bluff: Bed 1, scarce.
- Ogivalina parvula* (Ulrich and Bassler). Wailes Bluff; recorded by Ulrich in Maryland Geological Survey (as *Membranipora parvula*).
- \**Stylopora spongites* (Pallas). Wailes Bluff: Bed 1, two good-sized colonies, 1942. This is a southern species, known in the Recent from Gulf of Mexico,

the West Indies, and (doubtfully) Malacca. In the Pleistocene it has previously been known north to South Carolina, and I have collected it in Zone 17 of the Choptank Miocene at Jones Wharf, Md.

*Schizoporella unicornis* (Johnston). Langleys Bluff: Basal *Ostrea* bed, rare on *Ostrea*, 1942. First record for Maryland Pleistocene.

\**Palmicellaria convoluta* Ulrich and Bassler. Wailes Bluff: Bed 1, rare, 1938-45. Not recorded from the Pleistocene by Canu and Bassler. My largest specimen is a colony measuring about 12 by 8 by 5 cm.

\**Hippoporidra edax* (Busk). Wailes Bluff: Bed 1, scarce, 1935-42. Occurs on the shell of *Nassarius trivittatus*, which it distorts in a characteristic way. Not previously recorded in the fossil state, and not known north of North Carolina in the Recent.

## MOLLUSCA

### PELECYPODA

*Nucula proxima* Say. Wailes Bluff: Bed 1, fairly common. Langleys Bluff: *Mulinia* bed, rather common.

*Nuculana acuta* (Conrad). (*Leda acuta*.) Wailes Bluff: Bed 1, common; bed 3, rare. Langleys Bluff: *Mulinia* bed, common.

*Yoldia linatula* (Say). Wailes Bluff: Bed 1, not common. Langleys Bluff: *Mulinia* bed, 1942, scarce and small (not previously recorded).

*Arca ponderosa* Say. Wailes Bluff: Bed 1, fairly common. Langleys Bluff: *Mulinia* bed, rare. I cannot satisfactorily distinguish as a species *Eontia palmerae* MacNeil, described from Wailes Bluff.

*Arca transversa* Say. Wailes Bluff: Bed 1, abundant. Langleys Bluff: *Mulinia* bed, common. Brown (1946) has reported a small pearl in a valve of this species he collected at Wailes Bluff. He found only two previous records of fossil pearls in the Pleistocene, both from England.

*Ostrea virginica* Gmelin. Wailes Bluff: Bed 1, scarce; bed 3, abundant, making up the bulk of the bed. Langleys Bluff: Basal and Upper *Ostrea* beds, abundant; *Mulinia* bed, casual.

*Mytilus recurvus* Rafinesque. (*M. hamatus*.) Wailes Bluff: Bed 1, scarce; bed 3, common. Langleys Bluff: Basal *Ostrea* bed, 1941-42, 3 or 4 fragmentary valves; Upper *Ostrea* bed, 1942, one pair (not previously recorded).

\**Volsella modiolus* (Linné). Wailes Bluff: Bed 1, rare, 1938-42, S. F. Blake; 1941, R. J. Taylor. New to the Maryland Pleistocene. The half dozen specimens or fragments, only 2 of which are sufficiently complete for satisfactory comparison, are somewhat intermediate between *V. modiolus* and *V. tulipa* (Linné), resembling the latter in the angularity of the dorsal margin but lacking its inflation and reddish color. *Volsella modiolus* is known from Labrador to North Carolina and the west coast of Florida, and these specimens appear to be closest to those from western Florida. *Volsella tulipa* is definitely known from North Carolina to the West Indies.

*Elliptio complanatus* (Solander). (*Unio complanatus*.) Wailes Bluff: Bed 1, rare; I have found about 8 imperfect valves. Langleys Bluff; recorded by Maryland Geological Survey, apparently not found by later collectors. On July 4, 1939, while Dr. Julia A. Gardner and I were collecting at Langleys

Bluff, we found a number of imperfect valves in the Basal *Ostrea* bed at the contact with the underlying St. Marys formation, in a thin layer (about  $\frac{1}{2}$  inch thick) of gray sand accompanied by many rounded boulders. The thin sandy layer bearing *Elliptio* has not been found on subsequent visits, and evidently represented a very local situation, possibly a stream bed. The contact between the Pleistocene and the St. Marys is not visible at Wailes Bluff, and the few specimens of *Elliptio* I have found there occurred in the middle of the marine clay. In addition to this species, Richards lists an unidentified species of *Elliptio* from Wailes Bluff, Langleys Bluff, and other localities.

