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A YARMOUTHIAN MOLLUSCAN FAUNA IN THE
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UNITED STATES

By A. BYRON LEONARD



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A YARMOUTHIAN MOLLUSCAN FAUNA IN THE MIDCONTINENT REGION OF THE UNITED STATES

By A. BYRON LEONARD¹

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ABSTRACT

The molluscan fauna associated with the Pearlette volcanic ash, previously shown to be Yarmouthian in age, consists of more than 65 species of gastropods and sphaeriid pelecypods, collected from 20 localities distributed from northwestern Iowa through Nebraska, Kansas, and northwestern Oklahoma to northwestern Texas. Approximately 7 percent of the species range from lower Pliocene to Recent, 17 percent range from Aftonian to Recent, 20 percent are restricted to Yarmouthian deposits, and the remainder range from Yarmouthian to Recent. Eight terrestrial and 6 aquatic species are extinct, 9 terrestrial and 9 aquatic species are extralimital; approximately half the total faunal assemblage is extinct or extralimital in distribution.

From deductions based upon the ecological requirements of extralimital species it is concluded that (1) the midcontinent region was better provided with permanent bodies of water in Yarmouthian time than it is at the present; (2) annual mean temperature was probably not much if any lower than at present, since the ecological requirements of most of the extralimital species would be satisfied by assuming a more equitable climate, lacking extreme fluctuations toward summer highs and the frequently accompanying severe droughts; (3) there is no evidence of widespread forests on the plains portion of the midcontinent region, since true forest genera, such as *Mesodon*, *Anguispira*, *Mesomphix*, *Triodopsis*, and others, are entirely lacking in the assemblage; (4) the molluscan fauna in the midcontinent region has been declining since Yarmouthian time; the Recent fauna of Meade and Clark Counties, Kansas, includes 21 species, whereas the Yarmouthian fauna of the same area totals 45 species, only ten species being common to both faunal assemblages.

INTRODUCTION

Studies of the molluscan faunas of the late Tertiary and Pleistocene epochs have been in progress in Kansas for several years. The summer field season of 1947 brought to an advanced stage the studies of Pleistocene molluscan faunal assemblages associated with deposits containing the Pearlette volcanic ash lentils. At that time the scope of the study was expanded to a regional investigation, which extended from northwestern Iowa and southeastern South Dakota across Nebraska, Kansas, and northwestern Oklahoma to northwestern Texas. The regional investigation was carried on by a team consisting of Dr. JOHN C. FRYE, executive director of the Kansas Geological Survey, Miss ADA SWINEFORD, petrographer, of the Kansas Geological Survey, and myself, temporarily employed by the Kansas Geological Survey. Dr. FRYE concerned himself primarily with stratigraphic relations of the deposits; Miss SWINEFORD studied the petrographic character of the volcanic ash; and I devoted attention to the molluscan faunas which in many places are found associated with deposits containing the Pearlette volcanic ash.

As a result of this cooperative effort, the data compiled from a study of the stratigraphic relations of the deposits containing the Pearlette volcanic ash, distinctive petrographic characters of the ash, and distinctive attributes of the molluscan fauna in deposits containing the Pearlette ash, enabled us to establish the contemporaneity of the beds containing this ash over the area under consideration. Relationships to the glacial tills in Iowa, Nebraska and South Dakota, and to the overlying loesses over a much wider area, serve to establish the Yarmouthian

age of the deposits containing the Pearlette volcanic ash and its associated molluscan fauna (FRYE, SWINEFORD, & LEONARD, 1948). These deposits are given different formational names in the several states involved; in Iowa they are included in the basal part of the Loveland formation; in Nebraska, they are known as the Sappa formation; in Texas, they are assigned to the Tule formation; in Oklahoma, they are part of the Meade formation; and in Kansas, they are included in the Sappa member of the Meade formation (fig. 1).

There seems little doubt that the Pearlette volcanic ash was deposited in its present position by water, although it is obvious from its volcanic origin, that it was airborne to the region in which it is found. The conclusion that the Pearlette ash deposits of the plains country are water-laid is based on the observation that the ash occurs in lentils, is almost universally stratified, and occurs in a succession of stratified deposits which in many places contain aquatic mollusks. Evidently, much of the ash was deposited in already existing ponds or lakes, for underlying beds in some localities contain a rich population of aquatic mollusks, while overlying beds may be nonfossiliferous. Nevertheless, the molluscan faunas associated with beds containing the Pearlette volcanic ash are not restricted to aquatic species. Shells of terrestrial mollusks almost invariably appear in these deposits, also. Presumably, these shells were washed or blown in from nearby slopes or possibly from greater distances, since such shells are very buoyant when air is trapped within them. A few deposits yield only the shells of terrestrial mollusks.

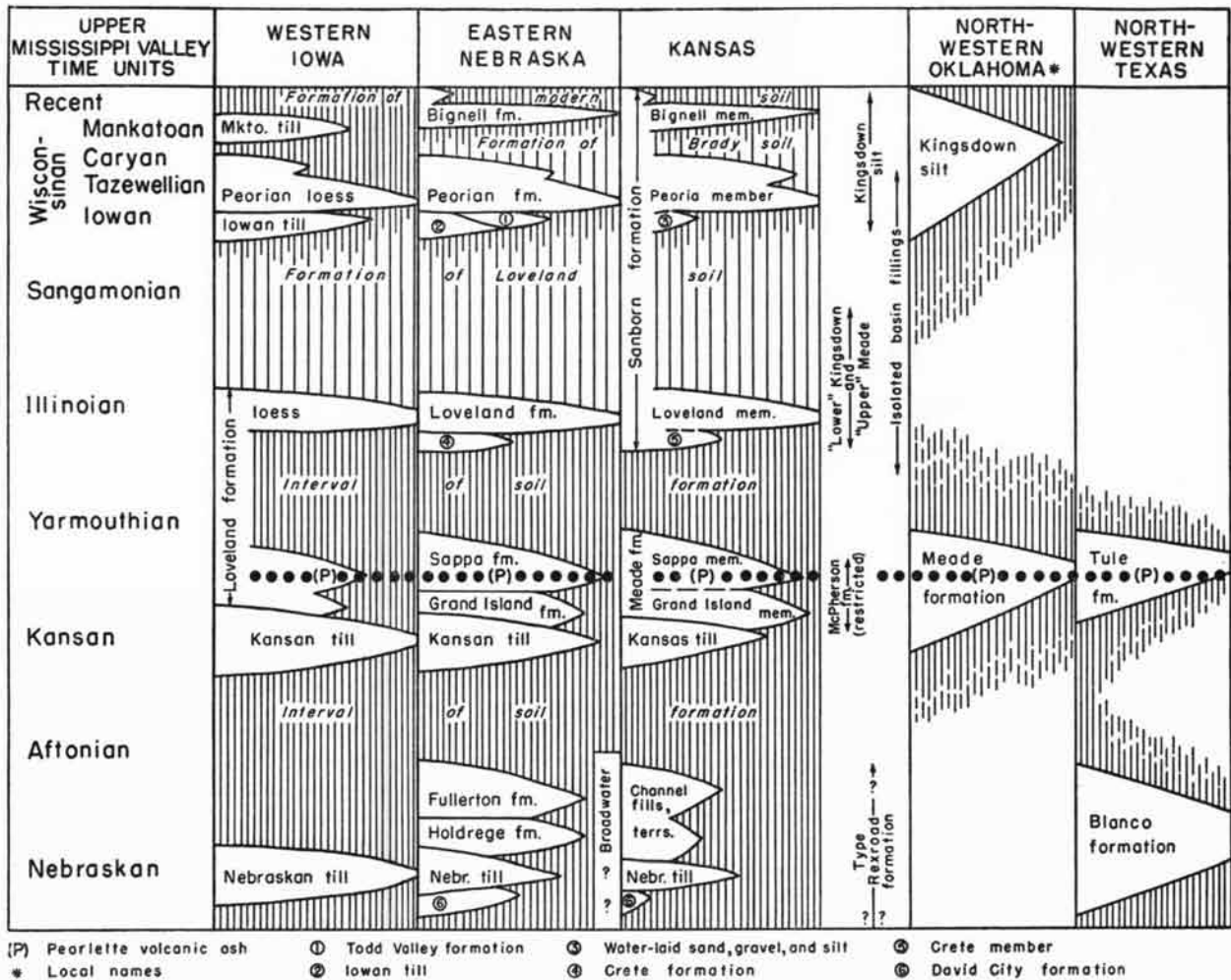


FIGURE 1.—Chart showing classification and correlation of various stratigraphic units in the Missouri Valley region and central and southwestern Great Plains (from FRYE, SWINEFORD & LEONARD, 1948, p. 520). The stratigraphic position of the Pearlette volcanic ash, with which the Pearlette molluscan faunal assemblage is associated, is shown by large dots.

YARMOUTHIAN FAUNAL LOCALITIES

The geographical distribution of the localities considered in this report is shown on Figure 2. At 20 of the 50 localities shown on the map, the deposits bear molluscan fauna and at 18 of the 20 localities, the molluscan fauna is intimately associated with the Pearlette ash. At 2 localities, the ash is not present in the section, but the stratigraphic relations of the fossiliferous deposits and characteristics of the fauna show conclusively that they belong in the basal part of the Loveland formation (Iowa classification, locality No. 2) and Meade formation (Oklahoma classification, locality No. 43). The localities from which molluscan faunas were collected and studied are described in following paragraphs.

Locality No. 2, Iowa.—Deposits exposed in road cut on the north side of U. S. Highway 18, Lyons County, Iowa, 2.5 miles east of Canton, South Dakota. The ash bed is not present in this section, but stratigraphic relations and the characteristics of the molluscan fauna conclusively indicate Yarmouthian age of the fossil-bearing deposit.

Locality No. 3, Iowa.—Silt below Pearlette volcanic ash are exposed in Sec. 6, T. 81 N., R. 44 W., Harrison County, and in Sec. 36, T. 82 N., R. 44 W., Monona County $\frac{1}{2}$ mile east and 5 to 6 miles north of Little Sioux. These two places are grouped together, since the exposure is practically continuous, and since the fauna shows only facies differences.

The southern locality yields a fauna of predominantly aquatic species, whereas the northern faunal assemblage is predominantly terrestrial. At both places the molluscan fauna is found in stratified silts 0 to 5 feet below the Pearlette volcanic ash, which was apparently deposited in a shallow pond, probably a meander scar of the Missouri River or a tributary.

Locality No. 5, Nebraska.—Center N line, NW $\frac{1}{4}$, Sec. 34, T. 33 N., R. 4 W., approximately 6 miles southeast of Santee, Knox County. The fauna is found in gray silts below the Pearlette volcanic ash. I am indebted to Mr. E. C. REED, of the Nebraska State Geological Survey, for samples of ash, and for samples of the fossiliferous silt below the ash.

Locality No. 9, Nebraska.—An abandoned open-pit ash mine, formerly operated by the Cudahy Packing Co., SE $\frac{1}{4}$, Sec. 11, T. 2 N., R. 20 W., approximately 5 miles northwest of Orleans, Harlan County. The mollusks occur here in sands and silts above the ash, and below a section of Loveland and Peoria silt.

Locality No. 13, Kansas.—Road ditch, center N. line, SW $\frac{1}{4}$, Sec. 33, T. 1 S., R. 9 W., 3 miles north and 1.8 miles west of Burr Oak, Jewell County. The fauna is found in 3 feet of coarse to fine sand below 3 feet of ash; the Pleistocene section rests on Niobrara chalk. Some mollusks are scattered through the fine sand; all are terrestrial species washed in from surrounding slopes.

Locality No. 20, Kansas.—Exposure in ravine, NE $\frac{1}{4}$, SW $\frac{1}{4}$, Sec. 21, T. 13 S., R. 26 W., 11 miles south and 1 $\frac{1}{2}$ miles east of Quinter, Gove County. Mollusks occur in 6 feet of silt, sand and pebbles of reworked Niobrara chalk below 13 feet of ash; the Pleistocene section rests on Niobrara chalk. The molluscan fauna is predominantly terrestrial, but there are a few species of aquatic habit. Plant remains, suggesting *Typha*, were found in the ash and in the gray silts immediately below.