- Pandora gouldiana* Dall. Wailes Bluff: Bed 1, scarce. Langleys Bluff: *Mulinia* bed, half a dozen specimens, 1942-45 (not previously recorded).
- \**Lyonsia hyalina* Conrad. Wailes Bluff: Bed 1, single valve, 1941. Langleys Bluff: *Mulinia* bed, reported by Richards.
- Lucina multilincata* Tuomey and Holmes. Langleys Bluff: *Mulinia* bed, 2 valves, 1942 (not previously recorded); found in borings filled with *Mulinia*, the specimens very small, only 1.5 to 2 mm. high. New to the Maryland Pleistocene. Recent range, North and South Carolina.
- Lucinoma filosa* (Stimpson). Langleys Bluff: *Mulinia* bed, 1 pair, 1942 (not previously recorded). New to the Maryland Pleistocene. Recent range, Maine to Florida.
- Dicricella quadrisulcata* Orbigny. Wailes Bluff, rare, collected only by Smith, who writes me that he got a single rather depauperate specimen.
- Rochefortia planulata* (Stimpson). Wailes Bluff: Bed 1, rare. Langleys Bluff: *Mulinia* bed, 2 valves, 1942 (not previously recorded).
- Aligena elevata* (Stimpson). Wailes Bluff; recorded in Maryland Geological Survey; not found by any subsequent collector.
- Callocardia morrhuana* Linsley. Wailes Bluff: Bed 1, scarce. (Includes *C. morrhuana* and *C. sayana* of Smith, according to Richards.) Langleys Bluff: *Mulinia* bed, 1940-45, 3 pairs and 7 or 8 single valves (not previously recorded).
- Venus mercenaria* Linné. Wailes Bluff: Bed 1, common; bed 2, recorded by Mansfield; bed 3, abundant. Langleys Bluff: Basal *Ostrea* bed, common, and occurring even below it in the top of the St. Marys formation; *Mulinia* bed, scarce; Upper *Ostrea* bed, abundant.
- Venus campechiensis* Gmelin. Wailes Bluff: Bed 1, reported by Richards, who writes me that he got young specimens.
- Gemma gemma* (Totten). Wailes Bluff: Bed 1, 4 valves; bed 3, rare.
- Petricola pholadiformis* Lamarck. Wailes Bluff: Bed 1, scarce.
- Tellina tenera* Say. Wailes Bluff: Bed 1, rare. Langleys Bluff: *Mulinia* bed, 1941-42, rare (not previously recorded).
- Macoma balthica* (Linné). Wailes Bluff: Bed 1, scarce; bed 3, scarce. Langleys Bluff: *Mulinia* bed, 1942, 2 valves (not previously recorded).
- Macoma calcarca* (Gmelin). Wailes Bluff; "a few fragments" recorded by Maryland Geological Survey; not found by any subsequent collector.
- Cumingia tellinoides* (Conrad). Wailes Bluff: Bed 1, rare. I have found only 2 valves.
- Tagelus gibbus* (Spengler). Wailes Bluff: Bed 1, fairly common toward the top. Langleys Bluff: *Mulinia* bed, rare toward the top.

- Ensis directus* (Conrad). Wailes Bluff: Bed 1, not common. Perfect paired valves are not rare, although the Maryland Geological Survey reported only fragments.
- \**Spisula solidissima* Dillwyn. Wailes Bluff: Bed 1, a single perfect left valve measuring 57 by 42 mm., 1947; bed 3, a pair of smaller valves consisting of umbonal region only, 1947, of this genus and presumably of this species. New to the Maryland Pleistocene.
- Mulinia lateralis* (Say). Wailes Bluff: Bed 1, abundant, often concentrated in borings; bed 3, scarce. Langleys Bluff: *Mulinia* bed, abundant, and occurring in great numbers in borings sometimes a couple of feet long, as at Wailes Bluff.
- Rangia cuneata* (Gray). Wailes Bluff: Bed 1, rather common, usually as single valves; bed 2, recorded by Mansfield; bed 3, one valve. Langleys Bluff: *Mulinia* bed, scarce.
- Mya arenaria* Linné. Wailes Bluff: Bed 1, not uncommon in upper part; bed 3, abundant. Langleys Bluff: Basal *Ostrea* bed, common in places below the oysters; *Mulinia* bed, 1 pair in upper part; Upper *Ostrea* bed, common. It is odd that Mansfield did not find this species at Langleys Bluff; it was among the few species recorded in the Maryland Geological Survey (1906).
- Corbula contracta* Say. Wailes Bluff: Bed 1, scarce; bed 3, reported by Mansfield (1 specimen). Langleys Bluff: *Mulinia* bed, 1938-42, a pair and a single valve (not previously recorded).
- Barnea costata* (Linné.) Wailes Bluff: Bed 1, abundant as paired valves in their natural position. Langleys Bluff: *Mulinia* bed, common as paired valves.
- \**Barnea truncata* (Say). Wailes Bluff: Bed 1, rather common in pieces of cypress wood (*Taxodium* sp., identified by Dr. Arthur Koehler and Dr. W. C. Darrah), 1938-42, the specimens all small, none over about 2 cm. long; rarely free in the clay and much larger (a pair 4.2 cm. long, 1941, R. J. Taylor; 2 pairs and a single valve up to 5.2 cm. long, 1942-45, S. F. Blake). Langleys Bluff: *Mulinia* bed, several specimens up to 3.2 cm. long in a cypress log, 1942 (not previously recorded). New to the Maryland Pleistocene.
- \**Martesia cuneiformis* (Say). Wailes Bluff: Bed 1, rather common in pieces of *Taxodium* wood, 1940. New to the Maryland Pleistocene.
- \**Bankia gouldi* Bartsch. Wailes Bluff: Bed 1, rather common in pieces of *Taxodium* wood, 1938-40. Identified by Dr. Paul Bartsch. Not previously recorded as a fossil; Recent range, Virginia southward.

## SCAPHOPODA

- \**Dentalium* cf. *entale simpsoni* Henderson. Wailes Bluff: Bed 1, one specimen, 1942. New to the Maryland Pleistocene. The specimen, consisting only of a tip 1.5 mm. long, agrees as far as it goes with material of this form, the American representative of the European *D. entale*.

## GASTROPODA

- Teinostoma cryptospirum* (Verrill). Wailes Bluff: Bed 1, 7 specimens. Langleys Bluff: *Mulinia* bed, 1 imperfect specimen, 1942 (not previously re-

corded). Otherwise collected only by Smith, who wrote me that he found 2 specimens at Wailes Bluff.

\**Trochostoma* cf. *reclusum* Dall. Wailes Bluff: Bed 1, one specimen, 1941-42. New to the Maryland Pleistocene. *T. reclusum* is known as a Recent species from off North Carolina and from the Gulf of Mexico.

\**Vitrinella blakei* Rehder. Wailes Bluff: Bed 1, 1942, single specimen (the type). New to the Maryland Pleistocene. Closely related to *V. shimeri* Clapp, described from Pleistocene deposits in a subway excavation, Boylston Street, Boston, Mass.

*Epitonium angulatum* (Say). Langleys Bluff: *Mulinia* bed, 2 specimens, 1935-41 (not previously recorded). New to the Maryland Pleistocene. Range in Recent, Connecticut to Texas.

*Epitonium denticulatum* (Sowerby). Wailes Bluff: Bed 1, rare. Langleys Bluff: *Mulinia* bed, one small specimen, 1942 (not previously recorded).

*Epitonium humphreysii* (Kiener). (*Scala sayana*.) Wailes Bluff; reported by Smith as rare. Langleys Bluff: *Mulinia* bed, 1935-41, scarce (not previously recorded).

*Epitonium lineatum* (Say). Wailes Bluff: Bed 1, rather common; bed 3, rare. Langleys Bluff: *Mulinia* bed, scarce.

*Epitonium multistriatum* (Say). Wailes Bluff; reported by Smith as uncommon.

*Epitonium* cf. *samanae* (Orbigny). Wailes Bluff; reported by Smith as rare. An additional unnamed *Epitonium* is listed by Smith from Wailes Bluff.

*Pyramidella* (*Sulcorinella*) sp. Wailes Bluff: Bed 1, scarce. Langleys Bluff: *Mulinia* bed, 1935-42, scarce (not previously recorded). This is presumably the species reported from Wailes Bluff by Smith on authority of Bartsch as an unnamed new species.

\**Sayella* aff. *fusca* (C. B. Adams). Wailes Bluff: Bed 1, rare, 1938-42; bed 3, 2 specimens, 1939. Langleys Bluff: *Mulinia* bed, 1942, rare (not previously recorded). New to the Maryland Pleistocene. Identified by Dr. H. A. Rehder.

*Turbonilla interrupta* (Totten). Wailes Bluff: Bed 1, common. Langleys Bluff: *Mulinia* bed, fairly common (not previously recorded). Smith states that Bartsch had recognized 51 new species of *Turbonilla* among material brought together from various collectors. As these have not been published, I have followed the Maryland Geological Survey in using this specific name.

*Odostomia acutidens* Dall. Wailes Bluff: Beds 1 and 3, rare. Langleys Bluff: *Mulinia* bed, 1935-42, rare (not previously recorded).

\**Odostomia disparilis* Verrill. Wailes Bluff: Bed 1, scarce, 1938-42. Langleys Bluff: *Mulinia* bed, about 40 specimens, 1942 (not previously recorded). New to the Maryland Pleistocene. Identified by Dr. H. A. Rehder. Previously known only from North Carolina.

\**Odostomia impressa* (Say). Wailes Bluff: Beds 1 and 3, scarce. Langleys Bluff: *Mulinia* bed, rare, 1935-42 (not previously recorded). Previously recorded in the Maryland Pleistocene only from Federalsburg, Caroline County.

*Odostomia seminuda* (Adams). Wailes Bluff: Bed 1, rather common. Langleys Bluff: *Mulinia* bed, scarce, 1935-42 (not previously recorded). Smith (1920, p. 86) took up for this species the name *Odostomia melanoides* (Conrad). Dr. H. A. Pilsbry writes me that Conrad's type is not at

- Philadelphia, and as his description is ambiguous and his figure a mere smudge, I prefer to retain the name *O. seminuda*. Smith states that Bartsch had distinguished 10 new species of the genus in Wailes Bluff material, belonging to the sections *Chrysallida* (1 species), *Menestho* (1 species), and *Evalea* (8 species), but they have not yet been published.
- \**Odostomia (Iolaea) cf. hendersoni* Bartsch. Wailes Bluff: Bed 1, single specimen, 1942. Langleys Bluff: *Mulinia* bed, 2 specimens, 1942 (not previously recorded). New to the Maryland Pleistocene. Identified by Dr. H. A. Rehder.
- Polinices duplicata* (Say). Wailes Bluff: Bed 1, common; bed 3, reported by Mansfield (1 specimen). Langleys Bluff: *Mulinia* bed, fairly common.
- Crepidula convexa* Say. Wailes Bluff: Bed 1, fairly common.
- Crepidula fornicata* (Linné). Wailes Bluff: Bed 3, common. Langleys Bluff: *Mulinia* bed, scarce. The specimens of this species and the preceding are always small, the largest I have found being only 15 mm. long.
- Crepidula plana* Say. Wailes Bluff: Bed 1, common. Langleys Bluff: *Mulinia* bed, scarce. Becomes much larger than *C. fornicata*, reaching a length of 42 mm. (Wailes Bluff).
- Triphora perversa* (Linné). Wailes Bluff: Bed 1, rare. Langleys Bluff: *Mulinia* bed, 1935, single specimen (not previously recorded).
- \**Scila adamsii* (H. C. Lea). Wailes Bluff: Bed 1, 1938, a single characteristic fragment consisting of the base of a shell, 2.5 mm. long and 2.2 mm. in diameter. New to the Maryland Pleistocene.
- Eupleura caudata* (Say). Wailes Bluff: Bed 1, common. Langleys Bluff: *Mulinia* bed, common.
- Urosalpinx cinereus* (Say). Wailes Bluff: Beds 1 and 3, common.
- Mitrella lunata* (Say). (*Columbella lunata*.) Wailes Bluff: Bed 1, uncommon. Langleys Bluff: *Mulinia* bed, rare.
- Nassarius obsoletus* (Say). (*Ilyanassa obsoleta*.) Wailes Bluff: Bed 1, common; bed 3, one specimen (reported as rare by Mansfield). Langleys Bluff: *Mulinia* bed, rather common.
- Nassarius trivittatus* (Say). (*Nassa trivittata*.) Wailes Bluff: Bed 1, abundant. Langleys Bluff: *Mulinia* bed, common.
- Fulgur carica* (Gmelin). Wailes Bluff: Bed 1, common, attaining a length of 23 cm. Langleys Bluff: *Mulinia* bed, rare.
- Fulgur canaliculatum* (Linné). Wailes Bluff: Bed 1, common, usually small, my largest being 16 cm. long. Langleys Bluff: *Mulinia* bed, scarce (common according to Mansfield).
- Terebra dislocata* (Say). Wailes Bluff; recorded by Maryland Geological Survey, and Dr. Smith writes me that he got about 3 small specimens. Mansfield, Richards, and I did not find it.
- Mangelia cerina* (Kurtz and Stimpson). Wailes Bluff: Bed 1, abundant. Langleys Bluff: *Mulinia* bed, common.
- Actaeocina canaliculata* (Say). (*Tornatina canaliculata*.) Wailes Bluff: Bed 1, abundant. Langleys Bluff: *Mulinia* bed, common.
- Haminoca solitaria* (Say). Langleys Bluff: *Mulinia* bed, about 10 specimens, 1942 (not previously recorded); found in borings filled with *Mulinia*, the specimens all tiny, the largest only 2 mm. long. New to the Maryland Pleistocene. Recent range, Massachusetts to Georgia.