Locality No. 22, Kansas.—Road cut exposure, W line, Sec. 36, T. 14 S., R. 11 W., approximately 7 miles southeast of Dorrance, Russell County. The molluscan fauna occurs in stratified silt and fine sand below 0.7 feet of ash; the fauna is composed of aquatic and terrestrial species. The fauna from this locality has been listed as the Tobin faunule (FRYE, LEONARD & HIBBARD, 1943, p. 40-41).

Locality No. 23, Kansas.—Road cut, Sec. 28, T. 13 S., R. 10 W., approximately 9 miles south of Sylvan Grove, Lincoln County. The molluscan fauna was taken from stratified silts and sand below 7 feet of Pearlette volcanic ash. The exposure is situated in the abandoned Wilson Valley; the fauna has been previously reported (FRYE, LEONARD & HIBBARD, 1943, p. 41).

Locality No. 24, Kansas.—Exposure in cut bank of small creek, NE $\frac{1}{4}$, NW $\frac{1}{4}$, Sec. 29, T. 10 S., R. 5 W., 10 miles northwest of Minneapolis, Ottawa

County. The mollusks occur in limonite-infiltrated silts below 5 feet of Pearlette volcanic ash; both aquatic and terrestrial species are found.

Locality No. 25, Kansas.—Road cut exposure, SW $\frac{1}{4}$, Sec. 35, T. 15 S., R. 2 E., 4 miles west of Navarre, Dickinson County. The molluscan fauna occurs in silty clay both above and below 1 foot of Pearlette volcanic ash; both terrestrial and aquatic species are found.

Locality No. 33, Kansas.—Canyon exposure, Sec. 13, T. 30 S., R. 23 W., 13 miles east and $\frac{1}{2}$ mile south of Minneola, Clark County. The molluscan fauna, composed of both aquatic and terrestrial species, occurs in sandy silt below 4 feet of Pearlette volcanic ash.

Locality No. 34, Kansas.—Exposure in abandoned open-pit ash mine, Sec. 2, T. 31 S., R. 28 W., 6 miles north of Meade, Meade County. Mollusks occur in silts below 17 feet of Pearlette volcanic ash; the fauna is varied and the population is a dense one. Fossil vertebrates from these silts have been reported by HIBBARD (1944, p. 719-740).

Locality No. 35, Kansas.—Exposure in abandoned open-pit ash mine, SE $\frac{1}{4}$, SE $\frac{1}{4}$, Sec. 35, T. 31 S., R. 28 W., 1 mile west and $\frac{1}{2}$ mile north of Meade, Meade County. A molluscan fauna occurs in silts below 8 to 10 feet of Pearlette volcanic ash.

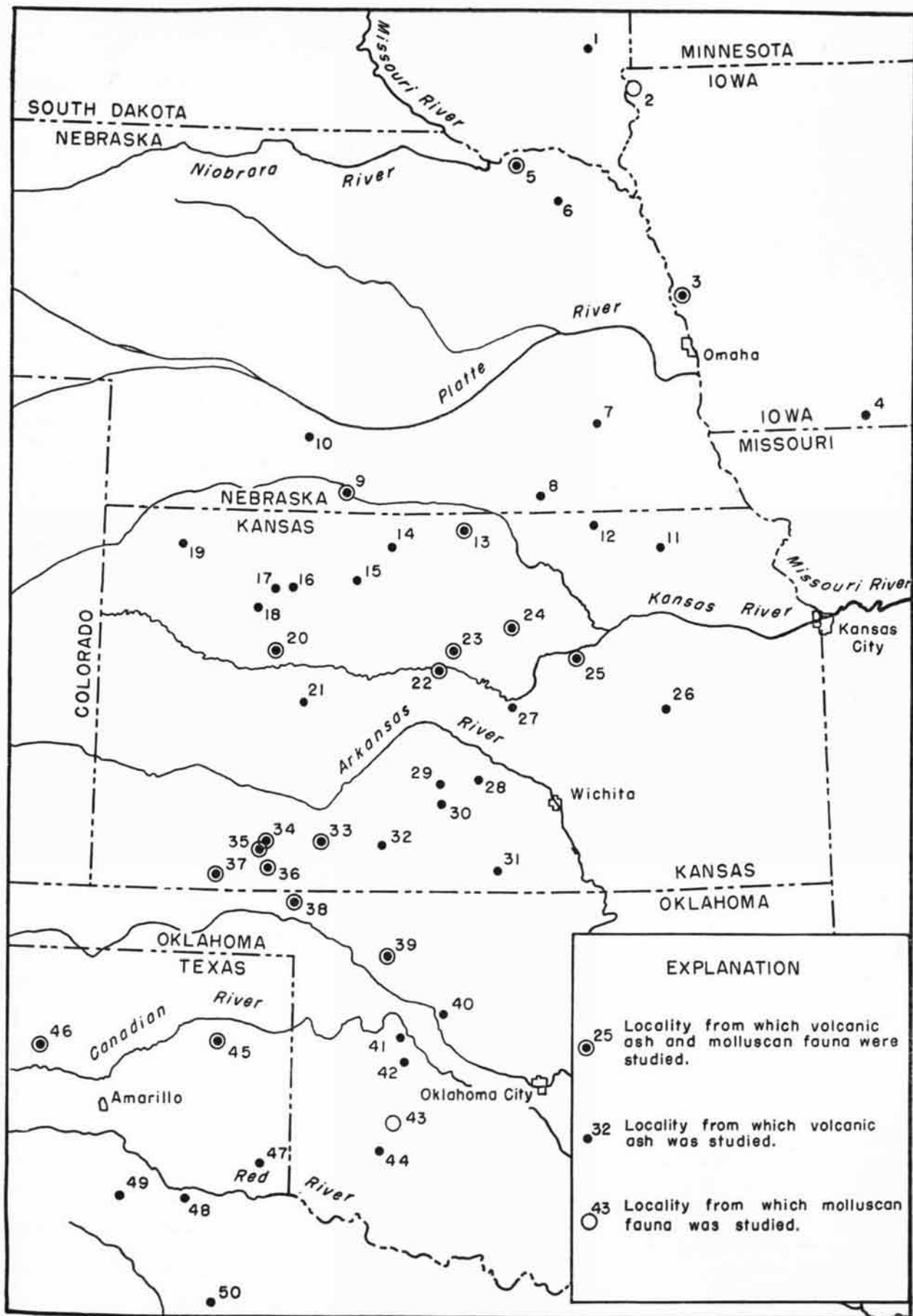
Locality No. 36, Kansas.—Exposure in open-pit ash mine, NE $\frac{1}{4}$, Sec. 26, T. 32 S., R. 28 W., 3 miles south of the east edge of Meade, Meade County. The molluscan fauna occurs in stratified silts below 18 feet of Pearlette volcanic ash; the pit has been worked commercially until recent years.

Locality No. 37, Kansas.—Canyon exposure, NW $\frac{1}{4}$, NW $\frac{1}{4}$, Sec. 35, T. 33 S., R. 32 W., approximately 2 miles east of Arkalon, Seward County. At this place the disposition of the fossil mollusks is unusual, since they occur in the upper few feet of the Pearlette volcanic ash deposit, which is, however, more or less contaminated with silt. The fauna is a mixture of aquatic and terrestrial species.

Locality No. 38, Oklahoma.—Open-pit mine, Sec. 8, T. 5 N., R. 28 E., near the north border of Gate, Beaver County. The molluscan fauna occurs in silts below 30 feet of Pearlette volcanic ash; both terrestrial and aquatic species are found.

Locality No. 39, Oklahoma.—Canyon exposure, NW $\frac{1}{4}$, Sec. 23, T. 23 N., R. 18 W., 2 $\frac{1}{2}$ miles west and $\frac{3}{4}$ miles north of Quinlan, Woodward County. The molluscan fauna is in silts below 8 feet of Pearlette volcanic ash; both terrestrial and aquatic species are found.

Locality No. 43, Oklahoma.—Road cut, center N line Sec. 16, T. 8 N., R. 17 W., 9 $\frac{1}{2}$ miles east and 1 mile north of Rocky, Washita County. A sample of Pearlette volcanic ash was collected at or near this locality by the Oklahoma Geological Survey, but I was unable to find the ash exposure. However, the



exposure indicated is typical of the Grand Island-Sappa succession and the silts and fine sands in the upper part of the section contain a molluscan fauna which is typical of that elsewhere associated with the Pearlette volcanic ash.

Locality No. 45, Texas.—Canyon exposure, NW $\frac{1}{4}$, Sec. 14, Block 1, 5 miles north and 7 miles west of Miami, Roberts County. Mollusks occur below 8 feet of Pearlette volcanic ash; the silts below the ash are not generally fossiliferous; a small but significant molluscan assemblage was obtained from a

small lentil of sandy silt. I am indebted to Judge J. O. MEADE of Roberts County, who assisted me in locating this outcrop, and to Mr. C. E. HILTON, rancher, who gave permission to collect at this locality.

Locality No. 46, Texas.—One-half mile north of road, 6 miles west of Channing, Hartley County. Mollusks occur in gray silt below 12 feet of Pearlette volcanic ash; the fauna contains both terrestrial and aquatic species. This section is discussed briefly by EVANS & MEADE (1945, p. 493).

DESCRIPTION OF MOLLUSCAN GENERA AND SPECIES

STRUCTURAL FEATURES OF GASTROPOD SHELLS

Distinctive features of Yarmouthian molluscan faunas of the midcontinent plains region have been discussed briefly by LEONARD (in FRYE, SWINEFORD and LEONARD, 1948, p. 501-525) and a chart showing the occurrence and distribution of the fauna has been published (*ibid*, fig. 2). It is the purpose of this paper to describe and illustrate the kinds of mollusks comprising the fauna, and to discuss the paleoecological inferences to be drawn from the composition of the fauna.

The named parts of a gastropod shell are shown in Figure 3. The spiral coils which compose the tubular shell are called the *whorls*; the *nuclear whorls*, which are the first formed (generally while the embryonic animal is still within the egg membrane) are found at the *apex*; the *body whorl* is the last to be formed, and terminates at the *aperture*, or the opening through which the body of the animal emerges when the snail is active. The whorls above the body whorl form the *spire*. The cemented seam, commonly indented, between the whorls, is known as the *suture*. The whorls are typically wound around a central *axis* or *columella*; this may be hollow, and when open to the outside, the opening is called the *umbilicus*. If the umbilicus is reduced to a narrow slit, the shell is said to be *rimate*; if the opening is closed, the shell is *imperforate*. The shell forms a *lip* or *peristome* around the aperture; the peristome may be thickened, reflected, or toothed; if not it is said to be *simple*. In some gastropods, the aperture or peristome is provided with excrescences called *denticles*, *teeth*, *lamellae* or *folds*; these structures may be set on a thickened ridge or *callus*. The folds or lamellae, which serve an unknown purpose, are named according to their position (fig. 3). The surface of the shell may be embellished with raised *growth striae*, which in some snails are developed as

riblets or *costae*; these may be approximately transverse to the axis of the whorl, or parallel with it, or both types may be present. A few shells, as *Retinella*, bear indented lines. One genus of the Yarmouthian fauna, *Ferrissia* (Pl. 1, fig. C), possesses a shell which is not obviously spiraled, and another, *Deroceras*, has a degenerate type of shell, developed internally, which has the form of a flat plate (Pl. 5, fig. E), not obviously spiraled but bearing more or less conspicuous concentric growth lines.

In the typical spiral form of gastropod shell, the coils are wound either to the right, in which case the shell is said to be *dextral*, or toward the left, in which case the shell is said to be *sinistral*. In order to determine this characteristic by inspection, the shell is held with the apex uppermost and the aperture directed toward the observer; if the shell is dextral, the aperture, or the greater part of it, lies to the right of the central axis, and *vice versa*.

The shells of pelecypod mollusks (bivalves, mussels, or clams) are composed of two more or less equal halves or *valves*, arranged on either side of the sagittal axis of the animal. The valves are of a living clam provided with an elastic ligament along the hinge line and internally the shell bears toothlike excrescences along the mid-dorsal attachment, which apparently contribute to rigidity of attachment of the two valves. The architecture of the hinge-line is used in classification of these animals.