## ARTHROPODA

## OSTRACODA

(Identified by Willis L. Tressler.)

- \**Cytheridca punctillata* Brady. Wailes Bluff: Bed 1, common. Langleys Bluff: *Mulinia* bed, common, 1942. New to the Maryland Pleistocene.
- \**Cythercis tuberculata* Sars. Wailes Bluff: Bed 1, 2 specimens. Langleys Bluff: *Mulinia* bed, 2 specimens, 1942. New to the Maryland Pleistocene.
- \**Loxococoncha impressa* Baird. Wailes Bluff: Bed 1, single specimen. Langleys Bluff: *Mulinia* bed, single specimen, 1942. New to the Maryland Pleistocene.
- \**Xestoleberis* sp. Wailes Bluff: Bed 1, single specimen. New to the Maryland Pleistocene.

## CIRRIPEDIA

*Balanus crenatus* Bruguière. Wailes Bluff: Bed 1, uncommon; bed 3, common; the specimens always small. Langleys Bluff: Basal *Ostrea* bed and *Mulinia* bed, 1942, scarce (not previously recorded).

## DECAPODA

(Identified by Mary J. Rathbun and W. L. Schmitt.)

- Callianassa atlantica* Rathbun. Wailes Bluff: Bed 1, scarce.
- \**Callianassa* cf. *matsoni* Rathbun. Wailes Bluff: Bed 1, 1934 (imperfect specimen). New to the Maryland Pleistocene. *Callianassa matsoni* is definitely known only from the Miocene of Florida.
- \**Pagurus pollicaris* (Say). Wailes Bluff: Bed 1, 1940, R. J. Taylor (small major chela lacking the movable finger); 1941, S. F. Blake (large major chela lacking only tips of the fingers and the extreme base of the hand). New to the Maryland Pleistocene.
- \**Callinectes ornatus* (Ordway). Wailes Bluff: Bed 1, 1934 (carapace and abdomen). New to the Maryland Pleistocene.
- Callinectes sapidus* Rathbun. Wailes Bluff: Bed 1, fairly common. Langleys Bluff: *Mulinia* bed, scarce (not previously recorded).
- Cancer irroratus* Say. Wailes Bluff: Bed 1, scarce. Langleys Bluff: *Mulinia* bed, 1 large, much-worn immovable finger, 1942 (not previously recorded).
- Panopeus herbstii* Milne Edwards. Wailes Bluff: Bed 1, not common. Langleys Bluff: *Mulinia* bed, 1935, rare (not previously recorded).
- \**Libinia dubia* Milne Edwards. Wailes Bluff: Bed 1, two carapaces, 1942. New to the Maryland Pleistocene.

## STOMATOPODA

*Squilla empusa* Say. Wailes Bluff: Bed 1, common. Langleys Bluff: *Mulinia* bed, 1942, rare (not previously recorded).

The most conspicuous single feature of bed 1 at Wailes Bluff and the *Mulinia* bed at Langleys Bluff is the presence of numerous burrows, usually about 2 inches in diameter and up to 2 feet or more in

length, crammed full of *Mulinia* valves mixed with other small shells and shell fragments. Although sometimes nearly vertical, they are usually on a slant, and none have been observed extending to the top of the bed in which they occur. At the base of the cliff at Wailes Bluff the shells in them are often firmly cemented together. Smith (1920, p. 86) attributed these burrows to *Barnea costata*, but Dr. Rehder informs me that *Barnea* does not construct such burrows. It seems most probable that they were the work of some stomatopodous crustacean of fair size. The only such animal known from Wailes Bluff and Langleys Bluff is *Squilla empusa*, which is common at Wailes Bluff but rare at Langleys Bluff. The description of its burrow given by Brooks (1885, p. 11), however—"in hard muddy bottom, in or on the sides of channels where there is a rapid current . . . a shallow U-shaped burrow, open at both ends"—does not at all agree with any of the burrows actually found. His description of the burrow of *Lysiosquilla* sp.—"a deep cylindrical vertical burrow, which goes down for several feet"—is much more appropriate, but he states that this species lives in pure sea sand on beaches which are directly exposed to the ocean swell, a condition very different from that prevailing when the blue clay beds of Wailes Bluff and Langleys Bluff were formed. The burrows are so abundant that it is hard to believe that their makers could have passed away without leaving some bodily trace of their presence, but so far none has been found.