For present purposes, we may consider two groups of gastropods or snails; branchiate snails, provided with gills for respiration, and pulmonate snails, which have lost the gills, and in which a vascularized portion of the mantle (a membrane which covers the greater part of the body) acts as a lung. Branchiate snails are confined to an aquatic habitat, or to extremely moist situations; pulmonate snails typically inhabit places removed from water, and are said to be *terrestrial* in habit, or they may have sec-

FIGURE 2.—Map showing geographic distribution of the localities from which the fossil molluscan faunas were studied. These are briefly described in the text, pp. 6-9.

ondarily adapted themselves to an aquatic environment. Aquatic pulmonates, while at the surface of the water, enclose a quantity of air in the "pulmonary" chamber, and extract and use the contained oxygen while they are submerged; they are forced to return to the surface when the oxygen is exhausted, although some aquatic pulmonates are able to use their "lungs" for extraction of oxygen directly from the water in which the animals live. Most branchiate snails, and some pulmonates, are provided with an *operculum*, a shieldlike device attached to the

foot of the animal, which closes the aperture of the shell when the animal retires within it; such snails are said to be *operculate*. Pelecypods are universally branchiate animals.

The molluscan fauna described in this paper comprises 65 species of gastropods and pelecypods. In the following discussion of species, no attempt is made to give a complete systematic synonymy of the respective kinds; references are limited to (1) the original description of the species; (2) the first use of the present name combination, if different

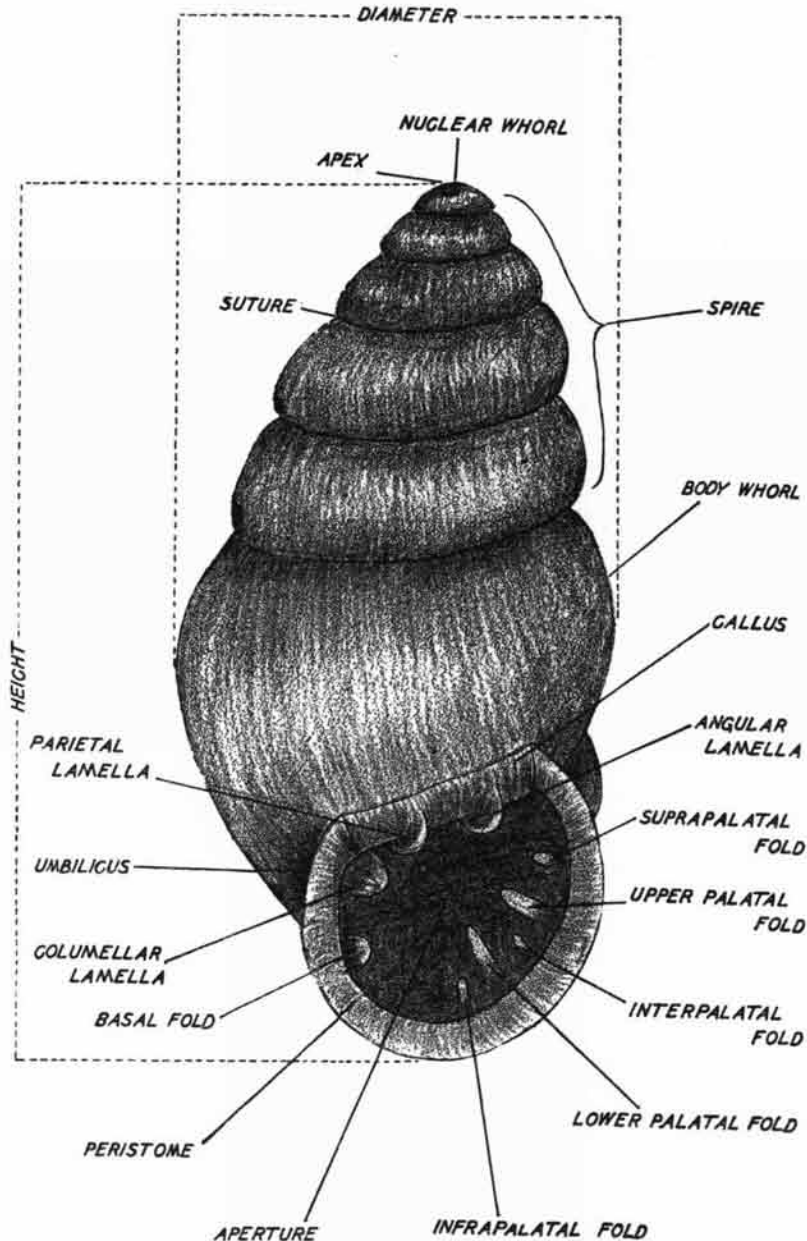


FIGURE 3. Diagram illustrating the use of descriptive terms applied to a gastropod shell.

than that used originally; and (3) previous reports of the several species from Yarmouthian interglacial deposits of the Pleistocene in the region under consideration. The heading "Occurrence" refers only to the localities mentioned in this report.

CLASS GASTROPODA

FAMILY VALVATIDAE GRAY

GENUS VALVATA MÜLLER, 1774

The snails of this genus are aquatic in habit, respiration being carried on by an enlarged, plumose left cervical gill; the right gill is reduced to a naked appendage.

Shells small, spiral, dextral, turbinate to subdiscoidal, whorls rounded or carinate; aperture entire (forming a complete circumference), circular; lip simple, sharp; operculum orbicular and multispiral.

The genus is holarctic in distribution. It occupies a wide variety of habitats, from shallow ponds and streams to the deeper parts of lakes, but flourishes where aquatic plants such as *Ceratophyllum*, *Chara*, and *Potamogeton* are abundant. The animals do not feed directly upon these higher plants, but upon microscopic organisms, such as diatoms, which are found upon the plants.

Species assigned to the genus *Valvata* occur as fossils in the geologic column from Jurassic to Recent.

Valvata tricarinata SAY

Plate 1, figure B

Cyclostoma tricarinata SAY, 1817, Jour. Acad. Sci. Philadelphia, vol. 1, p. 13.

Valvata tricarinata (SAY) DESHAYES & EDWARDS, 1838, in Lamarck's Nat. Hist. Animaux sans Vert., vol. 8, p. 507; —, FRYE, LEONARD & HIBBARD, 1943, Jour. Geol., vol. 51, p. 40, 42; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Lyons County, Iowa (loc. 2); Russell, Lincoln, and Clark Counties, Kansas (locs. 22, 23, 33); Beaver County, Oklahoma (loc. 38).

Type locality.—Not specified, but probably in the eastern United States.

Vertical distribution.—Yarmouth to Recent.

Areal distribution and ecology.—Eastern United States west to Iowa; Great Slave Lake south to the Ohio River and Virginia. The Iowa records are nearest the midcontinent region; I have no records from the region itself. *Valvata tricarinata* lives in rivers, lakes and permanent ponds, particularly where vegetation is abundant. It has been taken in depths up to 10 meters, and shells (not living animals) have been dredged from waters 39 meters in depth.

Description.—Shell turbinate, having 4 rounded whorls, which bear three strong carinae; whorls generally round in cross section, but flattened between

carinae; spire elevated, but depressed at apex; sculpture of coarse growth lines, crossed by spiral lines which are visible only with high magnification; suture distinct, well impressed; body whorl large, with three distinct, sharp carinae, one on periphery, one on the shoulder, and one on the base which encircles umbilicus; aperture circular, modified somewhat by carinae; lip simple, sharp, and continuous across the parietal wall; diameter of shell, 4.5 to 5 mm. The size, shape, and well-developed carinae serve as the principal recognition characters of this species; it is unlike any other species known from Yarmouthian deposits.

Remarks.—Variations among shells belonging to *Valvata tricarinata* particularly include the number and degree of development of the carinae, but these are not susceptible to interpretation as geographic races. All individuals seen in the course of this study are typical of the tricarinate form.

Living specimens of this gastropod have an operculum which closes the aperture when the animal withdraws into the shell. The operculum is chitinous and accordingly is not preserved ordinarily as a fossil. I have never recovered an operculum representing this species from any fossiliferous sediment.

Valvata lewisi CURRIER

Plate 1, figure A

Valvata striata LEWIS, 1860, Proc. Philadelphia Acad., p. 260.

Valvata lewisi CURRIER, 1868, Kent Sci. Inst. Misc. Pub. No. 1, p. 9 (new name for *V. striata*); —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Lincoln County, Kansas (loc. 23).

Type locality.—Little Lake, New York.

Vertical distribution.—Yarmouth to Recent. *Valvata lewisi*, like the more common species, *V. tricarinata*, is rare in Loveland and Peoria silts; it is known from Cretian deposits.

Areal distribution and ecology.—Northern United States, from Atlantic to Pacific Oceans, northward in British America to upper Mackenzie River; its southern distribution is not well known, but it is recorded from La Salle County, northern Illinois. The Lincoln County, Kansas, record is far out of the range of the living species. *Valvata lewisi* inhabits ponds and lakes, especially the latter, living in water little more than 1 meter in depth, crawling about on the mud or on aquatic vegetation.

Description.—Shell turbinate, perforate; whorls $3\frac{1}{2}$ rapidly increasing in size, regularly striate; suture deeply impressed; spire depressed, apex flattened; aperture subcircular; lip simple, thin, appressed to body whorl; umbilicus wide and deep, exhibiting interior whorls; height of shell, 3 to 3.5 mm; diameter, 4.5 to 5 mm.

Remarks.—*Valvata tricarinata* is much more widely distributed in midcontinent Yarmouthian deposits than *V. lewisi*, and it is also more abundant

locally. The latter is easily distinguished from *V. tricarinata*, since it lacks carinae on the whorls.

FAMILY AMNICOLIDAE GILL, 1863

GENUS AMNICOLA GOULD & HALDEMAN, 1841

The animals of this genus are gill-bearing operculates of strictly aquatic habit, living in rather quiet shallow water of ponds and streams. They are distributed throughout the world. Populations subject to wave action along the shores of large lakes generally are dwarfed in comparison to populations of the same species living in streams.

Shell small, ovately conical to elongate, spiral, apex subacute; whorls convex, 4 to 6 in number; aperture ovately rounded; peristome continuous; lip simple, sharp; columella not thickened; perforate, umbilicus narrowly to widely open; operculum thin, corneous, paucispiral, generally striate, spirally and longitudinally.

Identification of species in the genus is based mostly on various characters of the soft anatomy, such as the genital system, jaw, radula, and operculum, none of which is preserved in the fossil state. Characters of the shell are much less reliable for establishing specific relationships, since the structure of the shell is much more susceptible to local environmental conditions than are the soft parts.

Ammicola limosa parva LEA

Plate 1, figure E

Ammicola parva LEA, 1841, Proc. Am. Phil. Soc., vol. 2, p. 34.

Ammicola limosa parva CHADWICK, 1906, Bull. Wisconsin Nat. Hist. Soc., vol. 4, p. 88; —, FRYE, LEONARD & HIBBARD, 1943, Jour. Geol., vol. 51, p. 41; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Lyons County, Iowa (loc. 2); Beaver County, Oklahoma (loc. 38).

Type locality.—Not specified exactly.

Vertical distribution.—Yarmouth to Recent, but recorded from the midcontinent region only from the Yarmouthian interglacial deposits and sparingly from the Recent in this region.

Areal distribution and ecology.—New England and New Jersey westward to Utah, and Manitoba,

and southward to Texas (*Ammicola limosa*); the distribution of *A. limosa parva* is imperfectly known, but there are authentic records of it from Ohio, Indiana, Illinois, Iowa, and Missouri. This snail is an inhabitant of rivers, creeks, quiet ponds, and small lakes; it seems to thrive both in waters which contain growths of aquatic vegetation and those lacking them. SAY (1817), in writing of the type locality of *A. limosa*, states that this species is "extremely numerous on the muddy shores of the rivers Delaware and Schuylkill between high and low water marks."

Description.—Shell conical to depressed conical, rimate, whorls 4 in number, inflated turbinate, regularly increasing in size; body whorl globose; aperture orbicularly ovate, rounded below and but slightly angled above; peristome simple, sharp, a little thickened within; inner lip sharp, joining parietal wall at umbilical region, but free across most of parietal region; height, 3 to 3.5 mm.

Remarks.—The genus *Ammicola* is represented in Aftonian deposits in the midcontinent region, but not by the species *A. limosa*. Ecological conditions in the midcontinent area during Pleistocene time seem never to have been really favorable for *Ammicola*, since populations are sparse, and scattered. There are no authentic records of living *A. limosa parva* in the midcontinent region.