## VERTEBRATA

### PISCES

- \**Odontaspis littoralis* (Mitchill). Sand shark (Carchariidae). Wailes Bluff: Bed 1, one tooth, 1942. New to the Maryland Pleistocene. Identified by E. D. Reid.
- \**Dasyatis* cf. *centrourus* (Mitchill). Sting ray (Dasyatidae). Wailes Bluff: Bed 1, a well-preserved tail spine 9.2 cm. long, essentially complete except for the tip, 1942, S. F. Blake; another specimen 4.8 cm. long, lacking the distal half, 1942, W. E. Salter. New to the Maryland Pleistocene. Identified by Dr. L. P. Schultz and E. D. Reid.
- \**Myliobatis* cf. *fremenvillii* Le Sueur. Eagle ray (Myliobatidae). Wailes Bluff: Bed 1, one tooth in *Mulinia*-filled boring, 1942, W. E. Salter. New to the Maryland Pleistocene. Identified by E. D. Reid.
- \**Brevoortia* cf. *tyrannus* (Latrobe). Menhaden (Clupeidae). Wailes Bluff: Bed 1, one opercle, 1942. New to the Maryland Pleistocene. Identified by E. D. Reid.
- \**Roccus saxatilis* (Walbaum). Rockfish, or striped bass (Serranidae). Wailes Bluff: Bed 1, 1940, R. J. Taylor; bed 1, 1940, S. F. Blake (parts of skull, including 2 dentaries, 2 premaxillaries, 1 maxillary, vomer, and various



other cranial bones). New to the Maryland Pleistocene. Identified by E. D. Reid.

\**Micropogon undulatus* (Linné). Croaker, or hardhead (Sciaenidae). Wailes Bluff: Bed 1, 1941 (lower right pharyngeal, a dorsal spine, and some small fragmentary bones). New to the Maryland Pleistocene. Identified by E. D. Reid.

\**Pogonias* cf. *cromis* (Linné). Drum (Sciaenidae). Wailes Bluff: Bed 1, 1935 (imperfect skull); two scales, 1943, the larger 3.5 by 2.8 cm. New to the Maryland Pleistocene. Skull identified by Dr. G. S. Myers, scales by Dr. L. P. Schultz and E. D. Reid.

\**Prionotus* aff. *evolans* (Linné). Sea-robin (Triglidae). Wailes Bluff: Bed 1, two nearly perfect skulls, 1938 and 1940, also fragmentary outer bones of head, 1937. New to the Maryland Pleistocene. Identified by E. D. Reid.

#### MAMMALIA

*Tursiops* sp. Bottle-nose dolphin (Delphinidae). Wailes Bluff: Bed 1, toward the bottom of the bank, 1938, S. F. Blake and F. S. MacNeil (3 ribs and 9 vertebrae; Blake, 1939, p. 99); also a single vertebra on beach at or near the same spot, 1938, Blake. Identified by G. S. Miller and Remington Kellogg. This is apparently the only definite record of a member of this family from the Pleistocene of the Atlantic coast.

On July 5, 1942, in the Basal *Ostrea* bed at Langleys Bluff, I collected a broken anterior rib which resembles fairly closely the corresponding ribs of living finback whales (*Balaenoptera*) but is not sufficient for specific identification (Dr. Remington Kellogg). Oysters of the Basal *Ostrea* bed were in contact with the rib above and 2 pairs of *Mya arenaria* in their natural vertical position directly below it, but the state of fossilization is definitely that of a Miocene, not a Pleistocene bone, and there is every reason to believe that it was redeposited from the underlying Miocene.

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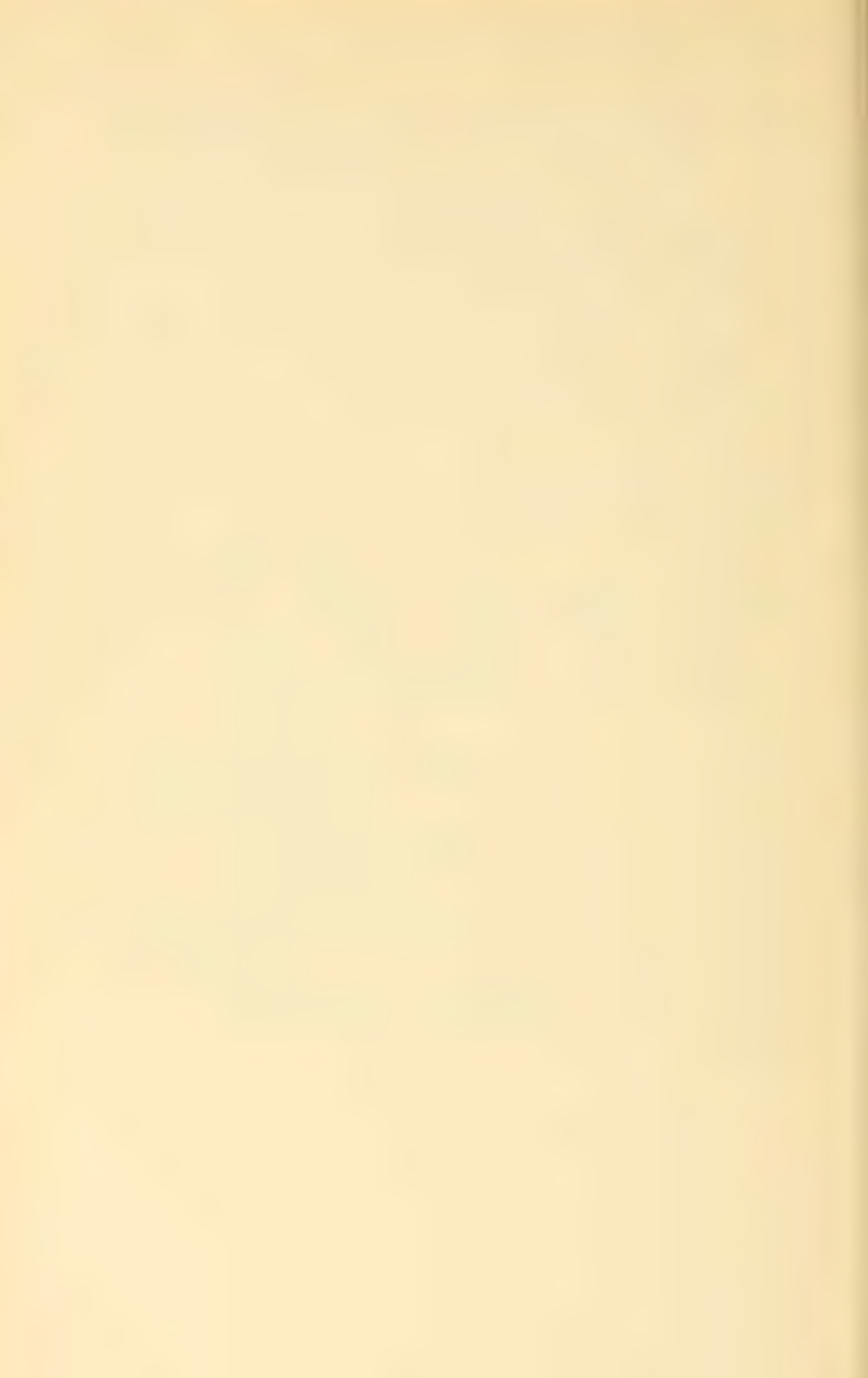
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SMITHSONIAN MISCELLANEOUS COLLECTIONS  
VOLUME 121, NUMBER 13

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**Roebling Fund**

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REGARDING WASHINGTON, D. C.,  
PRECIPITATION AND TEMPERATURE,  
1952 AND 1953

BY

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(PUBLICATION 4130)

CITY OF WASHINGTON  
PUBLISHED BY THE SMITHSONIAN INSTITUTION  
MARCH 3, 1953

The Lord Baltimore Press  
BALTIMORE, MD., U. S. A.



## Roebling Fund

# REGARDING WASHINGTON, D. C., PRECIPITATION AND TEMPERATURE, 1952 AND 1953

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Nine years ago I drew attention to a period of 27.0074 days in the precipitation at Washington, D. C.<sup>1</sup> Since then I have published annually in advance 175 dates throughout each year in which the average daily precipitation was expected to exceed the average daily precipitation on all other days of those years. From statistical studies of Washington precipitation, January 1924 to December 1941, it was believed that the precipitation for the days I, II, III, IV, V, XII, XIII, XV, XVII, XVIII, XXII, XXVI, and XXVII of the 27.0074-day cycles, based on January 1, 1924, as the first I day, would average 142 percent as great as the average precipitation on all other days. For 18 successive years, ending December 1951, the average precipitation on those selected days has been for each year above that for all other days, and the ratio  $\frac{\text{average selected}}{\text{all others}}$  for 18 years was 146 per cent.<sup>2</sup>

In 1952, for the first time in 19 years, that ratio fell below unity, and was, in fact, only 62 percent, as shown in table 1. In only 3 months out of 12 did that ratio exceed unity.

On July 8 and 9 there fell 2.42 inches of rain, on August 31 and September 1, 3.60 inches, and on November 20 and 21, 4.77 inches, all being on days not included among my "preferred" dates. These heavy rainfalls were unusual and contributed largely to the failure of my forecast.

I sought to discover why the nineteenth year differed so widely from the previous 18. Had the cycle utterly failed? Or had there been a displacement of phases, with the cycle still persisting? To fix ideas on this inquiry, I give in figure 1 a replica of curve 1 of figure 1 of my publication of 1944, cited above, and above it the

<sup>1</sup> Smithsonian Misc. Coll., vol. 104, No. 3, 1944.

<sup>2</sup> Smithsonian Misc. Coll., vol. 117, No. 9, 1952.

average precipitation for the days I to XXVII of the 13 complete cycles of 1952, based on day number I, being January 10, 1952, which is the next succeeding day number I after those of 1951.

It will be seen from figure 1 that "preferred" days I, II, XV, XXVII, and XXVIII in the average of the cycles of 1952 are high in precipitation, but the remaining eight "preferred" days of the 27 days of the cycle fall below the average during 1952. But days VIII, XIV, XVI, XIX, XX, XXIV, and XXV, not among the "preferred" days of the cycle, had high precipitation in 1952. Especially the day XX is so extraordinarily high that it would be unlikely to happen for any

TABLE I.—*Statistics of Washington precipitation, 1952*

		Jan.	Feb.	Mar.	Apr.	May	June	
Average	} Pfd. ....	0.198	0.034	0.034	0.333	0.027	0.082	
per day		All other ....	0.101	0.097	0.270	0.139	0.160	0.106
Ratio	Pfd. ....	1.96	0.35	0.13	2.40	1.29	0.77	
	All other .....	...	...	...	...	...	...	
Total ppt.		4.48	1.99	4.60	7.28	5.59	2.87	
Normal ppt.		3.55	3.27	3.75	3.27	3.70	4.13	
Percent normal		126	61	123	223	151	144	
		July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Average	} Pfd. ....	0.076	0.159	0.028	0.013	0.034	0.082	0.109
per day		All other ....	0.161	0.304	0.213	0.031	0.467	0.137
Ratio	Pfd. ....	0.47	0.50	0.13	0.42	0.08	0.60	0.62
	All other .....	...	...	...	...	...	...	...
Total ppt.		3.63	7.25	3.80	0.70	7.08	3.36	52.63
Normal ppt.		4.71	4.01	3.21	2.84	2.37	3.22	42.16
Percent normal		77	181	119	28	299	104	125

cycle day if the cycle is illusory. I infer that the cycle of 27.0074 days still stands, but the phases of it are shifted to 2 days earlier than in former years. Under that interpretation, the precipitation for cycle days I, II, III, X, XI, XIII, XV, XVI, XX, XIV, XV, XVI, XVII, if substituted for the "preferred," would be found to yield the results in table 3 for the year 1952, in which 8 of the 12 months are favorable, and the year's ratio, 1.57, becomes normal.