FAMILY POMATIOPSISIDAE STIMPSON, 1865

GENUS POMATIOPSIS TRYON, 1862

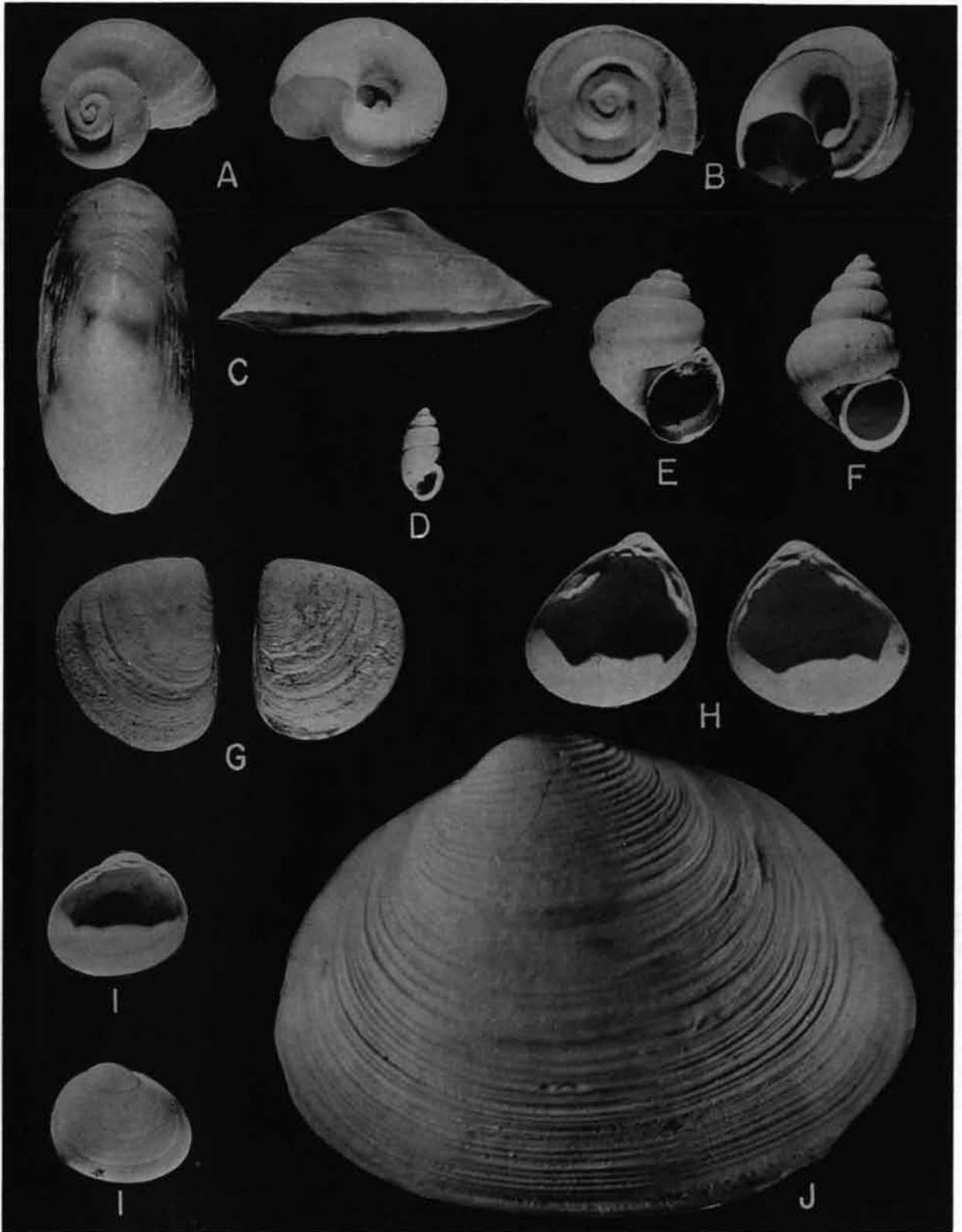
The snails of the genus *Pomatiopsis*, although branchiate, are not strictly aquatic in habit, as are species of *Ammicola*. They are sometimes referred to as "amphibious" snails, since they are often found considerable distances from water (BERRY, 1943, p. 60), but they are capable of surviving long periods of submergence. Typically, they are inhabitants of moist situations near the margins of streams.

Shells somewhat similar to those of some amnicolids, elongate, turreted, thin, rather smooth, umbilicate; aperture expanded, peristome continuous, thin, slightly reflected; operculum corneous, subspiral, with spiral and transverse sculpture.

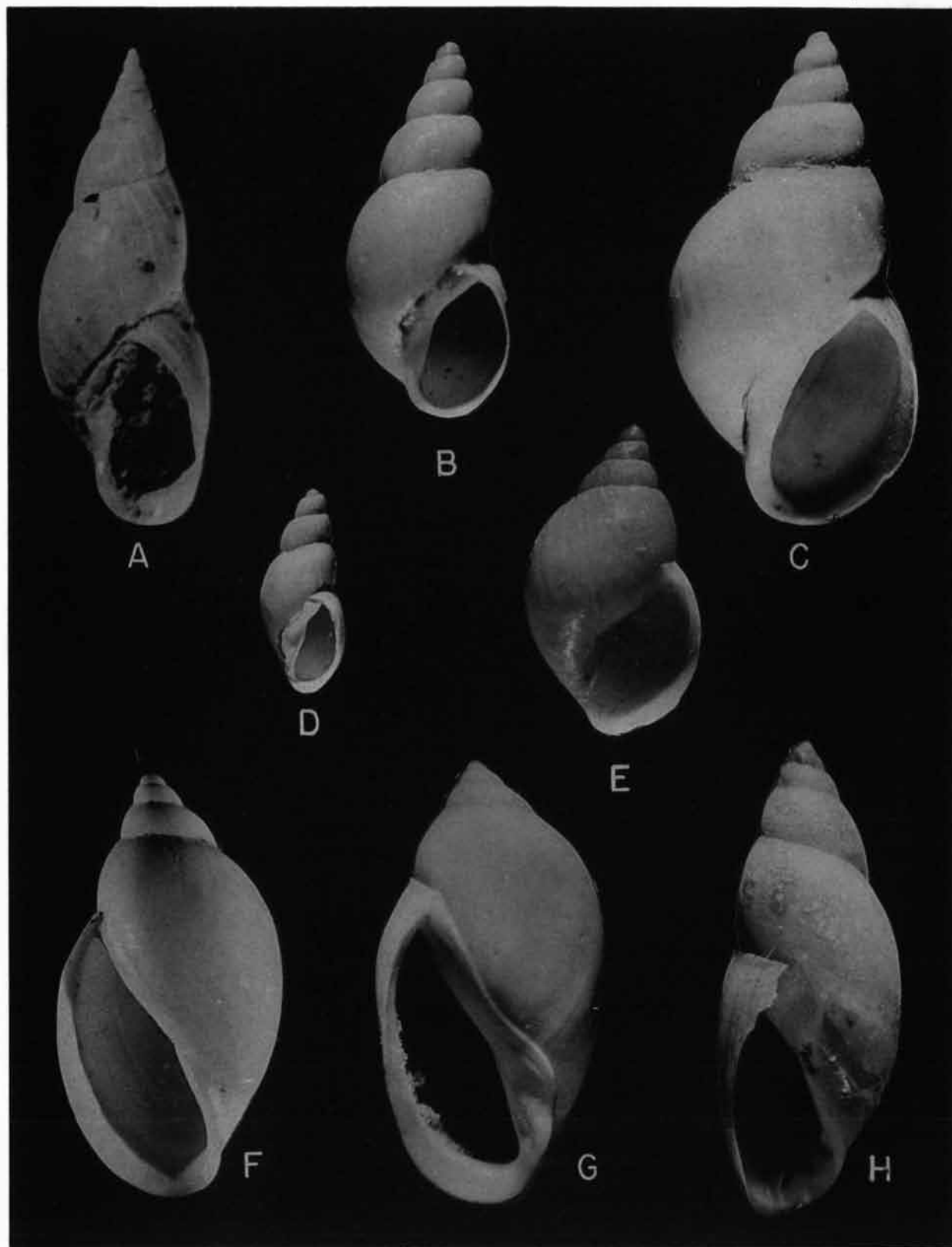
EXPLANATION OF PLATE 1

(All figures 7 times natural size)

FIGURE	PAGE	FIGURE	PAGE
A.— <i>Valvata lewisi</i> CURRIER, spiral and umbilical views (left and right, respectively).....	11	F.— <i>Pomatiopsis cincinnatiensis</i> (LEA).....	13
B.— <i>Valvata tricarinata</i> (SAY) spiral and umbilical views (left and right, respectively).....	11	G.— <i>Pisidium compressum</i> PRIME, left and right valves, external view	40
C.— <i>Ferrissia parallela</i> (HALDEMAN); left, dorsal view; right, profile from left side.....	21	H.— <i>Pisidium compressum</i> PRIME, left and right valves, interior view	40
D.— <i>Carychium pereziquum</i> BAKER.....	22	I.— <i>Pisidium abditum</i> HALDEMAN; upper, interior view of left valve; lower, external view of left valve... ..	40
E.— <i>Ammicola limosa parva</i> LEA.....	12	J.— <i>Sphaerium solidulum</i> PRIME, exterior of left valve..	40



LEONARD—Pleistocene Mollusca



LEONARD—Pleistocene Mollusca

The genus is confined to the Western Hemisphere, but is closely related to the European genus *Pomatiopsis*, as the name *Pomatiopsis* suggests. The earliest record of the genus in the geologic column is from deposits of Oligocene age.

Pomatiopsis cincinnatiensis (LEA)

Plate 1, figure F

Cyclostoma cincinnatiensis LEA, 1840, Proc. Am. Phil. Soc., vol. 1, p. 289.

Pomatiopsis cincinnatiensis WALKER, 1918, Synopsis, p. 148; —, FRYE, LEONARD & HIBBARD, 1943, Jour. Geol., vol. 51, p. 40; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Russell, Dickinson, and Seward Counties, Kansas (locs. 22, 25, 37).

Type locality.—"Vicinity of Cincinnati, Ohio."

Vertical distribution.—Yarmouth to Recent, but unknown in the midcontinent region except from deposits of Yarmouthian age.

Areal distribution and ecology.—Western New York westward to Minnesota and Iowa; Michigan southward to Ohio River. The habitat preferences of *Pomatiopsis cincinnatiensis* are similar to those of the more widespread, branchiate *P. lapidaria*, which is more often found in moist situations near water than in it. *P. cincinnatiensis* is perfectly at home when submerged, hence the term "amphibious" is often applied to it. This snail is able to survive considerable periods of drought by closing the aperture tightly with the operculum.

Description.—Shell conical, elongate, turreted, perforate; whorls 4 to 5 in number; spire conical, but less elongate than in *Pomatiopsis lapidaria*; body whorl large, convex; suture deeply incised; surface sculpture of fine, crowded growth striae; aperture orbicular, peristome continuous, simple, slightly reflected, well rounded below; umbilicus round, rather wide and deep; total height of shell, 4.5 to 5 mm.

Remarks.—*Pomatiopsis cincinnatiensis* is unlike any other species in the Yarmouthian fauna and most closely resembles *Amnicola limosa parva*, from which it may be distinguished readily by its size and shape.

It is worthy of note that the larger branchiate snails, such as *Campeloma*, *Pleurocera*, and *Goniobasis*, are unknown in the region under consideration, either as fossils or living animals.

FAMILY LYMNAEIDAE BRODERIP, 1839

GENUS LYMNAEA LAMARCK, 1799

The animals of this genus are more or less aquatic in habit, but since they lack gills, adaptation to an aquatic life is secondary. There is a wide variation in degree of adaptation to environments; some species are able to live submerged for long periods, using dissolved oxygen in the water, while others scarcely ever enter water but live on the damp mud and debris of shores.

Shells ovately oblong or elongated, spire attenuated, body whorl expanded; peristome thin, more or less flared, invariably simple, not greatly thickened within; aperture ovate to ovately oblong, more or less rounded in some; axis gyrate; no true umbilicus, though commonly a small chink; surface sculpture consisting of fine transverse and spiral lines, the surface of some shells malleated; corneous periostracum present in fresh shells but absent in fossilized shells.