I do not know what caused this apparent shift of phases. Possibly the haziness of the atmosphere has been altered by the intensive artillery and heavy bombing actions of the Korean war, and by the tests here and in Russia and Britain of atomic bombs. It is altogether uncertain whether this change of phases will persist in 1953. Accordingly I give in table 2 the "preferred" days of the cycles as heretofore, and in addition, designated by italic type, the dates which should be

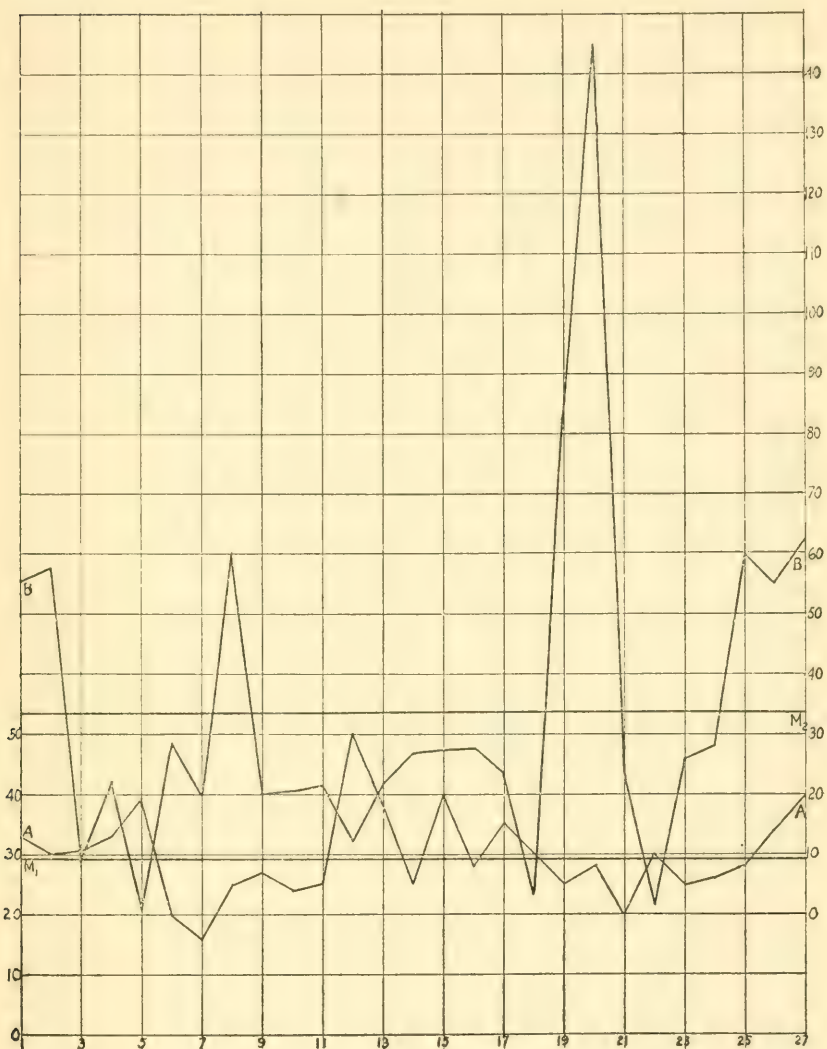


FIG. 1.—Frequency of precipitation on days of 27.0074-day cycle.  
 A, Average, 1924 to 1941. B, Average, 1952.

TABLE 2.—Predicted dates when average daily precipitation at Washington should exceed that on other dates for the year 1953

"Preferred"*							
cycle places	Jan.	Feb.	Mar.	Apr.	May	June	
I.....	22	18	17	13	10	6	
II.....	23	19	18	14	11	7	
III.....	24	20	19	15	12	8	
IV†.....	25	21	20	16	13	9	
V.....	26	22	21	17	14	10	
X.....	4, 31	27	26	22	19	15	
XI.....	5	28, 1	27	23	20	16	
XII.....	6	2	1, 28	24	21	17	
XIII.....	7	3	2, 29	25	22	18	
XV.....	9	5	4, 31	27	24	20	
XVI.....	10	6	5	1, 28	25	21	
XVII.....	11	7	6	2, 29	26	22	
XVIII.....	12	8	7	3, 30	27	23	
XX.....	14	10	9	5	2, 29	25	
XXII.....	16	12	11	7	4, 31	27	
XXIV.....	18	14	13	9	6	2, 29	
XXV.....	19	15	14	10	7	3, 30	
XVI.....	20	16	15	11	8	4	
XVII.....	21	17	16	12	9	5	
"Preferred"*							
cycle places	July	Aug.	Sept.	Oct.	Nov.	Dec.	
I.....	3, 30	26	22	19	15	12	
II.....	4, 31	27	23	20	16	13	
III.....	5	1, 28	24	21	17	14	
IV†.....	6	2, 29	25	22	18	15	
V.....	7	3, 30	26	23	19	16	
X.....	12	8	4	1, 28	24	21	
XI.....	13	9	5	2, 29	25	22	
XII.....	14	10	6	3, 30	26	23	
XIII.....	15	11	7	4, 31	27	24	
XV.....	17	13	9	6	2, 29	26	
XVI.....	18	14	10	7	3, 30	27	
XVII.....	19	15	11	8	4, 31	28, 1	
XVIII.....	20	16	12	9	5	29, 2	
XX.....	22	18	14	11	7	31, 4	
XXII.....	24	20	16	13	9	6	
XXIV.....	26	22	18	15	11	8	
XXV.....	27	23	19	16	12	9	
XVI.....	1, 28	24	20	17	13	10	
XVII.....	2, 29	25	21	18	14	11	

\* Cycle days in italics would become "preferred" if the phase change of 1952 persists.

† Cycle days IV, V, XII, XVII, XVIII, XXII would cease to be "preferred" if said change persists.

substituted for "preferred" dates if the change of phases of 2 days persists in 1953. At the end of the year it will be seen which list is the better.

TABLE 3.—*Revised statistics of Washington precipitation*

Preferred dates 2 days earlier than in table 1

		Jan.	Feb.	Mar.	Apr.	May	June
Average	Pfd. ....	0.124	0.153	0.207	0.386	0.282	0.158
	per day } All other ....	0.159	0.000	0.085	0.079	0.096	0.048
Ratio	Pfd. ....	0.78	00	2.44	4.89	2.94	3.28
	All other ....	...	...	...	...	...	...

		July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Average	Pfd. ....	0.154	0.136	0.237	0.026	0.203	0.026	0.179
	per day } All other ....	0.078	0.326	0.030	0.020	0.274	0.196	0.115
Ratio	Pfd. ....	1.97	0.42	7.90	1.30	0.74	0.13	1.57
	All other ....	...	...	...	...	...	...	...

## TEMPERATURE AT WASHINGTON

Continuing previous reports on a period of 6.6485 days in Washington temperature, table 4 carries on from table 3 of last year's publication (Smithsonian Misc. Coll., vol. 117, No. 9).

In figure 2 are shown the relative frequencies with which the observed dates departed 0, 1, 2, and 3 days from dates predicted for 1952.

Possibly it may be significant, in view of what was shown above regarding precipitation in 1952, that temperature minima came most frequently one day before predicted. This has not occurred in former years.

TABLE 4.—*Dates in 1952 when minima in Washington temperatures were predicted and observed, and dates predicted for 1953*

	January				February					March			
1951 predicted	6	12	19	26	1	8	15	21	28	6	12	19	25
1952 observed	7	11	19	24	Jan. 30	7	15	23	26	7	..	16	26
1953 predicted	7	13	20	27	2	10	16	22		1	8	14	21 27
	April				May					June			
1952 predicted	1	8	14	27 28	4	11	18	24	31	7	13	20	27
1952 observed	1	8	15	24 26	3	13	19	29	30	8	12	21	30
1953 predicted	3	10	16	23 30	6	13	20	26		2	9	15	22 29
	July				August					September			
1952 predicted	3	10	16	23 30	5	12	19	25		1	8	14	21 28
1952 observed	2	10	16	25 ..	8	14	20	23	Aug. 31	7	17	22	27
1953 predicted	5	12	19	25	1	7	14	21 27		3	10	16	23 30
	October				November					December			
1952 predicted	4	11	18	24 31	7	13	20	26		3	10	16	23 30
1952 observed	3	9	17	26 30	7	11	22	29		2	9	15	20 28
1953 predicted	6	13	20	26	2	9	15	22 28		5	12	18	25

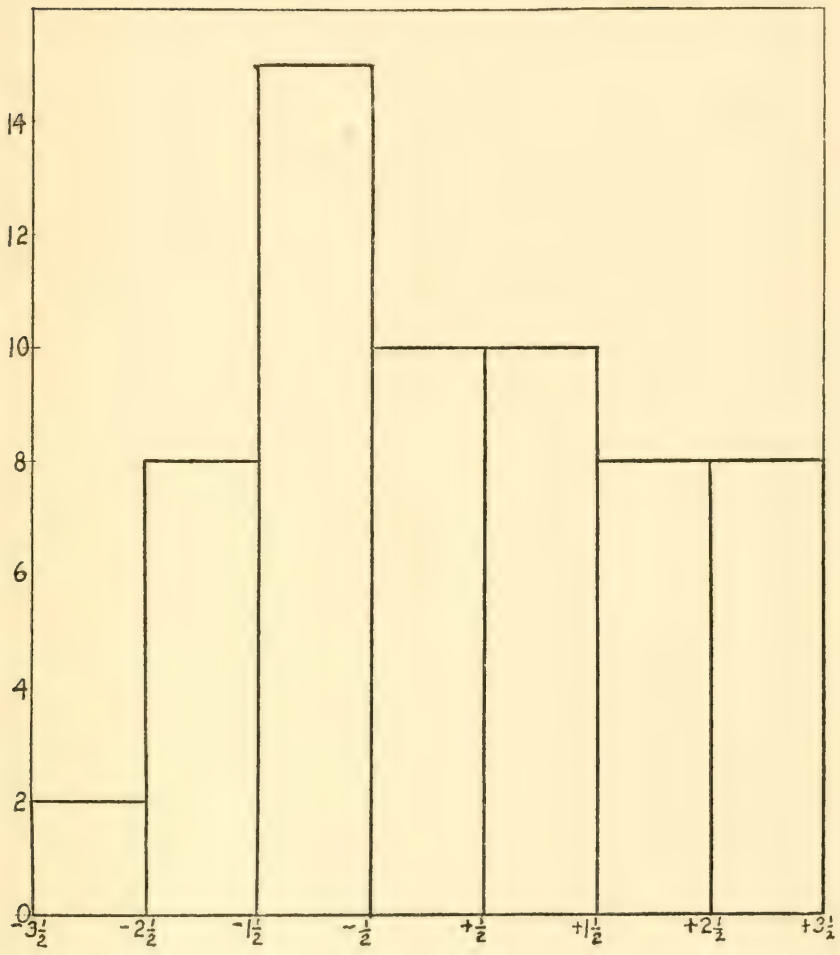


FIG. 2.—Relative frequency of temperature minima before and after predicted, 1952. Abscissae are days.



















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