The genus is world-wide in distribution, but is more numerous in north temperate countries. The first known lymnaeids appear in Upper Jurassic strata, but the maximum development occurs in late Tertiary deposits. *Lymnaea lavernensis* is a conspicuous element of the molluscan assemblage in the Laverne formation (lower Pliocene) of northwestern Oklahoma.

Lymnaea reflexa SAY

Plate 2, figure A

Lymnaea reflexa SAY, 1821, Jour. Acad. Nat. Sci. Philadelphia, vol. 2, p. 167; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Ottawa, Clark, and Meade Counties, Kansas (locs. 24, 33, 36).

Type locality.—Lake Superior.

Vertical distribution.—Afton to Recent.

Areal distribution and ecology.—Eastern Quebec to Manitoba; southward to Nebraska and Illinois. BAKER (1911, p. 337) includes southern Kansas in the range of living representatives of this species, but I know of no authentic post-Aftonian record of its occurrence there. Shells of *Lymnaea reflexa* occur in eastern Kansas in the mud of an abandoned meander scar of the Kansas River a few miles northwest of Lawrence, Douglas County, but living examples have not been discovered. *L. reflexa* is an

EXPLANATION OF PLATE 2

(All figures 7 times natural size except figure A, which is 2.5 times natural size)

FIGURE	PAGE	FIGURE	PAGE
A.— <i>Lymnaea reflexa</i> SAY.....	13	E.— <i>Lymnaea bulimoides</i> LEA.....	14
B.— <i>Lymnaea caperata</i> SAY.....	14	F.— <i>Physa anatina</i> LEA.....	21
C.— <i>Lymnaea palustris</i> (MÜLLER).....	15	G.— <i>Physa elliptica</i> LEA.....	21
D.— <i>Lymnaea parva</i> LEA.....	15	H.— <i>Aplexa hypnorum</i> (LINNE).....	22

inhabitant of quiet waters in creeks, rivers, ponds and lakes, where it lives attached to stones, floating debris, and submerged vegetation. It survives periods of drought, and is often found in the water of roadside ditches and other pools which are subject to seasonal drying.

Description.—Shell largest of genus in our fauna; elongate, narrow, rimate to imperforate; whorls 7 in number, flatly rounded, the last being much compressed; spire elongate, narrowly conical, two-thirds height of shell; surface sculpture consisting of fine to coarse transverse growth lines, crossed by fine spiral lines; suture impressed; aperture lunate to elongate-ovate, narrowed above, oblique; peristome thin and sharp at edge, thickened by a varix within; inner lip narrow, reflected over umbilical region, leaving narrow chink, or closing umbilicus entirely; columella oblique across its center, bearing a heavy plait which extends up into whorl; axis twisted; total height, 20 to 35 mm.

Remarks.—This large *Lymnaea* is abundant in in Aftonian deposits in southwestern Kansas; it is less common in Yarmouth sediments but, as noted above, it persists in certain parts of the midcontinent region to Recent times. Presumably, the species returned to this region at intervals whenever conditions were favorable.

Lymnaea bulimoides LEA

Plate 2, figure E

Lymnaea bulimoides LEA, 1841, Proc. Amer. Phil. Soc., vol. 2, p. 33; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Clark County, Kansas (loc. 33); Washita County, Oklahoma (loc. 43).

Type locality.—Oregon.

Vertical distribution.—Yarmouth to Recent. Not abundant at any level of the Pleistocene, and sporadically distributed at present in the midcontinent region.

Areal distribution and ecology.—The shells of species of *Lymnaea* are so variable that records are often unreliable; *L. bulimoides bulimoides* has often been confused with the races *L. bulimoides techella* and *L. bulimoides cockerelli*. The species ranges from the northwestern Pacific Coast region of the United States to Texas, Colorado and eastern Kansas. However, the individuals concerned here resemble the typical *L. bulimoides bulimoides*, rather than either of the two races that might be expected to occur here. For this reason, and because material is not abundant, the fossils are referred to *L. bulimoides bulimoides*, although not without some reservations. *L. bulimoides* and especially *L. bulimoides techella* and *L. bulimoides cockerelli* often live in ephemeral pools and are capable of surviving long periods with little water. PLSBRY (1896, p. 96) reports that in one instance *L. bulimoides cockerelli*

remained alive for 45 days after being packed in dry cotton.

Description.—Shell obtusely conical, whorls 5 to 6 in number, spire relatively short, conical; body whorl large, obtuse; surface sculpture consisting of fine to coarse growth striae; suture well impressed, but not deeply; aperture ovate, approximately half total height of shell; lip simple, scarcely reflected; umbilical chink large, open; total length, 8 to 12 mm.

Remarks.—Both *Lymnaea bulimoides techella* and *L. bulimoides cockerelli* live in Kansas, and there are records of both from Colorado (HENDERSON, 1924, p. 164). *L. bulimoides techella* ranges into eastern Kansas; *L. bulimoides cockerelli* occurs in western counties of the State.

Lymnaea caperata SAY

Plate 2, figure B

Lymnaea caperata SAY, 1829, New Harmony Disseminator of Useful Knowledge, vol. 2, p. 230.

Lymnaea caperata WHEATLEY, 1845, Cat. Shells U. S., Ed. 2, p. 23; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Russell and Meade Counties, Kansas (locs. 22, 36); Roberts and Hartley Counties, Texas (locs. 45, 46).

Type locality.—Indiana.

Vertical distribution.—Yarmouth to Recent. This species is a common component of molluscan faunal assemblages in the loess of Kansas, Iowa and nearby states. It has not been definitely recognized in undoubted Aftonian deposits, but since the species is sometimes confused with others, *Lymnaea caperata* may in truth date from Aftonian times.

Areal distribution and ecology.—*Lymnaea caperata* occurs in a broad belt across North America, from Yukon Territory and James Bay, on the north, to Maryland, Indiana, Colorado, and California, on the south. It occurs in coniferous and deciduous forests, prairies and plains, in Hudsonian, Canadian, Transition and Upper Austral life zones. The species is an inhabitant of small streams, ponds or pools, especially those which are dry through a part of the year; aestivating individuals often can be dug out of the mud of such depressions after the water has disappeared.

Description.—Shell ovately elongate, turreted, perforate, whorls 6 to 6½ in number, convex; suture deeply impressed; spire acutely conical, generally longer than aperture; body whorl large, convex, aperture ovate; peristome thin, simple at edge, but thickened by an internal callus; inner lip reflected over umbilicus but without closure of the opening; sculpture consisting of fine transverse lines crossed by rather heavy spiral lines; total height, 9 to 12 mm.; surface of shell commonly marked by varices resulting from renewed growth after aestivation or hibernation.

Remarks.—While *Lymnaea caperata*, in the main, is a component of molluscan faunas living at higher latitudes than that covered by the midcontinent region, the presence of this snail in a fossil assemblage indicates little concerning the climate since the species is tolerant of a wide range of temperature and other conditions. *L. caperata* is surpassed in this respect only by *L. palustris*, whose tolerance for ecological variations is amazing.

Lymnaea parva LEA

Plate 2, figure D

Lymnaea parva LEA, 1841, Proc. Amer. Phil. Soc., vol. 2, p. 33; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Gove, Russell, Lincoln, Clark, Meade, and Seward Counties, Kansas (locs. 20, 22, 23, 33, 35, 36, 37).

Type locality.—Cincinnati, Ohio.

Vertical distribution.—Afton to Recent. *Lymnaea parva* occurs locally in the later Pleistocene loesses, and is living in locally favorable situations in the midcontinent region.

Areal distribution and ecology.—Connecticut westward to Idaho; James Bay and Montana southward to Maryland, Kentucky, Oklahoma, southern New Mexico and Arizona. *Lymnaea parva* is rarely found in water; it is an inhabitant, rather, of wet, marshy places, where it lives out of the water on sticks, stones, and mud flats, particularly in situations shaded from direct sunlight.

Description.—Shell small for the genus, elongate-conical, turreted; growth striae fine and closely set; whorls 5 to 5½ in number, very convex, regularly increasing in size, the last relatively large; spire elevated, acute; suture deeply impressed; aperture roundly elliptical; outer lip of peristome thin, simple, inner lip thickened and reflected over columella; umbilical chink open; axis straight, not twisted; total height, 5 to 9 mm.

Remarks.—Small examples of *Lymnaea parva* are sometimes confused with *L. dalli*, which it resembles. *L. dalli* does not exceed 4 mm. in height, is more slender, the aperture is longer and narrower, and the umbilical opening is smaller.

Lymnaea palustris (MÜLLER)

Plate 2, figure C

Buccinum palustre MÜLLER, 1774, Verm. Terr., vol. 2, p. 131.
Limnaea palustris (MÜLLER) SOWERBY, 1826, Tankerville Catalogue, p. 42.

Lymnaea palustris (MÜLLER) FRYE, LEONARD and HIBBARD, 1943, Jour. Geol., vol. 51, p. 40, 42; —, FRYE, SWINEFORD and LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Lyons, Harrison, and Monona Counties, Iowa (locs. 2, 3); Knox and Harlan Counties, Nebraska (locs. 5, 9); Russell, Dickinson, and Clark Counties, Kansas (locs. 22, 25, 33); Beaver and Woodward Counties, Oklahoma (locs. 38, 39).

Type locality.—Oregon, for the subspecies *Lymnaea palustris nuttalliana*, which seems nearest the form considered here.

Vertical distribution.—Yarmouth to Recent.

Areal distribution and ecology.—Circumboreal; northern Europe, and Asia, North America from the Atlantic to the Pacific Oceans, Alaska southward to New Mexico. *Lymnaea palustris* is characteristic of the Hudsonian, Canadian and Transition life zones, but colonies live under a wide variety of ecological conditions. In the mountains of California, Utah, and Colorado, the species lives in lakes up to elevations of 10,000 feet. I have no records of it living in the region under consideration, but specimens of this species from Dawes County, western Nebraska, are in the collection of Recent mollusks at the University of Kansas.

Description.—Shell elongate conical, whorls 7 in number; spire acute, body whorl usually obese; suture well-impressed; surface sculpture consisting of fine, closely set transverse lines crossed by elevated spiral lines; surface of body whorl and in some specimens other whorls malleated; aperture varying from roundly to elongate ovate, somewhat expanded, peristome thin, simple; inner lip closely appressed to parietal wall, forming heavy callus; umbilicus usually rimate, sometimes imperforate; height, about 20 mm.

Remarks.—*Lymnaea palustris*, like most species of the genus, is highly variable, and seems susceptible to local changes in ecological conditions. A great many races have been named, not all of them of geographical significance, since they seem to be based on local variations. This state of confusion in the understanding of the races of this species has impelled me to use only the specific name here.

FAMILY PLANORBIDAE H. ADAMS & A. ADAMS, 1855

GENUS HELISOMA SWAINSON, 1840

Gastropods belonging to this genus are inhabitants of stagnant ponds, small lakes, and the quieter waters of streams. They are closely related to the Old World genus *Planorbis*, and in the older literature, the American species are reported under this name. The shells are remarkably similar in the two genera, but the internal anatomy is distinctly different.

The shells are plano-spiral, ultrasinistral, or ultra-dextral, the whorls are few in number, more or less carinate above, and in some species are carinate below; base infundibuliform; aperture expanded and thickened; spire depressed.

Under the name *Planorbis*, shells are recorded in North America from Eocene time, but the first record of true *Helisoma* seems to be that of *H. antrosa* from lower Pliocene deposits of northwestern Okla-

homa. The genus is abundantly represented in later deposits in the midcontinent region, with exception of the middle Pliocene Ogallala formation, from which no adequate molluscan fauna is known.

Helisoma antrosa (CONRAD)¹

Plate 3, figure B

Planorbis bicarinatus SAY, 1817, Nicholson's Encyclopedia, 1st Amer. Ed., article "Conchology," pl. 1, fig. 4 (no pagination).

Planorbis antrosus CONRAD, 1834, Amer. Jour. Sci., vol. 25, p. 343.

Helisoma antrosa (CONRAD) BAKER, 1928, Bull. 70, pt. 1, Wisconsin Geol. Nat. Hist. Surv., p. 317, pl. 19, figs. 8-15; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Gove County, Kansas (loc. 20); Woodward County, Oklahoma (loc. 39).

Type locality.—Randon's Creek, near Claiborne, Alabama.

Vertical distribution.—Lower Pliocene to Recent. *Helisoma antrosa* is an important component of the molluscan assemblage of the Laverne formation in Beaver County, Oklahoma (LEONARD & FRANZEN, 1944, p. 24); the species is known also from Aftonian and Yarmouthian deposits in the midcontinent region.

Areal distribution and ecology.—Maine to Oregon, and from Hudson Bay to Mexico. *Helisoma antrosa* lives in the eastern and northern portions of the midcontinent region in sporadically distributed populations, where it is an inhabitant of streams, ponds, and ephemeral pools.

Description.—Shell ultradextral, discoidal; body whorl angulate above and below; sculpture consisting of strong, transverse varyingly elevated growth lines, with fine spiral lines, the latter obsolete in some shells; umbilicus deep, infundibuliform, ex-

hibiting all the whorls; spire depressed; aperture having a somewhat bell-shaped enlargement; lip thin, simple, acute, commonly thickened within; diameter, 6 to 10 mm.

Helisoma antrosa may be distinguished from *H. trivolvis*, the only other representative of the genus in our fauna, by its smaller size, strongly angulate whorls, deep, funnel-shaped umbilicus, and expansion of the aperture.

Helisoma trivolvis (SAY)

Plate 3, figure A

Planorbis trivolvis SAY, 1819, Nicholson's Encyclopedia, 1st Amer. Ed., art. "conchology," pl. 2, fig. 2 (no pagination).

Helisoma trivolvis (SAY) BAKER, 1928, Bull. 70, pt. 1, Wisconsin Geol. Nat. Hist. Surv., p. 330, pl. 20, figs. 1-13, 22, 33; —, FRYE, LEONARD & HIBBARD, 1943, Jour. Geol., vol. 51, p. 41, 42; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Lincoln, Dickinson, Clark, Meade, and Seward Counties, Kansas (locs. 23, 25, 33, 36, 37); Beaver County, Oklahoma (loc. 38).

Type locality.—"French Creek, near Lake Erie."

Vertical distribution.—Yarmouth to Recent. Common in post-Yarmouthian Pleistocene deposits.

Areal distribution and ecology.—Atlantic coast and Mississippi River drainages, northward to Arctic British America and Alaska, southward to Tennessee, Missouri, and Kansas. The southern and western limits of distribution are not clear due to the uncertain systematic status of the species with respect to its races.

Helisoma trivolvis is an inhabitant of quiet or somewhat stagnant waters. It flourishes in ponds and sloughs, even though they may be choked with vegetation or polluted with decaying organic materials. It is invariably absent from flowing streams, or restricted to quiet coves along the stream course.

Description.—Shell ultrasinistral, plano-spiral; whorls 4 in number; sculpture consisting of coarse, obliquely transverse, raised lines, which may be associated with faint impressed spiral lines on earlier

1. BAKER (1945, p. 128) revived the name *anceps* MENCKE for this species. MENCKE based *anceps* (Synop. Meth. Moll., p. 86, 1830) on a figure by MARTIN LISTER (Conchyliorum et Tabularum Anatomicarum. Tab. 139, fig. 44, 1770). The figure is a crude woodcut of an immature planorbis shell, and quite unrecognizable. The name *anceps* is therefore unacceptable for this species.

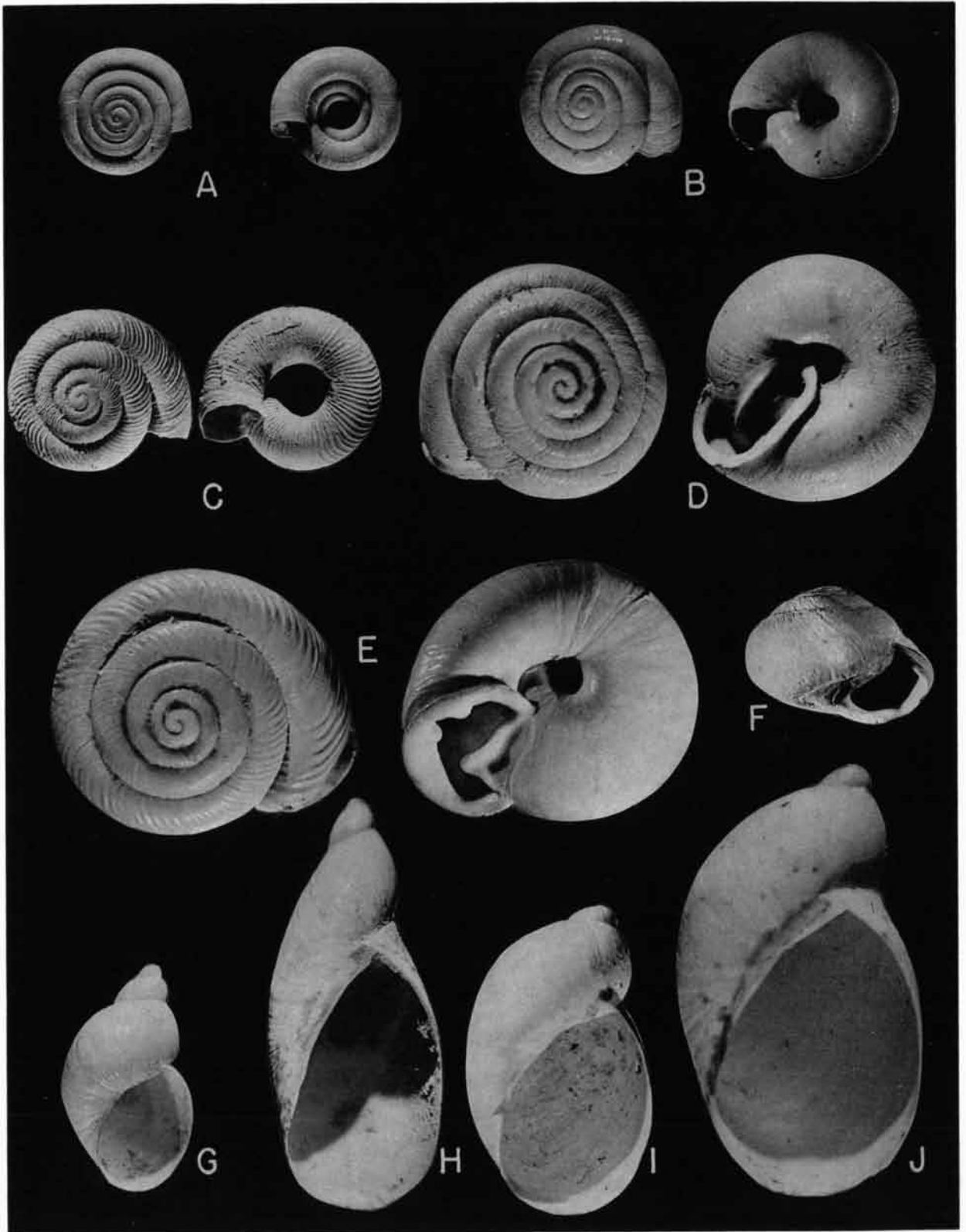
EXPLANATION OF PLATE 3

(All figures 7.4 times natural size, except figure A, which is 3.5 times natural size. In all figures the spiral surface of the shell is illustrated at left, umbilical surface at right)

FIGURE	PAGE	FIGURE	PAGE
A.— <i>Helisoma trivolvis</i> (SAY).....	16	F.— <i>Planorbula nebraskensis</i> LEONARD, holotype, from deposits beneath Pearlette volcanic ash, 6 mi. SE of Santee, Knox County, Nebraska.....	18
B.— <i>Helisoma antrosa</i> (CONRAD).....	16	G.— <i>Menetus pearlettei</i> LEONARD, holotype, from deposits beneath Pearlette volcanic ash, 4 mi. W of Navarre, Dickinson County, Kansas.....	19
C.— <i>Gyraulus labiatus</i> LEONARD, holotype, from beneath Pearlette ash, ¼ mi. NW of Gate, Beaver County, Oklahoma.....	19	H.— <i>Promenetus umbilicatellus</i> (COCKERELL).....	18
D.— <i>Planorbula vulcanata vulcanata</i> LEONARD, holotype from beneath Pearlette volcanic ash, 4 mi. W of Navarre, Dickinson County, Kansas.....	17	I.— <i>Gyraulus pattersoni</i> BAKER.....	20
E.— <i>Planorbula vulcanata occidentalis</i> LEONARD, holotype, from deposits beneath Pearlette volcanic ash, 13 mi. E, ½ mi. S of Minneola, Clark County, Kansas.....	17	J.— <i>Gyraulus similis</i> (BAKER).....	19



LEONARD—Pleistocene Mollusca



LEONARD—Pleistocene Mollusca

whorls; suture deeply impressed; spire generally plane, invariably depressed; base of shell indented, exhibiting 2 to 3 roundly convex whorls with a deep suture between them; aperture broadly lunate, expanded below, with a V-shaped angle above; lip simple, thin, acute, sometimes thickened a little within.

Remarks.—This species is like no other in this fauna, and may be recognized readily by its large size and planospiral structure. Its presence in an assemblage of fossils is a good indication of the presence of ponded waters, since the species is so restricted in its habitat preferences.

At four localities (Nos. 2, 5, 9, 24) fragmentary remains of some large species of *Helisoma* suggest *H. wisconsinensis*. The identity of these shells is quite uncertain, and they are only tentatively compared with this northern species, until more and better preserved material may make positive identification possible.

GENUS *PLANORBULA* HALDEMAN, 1842

The animals of this genus are similar to those of the genus *Gyraulus*, and the habitat requirements are similar. Planorbulids are pulmonates, but rather well adapted to aquatic life in quiet waters. The genus is limited to America and Africa, although rather closely related to the European and Asiatic genus *Segmentina*. American planorbulids are often listed in older studies under the genus *Segmentina*.

Shell discoidal, ultra-dextral, whorls few, increasing in size slowly and regularly, rounded or carinate above and below; aperture generally expanded somewhat, lip more or less thickened within; a set of 6 dentiform lamellae situated a short distance within the aperture.

The denticles are not apparent from casual inspection of the shell, but are easily seen when the shell is placed in a position to allow observation within the aperture.

Planorbula vulcanata vulcanata LEONARD

Plate 3, figure D

Planorbula vulcanata LEONARD, 1948, *Nautilus*, vol. 62, p. 43, pl. 2, figs. C, D; —, FRYE, SWINEFORD & LEONARD, 1948, *Jour. Geol.*, vol. 56, fig. 2.

Occurrence.—Harlan County, Nebraska (loc. 9); Jewell, Ottawa, and Dickinson Counties, Kansas (locs. 13, 24, 25).

Type locality.—4 miles west of Navarre, Dickinson County, Kansas; SE $\frac{1}{4}$, Sec. 35, T. 15 S., R. 2 E.

Vertical distribution.—Known only from deposits of Yarmouthian age.

Areal distribution and ecology.—The known distribution is limited to southern Nebraska, central and east-central Kansas. It may be inferred from the associations of this species and a knowledge of the ecological requirements of living planorbulids, that *Planorbula vulcanata* was an inhabitant of quiet, clear water in small lakes or ponds. There are no living *Planorbula* in the range of *P. vulcanata*.

Description.—Shell small for the genus, whorls 4½ in number, rounded above and peripherally, angulate below, plane on umbilical surface; body whorl expanded near aperture, deflected downward one-half width of preceding whorl; spire depressed toward nucleus; peristome wider than high, semi-lunate, except angulate below; lip flared, thickened, continuous across body whorl, with low crest a short distance behind; lamellae six, disposed as in *Planorbula armigera*, except principal parietal lamella truncate behind; diameter of shell, approximately 6 mm.

Remarks.—*Planorbula vulcanata* forms a conspicuous element of the molluscan assemblage at the type locality where it occurs in large numbers both above and below the Pearlette volcanic ash. The species is less well represented at the other localities.

Planorbula vulcanata occidentalis LEONARD

Plate 3, figure E

Planorbula vulcanata occidentalis LEONARD, 1948, *Nautilus*, vol. 62, p. 44, pl. 2, figs. E, F; —, FRYE, SWINEFORD & LEONARD, 1948, *Jour. Geol.* vol. 56, fig. 2.

Occurrence.—Clark and Meade Counties, Kansas (locs. 33, 34, 36); Beaver County, Oklahoma (loc. 38).

Type locality.—Thirteen miles east and one-half mile south of Minneola, Clark County, Kansas; Sec. 13, T. 30 S., R. 23 W.

EXPLANATION OF PLATE 4

(All figures 5.5 times natural size. Figures A-E, inclusive, illustrate spiral view at left, and umbilical view at right)

FIGURE	PAGE	FIGURE	PAGE
A.— <i>Helicodiscus parallelus</i> (SAY).....	34	G.— <i>Succinea avara</i> SAY.....	23
B.— <i>Zonitoides arboreus</i> (SAY).....	37	H.— <i>Oxyloma navarrei</i> , n. sp., holotype, from deposits beneath Pearlette volcanic ash, 4 mi. W of Navarre, Dickinson County, Kansas.....	23
C.— <i>Discus cronkhitei</i> (NEWCOMB).....	35	I.— <i>Succinea grosvenori</i> LEA.....	24
D.— <i>Stenotrema monodon</i> (RACKETT).....	35	J.— <i>Succinea ovalis</i> SAY.....	24
E.— <i>Polygyra texasiana</i> (MORICAND).....	35		
F.— <i>Hendersonia occulta</i> (SAY).....	38		

Vertical distribution.—Known only from deposits of Yarmouthian age.

Areal distribution and ecology.—*Planorbula vulcanata occidentalis* is a southwestern race of the typical species; it is known only from southwestern Kansas and northwestern Oklahoma.

Description.—Shell of moderate size for the genus, $4\frac{1}{2}$ to 5 whorls, body whorl enlarged and deflected downward near aperture; whorls obtusely angulate above, body whorl angulate below; spire depressed toward nucleus, umbilicus broadly infundibuliform, exhibiting all volutions to nucleus, widening rapidly from penultimate whorl; lip simple, without crest; lamellae disposed as in *Planorbula vulcanata vulcanata*, except principal parietal lamella less abruptly truncate behind; diameter, 6 to 8 mm.

Remarks.—This race may be distinguished from *P. vulcanata vulcanata* by the greater diameter of the shell, less acutely angled whorls, and less abrupt truncation of the principal parietal lamella. About 10 percent of the shells from the reported localities grade toward *P. vulcanata vulcanata*, or cannot be distinguished from the shells of that subspecies.

Planorbula nebraskensis LEONARD

Plate 3, figure F

Planorbula nebraskensis LEONARD, 1948, *Nautilus*, vol. 62, pl. 2, fig. A, B; ———, FRYE, SWINEFORD & LEONARD, 1948, *Jour. Geol.*, vol. 56, fig. 2.

Occurrence.—Lyons County, Iowa (loc. 2); Knox County, Nebraska (loc. 5).

Type locality.—Center N line, NW $\frac{1}{4}$ Sec. 34, T. 33 N., R. 4 W., 6 miles southeast of Santee, Knox County, Nebraska.

Vertical distribution.—Known only from the two localities above, of Yarmouthian age.

Areal distribution and ecology.—The known distribution of *Planorbula nebraskensis* indicates that it is a northern species, but further study of Yarmouthian faunas may extend its range. The close resemblance between *P. nebraskensis* and *P. wheatleyi*, the latter a species of southeastern United States, presents a problem in evolution which is unsolved, and likely to remain so until the Pleistocene history of molluscan faunas is better known. *P. armigera*, which lives within the former range of *P. nebraskensis*, is an inhabitant of small, stagnant bodies of water. Whether or not the latter occupied a similar environmental situation is a matter of conjecture.

Description.—Shell small for the genus, whorls 4 in number, tightly coiled; roundly angulate above, acutely angulate below, plane on umbilical surface; umbilicus narrowly infundibuliform, exhibiting all whorls, but inferior angles revealed only on last two volutions; peristome semilunate, except angulate below; a conspicuous crest a short distance behind peristome; diameter, 5.6 mm.

Remarks.—The silt from which the type of this species was obtained was sent to me by Mr. E. C. REED, Nebraska Geological Survey.

GENUS **PROMENETUS** BAKER, 1935

Promenetus is a genus of small pond snails which live among aquatic vegetation where they feed on diatoms associated with higher plants. The genus has a wide distribution; it has been recorded from Maine westward to Washington and Oregon, and from Hudson Bay and Alaska southward to New Mexico and Alabama. A single species (*P. imus*) has been recorded from the island of Bermuda.

The shells of this genus are ultradextral, depressed planospiral with a small number of whorls which increase rapidly in diameter, carinated or rounded at the periphery; left side with broad spire depression, exhibiting all the whorls, right side flat, showing all the whorls; aperture wider than high, outer lip thin.

Promenetus umbilicatellus (COCKERELL)

Plate 3, figure H

Planorbis umbilicatellus COCKERELL, 1887, *Conch. Exch.*, vol. 2, p. 68.

Promenetus umbilicatellus (COCKERELL) BAKER, 1945, *The Molluscan Family Planorbidae*, Univ. Illinois Press, p. 182; ———, FRYE, SWINEFORD & LEONARD, 1948, *Jour. Geol.*, vol. 56, fig. 2.

Occurrence.—Harrison and Monona Counties, Iowa (loc. 3); Knox County, Nebraska (loc. 5); Dickinson and Meade Counties, Kansas (locs. 25, 36); Washita and Woodward Counties, Oklahoma (locs. 39, 43); Roberts and Hartley Counties, Texas (locs. 45, 46).

Type locality.—Brandon and Birtle, Manitoba, Canada.

Vertical distribution.—Yarmouth to Recent. The genus *Promenetus* is known from Pliocene deposits, so it is not impossible that *P. umbilicatellus* may be discovered in older Pleistocene sediments.

Areal distribution and ecology.—Manitoba, southward to Mesilla, New Mexico; it has been recorded from Illinois, Michigan, Iowa, Minnesota, Colorado, Montana, the Dakotas and Wisconsin. The Iowa records are nearest our area, but there are no records from the limits of distribution considered in this study. *Promenetus umbilicatellus* lives in ponds and swamps, especially where aquatic vegetation is well developed.

Description.—Shell large for the genus, discoidal in shape, with $4\frac{1}{2}$ whorls; sculpture consisting of fine, obliquely transverse growth lines crossed by fine, crowded spiral lines; whorls rounded or but slightly angulate at periphery; spire flat, all volutions in same plane; suture distinctly impressed, but not channeled; base of body whorl roundly flattened, umbilicus large, round, and deep, exhibiting all whorls; aperture trianguloid, lip simple, thin, acute;

parietal wall with thin callus; diameter, 5 to 6 mm.

Remarks.—The wide, round umbilicus, and the fine spiral lines are the principal distinguishing characters of this species. It does not occur in large numbers at any of the localities studied; according to BAKER (1928, p. 384) it does not occur in dense populations in Recent faunas.

GENUS *MENETUS* H. ADAMS & A. ADAMS, 1855

The animals of this genus differ from *Promenetus* in the character of the internal anatomy; the habits of the animals and the structure of the shells are similar—in fact, *Promenetus* was regarded as a subgenus of *Menetus* until BAKER (1935, p. 46-48) raised the former to full generic status.

Menetus pearlettei LEONARD

Plate 3, figure G

Menetus pearlettei LEONARD, 1948, *Nautilus*, vol. 62, pl. 2, fig. I, J; —, FRYE, SWINEFORD & LEONARD, 1948, *Jour. Geol.*, vol. 56, fig. 2.

Occurrence.—Lyons County, Iowa (loc. 2); Knox and Harlan Counties, Nebraska (locs. 5, 9); Ottawa, Dickinson, Meade, and Seward Counties, Kansas (locs. 24, 25, 35, 36, 37); Roberts and Hartley Counties, Texas (locs. 45, 46).

Type locality.—SW $\frac{1}{4}$, sec. 35, T. 15 S., R. 2 W.; 4 miles west of Navarre, Dickinson County, Kansas.

Vertical distribution.—Known only from Yarmouth interglacial deposits.

Areal distribution and ecology.—Known from northwestern Iowa, across Nebraska, Kansas, northwestern Oklahoma and northwestern Texas. Its ecological requirements are unknown; other species of the genus live in ponds, lakes, and other quiet waters. *Menetus coloradensis*, to which *M. pearlettei* seems related, is known only from mountain lakes of Colorado. *Promenetus exacuus*, which is locally distributed in the midcontinent region, occurs in ponds and streams derived from artesian springs in southwestern Kansas; it has been reported from shallow ponds and lakes, and the quieter waters of streams from Alaska to New Mexico.

Description.—Shell, moderate size for the genus, ultradextral, lenticular, whorls 4 in number, increasing regularly in size toward aperture; spire not elevated; umbilicus depressed, exhibiting all volutions, diameter slightly less than half diameter of shell; periphery carinate; whorls slightly convex above, rounded below; sculpture consisting of fine, closely crowded growth striae, in some shells coalesced into coarser ridges; aperture trianguloid, the superior margin produced beyond the inferior margin; diameter of shell, approximately 5.5 mm.

Remarks.—*Menetus pearlettei* is intermediate in evolutionary development between *M. kansasensis* BAKER, abundant in Afton deposits of southwestern Kansas, and *M. coloradensis* BAKER, which is living

in the Front Range of the Rocky Mountains; it differs from both, among other things, in the lack of the "pinched" periphery.

GENUS *GYRAULUS* J. DE CHARPENTIER, 1837

Gyraulus is a genus of small pond snails of practically world-wide distribution. The habits of these planorbids are not unlike those of *Promenetus* and *Menetus*, and the shells are of the same general type. The shells are small, ultradextral, discoidal, having few, rapidly enlarging whorls, fully exposed above and below, and with a nearly median periphery, which may be obtusely angulated or carinated.

Gyraulus similaris (BAKER)

Plate 3, figure J

Planorbis similaris BAKER, 1917, *Bull. Amer. Mus. Nat. Hist.*, vol. 41, p. 529.

Gyraulus similaris BAKER, 1945, *The Molluscan Family Planorbidae*, Univ. Illinois Press, p. 75; —, FRYE, LEONARD & HIBBARD, 1943, *Jour. Geol.*, vol. 51, p. 40, 42; —, FRYE, SWINEFORD & LEONARD, 1948, *Jour. Geol.*, vol. 56, fig. 2.

Occurrence.—Jewell, Ottawa, Meade, and Seward Counties, Kansas (locs. 13, 24, 34, 36, 37); Beaver and Washita Counties, Oklahoma (locs. 38, 43); Roberts County, Texas (loc. 45).

Type locality.—Smartweed lake, near Tolland, Gilpin County, Colorado, at an altitude of 8,850 feet.

Areal distribution and ecology.—As a Recent species, this snail is known from a few localities in Colorado; CHAMBERLAIN & ROSCOE (1948, p. 10) include it in a check list of the Mollusca of Utah, without indicating any specific localities. The ecological requirements are little known save for the fact that it inhabits high mountain lakes; BAKER speaks of it as "abundant" in Smartweed Lake.

Description.—Shell, small for the genus, discoidal, spiral surface slightly concave, umbilical surface concave; whorls 4 in number, regularly increasing in size, rounded above and below; body whorl deflected downward near the rounded aperture; sculpture of fine, transverse growth striae; lip simple, not thickened within; diameter, approximately 6 mm.

Remarks.—This species has been reported by many, including myself, as *Gyraulus parvus*, since there has long been a tendency to group all small gyraulids with rounded periphery under that name. However, *G. similaris* is obviously distinct from *G. parvus*, which occurs neither in the Yarmouthian nor Recent molluscan faunas of the midcontinent region.

Gyraulus labiatus LEONARD

Plate 3, figure C

Gyraulus labiatus LEONARD, 1948, *Nautilus*, vol. 62, pl. 2, fig. G, H; —, FRYE, SWINEFORD & LEONARD, 1948, *Jour. Geol.*, vol. 56, fig. 2.

Occurrence.—Lyons County, Iowa (loc. 2); Knox and Harlan Counties, Nebraska (locs. 5, 9); Gove, Lincoln, Dickinson, Clark, Meade, and Seward Counties, Kansas (locs. 20, 23, 25, 33, 36, 37); Beaver, Woodward, and Washita Counties, Oklahoma (locs. 38, 39, 43); Roberts and Hartley Counties, Texas (locs. 45, 46).

Type locality.—Yarmouth deposits, one-fourth mile northwest of Gate, Beaver County, Oklahoma.

Vertical distribution.—Known only from Yarmouth interglacial deposits.

Areal distribution and ecology.—This species is distributed as a Yarmouthian fossil from northwestern Iowa, across Nebraska, Kansas, and northwestern Oklahoma to northwestern Texas. The ecological requirements of the species are unknown. Generally speaking, species of *Gyraulus* live in quiet waters, especially among plants, such as *Ceratophyllum* and other submerged vegetation.

Description.—Shell large for the genus, whorls 4 in number, not flattened above or below, except terminal half of body whorl above, whorls increasing regularly in size; first 2 whorls depressed below level of later volutions; sculpture consisting of fine to coarse, obliquely transverse growth striae, commonly crowded into irregularly spaced ridges; aperture ovate, not deflected downward, superior margin produced well beyond inferior margin; peristome continuous across parietal wall with no thinning.

The deeply incised suture, roundness and number of the whorls, the absence of downward deflection of the body whorl, and the lip across the parietal wall are the principal diagnostic features of this species.

Remarks.—This snail was widely distributed in Yarmouthian time, and at many of the localities where it occurs, the species forms a prominent element of the molluscan assemblage.

***Gyraulus pattersoni* BAKER**

Plate 3, figure I

Gyraulus pattersoni BAKER, 1938, *Nautilus*, vol. 51, p. 129, April; —, FRYE, SWINEFORD & LEONARD, 1948, *Jour. Geol.*, vol. 51, fig. 2.

Occurrence.—Lyons County, Iowa (loc. 2); Knox and Harlan Counties, Nebraska (locs. 5, 9); Ottawa, Dickinson, Meade, and Seward Counties, Kansas (locs. 24, 25, 36, 37); Beaver County, Oklahoma (loc. 38); Roberts and Hartley Counties, Texas (locs. 45, 46).

Type locality.—Six miles north of Ainsworth, Brown County, Nebraska.

Vertical distribution.—Known only from Yarmouth interglacial beds. BAKER (1938, pp. 129-30) refers to the deposits at the type locality as "most probably the Aftonian interglacial interval." I am informed by Mr. E. C. REED (personal communication) that BAKER accepted the statement of the

probable age of the deposit from others, who had correlated the deposits with Afton beds on little or no direct evidence. I have obtained, through the courtesy of Dr. BRYAN PATTERSON, Chicago Natural History Museum, a quantity of the sediment in which *Gyraulus pattersoni* was originally discovered and I was able to secure a series of topotypical specimens of *G. pattersoni* from this material, in addition to a representative molluscan fauna. The fauna is not comparable to Aftonian molluscan faunas known to me, and since *G. pattersoni* has been discovered in Yarmouthian deposits elsewhere, but not in beds of Aftonian age, I judge the Brown County, Nebraska, beds in question to be Yarmouthian in age.

Areal distribution and ecology.—The species was once widespread in the midcontinent region, and has not been reported elsewhere. Its ecological requirements are unknown. Its occurrence with other planorbid shells gives basis for the inference that its habits probably were similar to those of this group, even though the shell of *Gyraulus pattersoni* indicates a highly specialized animal.

Description.—Shell ultradextral, completely discoidal, plane on both upper and lower surfaces; whorls 6 in number, regularly and slowly increasing in diameter; suture well impressed, but not channeled; sculpture consisting of fine, transverse growth striae crossed by fine spiral lines; aperture not expanded, simple, rarely thickened in adult individuals; whorls almost rectangular in cross section, higher than wide. Diameter, 4 mm.

Remarks.—The extreme degree of depression, the almost perfectly plane surfaces on both sides of the shell, and the rectangular cross section of the whorls, makes this species unlike any other gyraulid known in this country or elsewhere. The present study has greatly enlarged its known range, since BAKER knew it only from the type locality.

FAMILY ANCYLIDAE MENKE, 1928

GENUS **FERRISSIA** WALKER, 1903

This is a genus of New World snails (the family is world-wide in distribution) which has sedentary habits and peculiarly developed shells. The shells are ovate to oblong, patelliform, more or less elevated, apex excentric and more or less posterior. In feeding the animal moves along carrying the shell like shield above it, and never extends itself beyond the limits of the protecting shell. Feeding places preferred by species of *Ferrissia* are smooth, more or less flat surfaces, such as the leaves or stems of plants like *Typha*, or smooth, submerged stones. *Ferrissia* is sometimes referred to as a fresh-water limpet, although the resemblance is purely superficial; the shells are limpet-like, but the animals differ greatly from the marine limpets.

Ferrissia parallela (HALDEMAN)

Plate 1, figure C

Ancylus parallelus HALDEMAN, 1845, Monograph of the Limnaeidae, pt. 2, inside back cover, No. 8, June.

Ferrissia parallela (HALDEMAN) BAKER, 1924, Trans. Wisconsin Acad. Arts, Sci. Letters, vol. 21, p. 126; —, FRYE, LEONARD & HIBBARD, 1943, Jour. Geol., vol. 51, p. 40, 42; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Harrison and Monona Counties, Iowa (loc. 3); Harlan County, Nebraska (loc. 9); Russell and Meade Counties, Kansas (locs. 22, 36); Washita County, Oklahoma (loc. 43); Roberts and Hartley Counties, Texas (locs. 45, 46).

Type locality.—New England.

Vertical distribution.—Yarmouth to Recent.

Areal distribution and ecology.—Nova Scotia and New England westward to Minnesota; Manitoba, Canada, southward to Rhode Island, central New York, northern Ohio and Indiana. It is absent from the midcontinent region.

Ferrissia parallela is an inhabitant of quiet waters where it is found on aquatic plants; it is seldom found in water over 2 meters in depth. It is almost strictly a pond or small lake species, rarely occurring in sluggish streams.

Description.—Shell elongate, narrow, lateral margins nearly straight, a little wider anteriorly, ends rounded; anterior slope convex, posterior slope concave above, convex below; left slope distinctly, but not strongly convex, right slope nearly straight to slightly convex; nucleus distinctly elevated, deflected toward the right, and slightly posterior to the center of the longitudinal axis of the shell; surface of nucleus granulose; remainder of shell embellished with fine, crowded growth striae, in some coalesced into distinct ridges; growth marks on adult shell prominent, characterized by thickening and change in degree of slope of shell; peristome smooth, simple, a little reflected in some shells; length, 5 to 7 mm., diameter, 2.5 to 3 mm., height, 1.5 to 2 mm.

Remarks.—The genus *Ferrissia* is divided into two subgenera on the basis of sculpture of the nucleus. The subgenus *Ferrissia* has radially striate nuclei, whereas the subgenus *Laevapex* has granulose nuclei. Unfortunately, the nuclei are usually deciduous, and scale off, making it impossible to determine the nature of the original sculpture. Consequently I have assumed, with some uncertainty, that these shells are *F. (Ferrissia) parallela*, even though they have no radial striations on the nucleus.

FAMILY **PHYSIDAE** DALL, 1870GENUS **PHYSA** DRAPERNAUD, 1881

Physa is a genus of pond or small-stream snails, usually found in quiet or stagnant water, but some species occur in swift, clear streams. The animal

and the shell are characterized by sinistral torsion, which is unusual among snails in this fauna. The genus is widely distributed in the Americas and northern Eurasia; it dates from the Cretaceous in North America.

The shell is sinistral, elongately spiral, the spire usually acute and typically shorter than the aperture; aperture contracted above, rounded below; outer lip thin, sharp, inner lip appressed to the columellar region, entirely closing the umbilicus, rarely leaving a small chink; sculpture of coarse to subobsolete spiral impressed lines.

Physa anatina LEA

Plate 2, figure F

Physa anatina LEA, 1866, Jour. Acad. Nat. Sci. Philadelphia, vol. 6, p. 171, pl. 24, fig. 94; —, FRYE, LEONARD & HIBBARD, 1943, Jour. Geol., vol. 51, p. 40, 42; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Seward County, Kansas (loc. 37); Washita County, Oklahoma (loc. 43).

Type locality.—“Northern tributary of the Arkansas River, Kansas.”

Vertical distribution.—Lower Pliocene (Laverne formation) to Recent. *Physa anatina*, which is common in the living molluscan fauna of the southwestern part of the midcontinent region, is not as common in Yarmouth deposits as *P. elliptica*; the latter is absent from the Recent molluscan fauna over most of the midcontinent region.

Areal distribution and ecology.—This species ranges from the western Mississippi Valley to Colorado and Wyoming, and southward to Oklahoma. *Physa anatina* is an inhabitant of quiet and stagnant water; it thrives in small ponds, or even in metal stock tanks. It responds readily to local environmental conditions, which have noticeable effects upon the size, shape, and weight of the shell.

Description.—Shell obliquely conical, sinistral, whorls 4 in number, convex, suture deeply impressed; spire conical, short, less than one fourth total height of shell; aperture elongate, more than one half length of shell; outer lip of peristome thin, simple, inner lip thickened, reflected upon body whorl; height of shell, 12 to 15 mm.

Remarks.—*Physa anatina* may be distinguished from *P. elliptica* by its more convex whorls, more deeply impressed suture, relatively longer aperture, thinner peristome, and thinner callus on the parietal wall.

Physa elliptica LEA

Plate 2, figure G

Physa elliptica LEA, 1834, Trans. Amer. Phil. Soc., n. s., vol. 5, p. 115, pl. 19, fig. 83; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Ottawa and Meade Counties, Kansas (locs. 24, 36); Beaver and Woodward Counties, Oklahoma (locs. 38, 39).

Type locality.—Unknown.

Vertical distribution.—Yarmouth to Recent. *Physa elliptica* occurs in large numbers in sink-hole deposits in southwestern Kansas and northwestern Oklahoma. The sediments, while not accurately dated, are obviously younger than Yarmouthian.

Areal distribution and ecology.—*Physa elliptica* is distributed east of the Mississippi River and north of Tennessee, according to CRANDALL (BAKER, 1928, p. 457), but since the species is often confused with *P. gyrina*, the exact limits of its distribution are not known. It is an inhabitant of brooks, living either on mud or stones, and it lives also in stagnant, ephemeral pools. It is said (BAKER, p. 458) to be sporadic in its distribution, but many local populations are large.

Description.—Shell imperforate, sinistral, elliptical; surface sculpture of fine spiral and transverse lines, giving the surface a silky texture (fossil shells commonly carry a high polish); whorls approximately 5 in number, the last cylindrical, large; spire short, obtusely conical, whorls flatly rounded; aperture long, narrow, somewhat over half length of shell; outer lip forming an almost uninterrupted curve from base to spire, thickened on inside by heavy callus; parietal wall provided with thin callus; inner lip tightly appressed to umbilical region; total height of shell, 10 to 13 mm.

Remarks.—*Physa elliptica*, unlike many species of the genus, is rather easily recognized; the regular elliptical shape, the short spire, and shining surface are quite characteristic. It is worthy of note that while the present distribution of the species is confined to a region north and east of the midcontinent region, *P. elliptica* has been found as a fossil only in the southern portion of the midcontinent region.

GENUS *APLEXA* FLEMING, 1820

Aplexa is a genus of pond snails, related to *Physa*, and occupying the same general type of habitat. The shells are sinistral, but they may be distinguished from those of *Physa* by the elongate, narrow spire, and highly polished surface, which usually persists on fossil shells.

The genus is most abundantly represented in Central America; it dates from Cretaceous time in North America.

Aplexa hypnorum (LINNÉ)

Plate 2, figure H

Bulla hypnorum LINNÉ, 1758, Syst. Nat. 10th ed., p. 727.

Aplexa hypnorum (LINNÉ) FLEMING, 1820, in Brewster's Edinburgh Encyclopedia, vol. 14, p. 617; —, FRYE, LEONARD & HIBBARD, 1943, Jour. Geol., vol. 51, p. 40; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Lincoln, Clark, and Meade Counties, Kansas (locs. 22, 33, 34, 35, 36).

Type locality.—Europe.

Vertical distribution.—Yarmouth to Recent; HENDERSON (1935, p. 265) reports a doubtful record, based on a fragment, from "Early Tertiary, Brook River, Arctic Canada."

Areal distribution and ecology.—Northern Europe and Asia, North America east of the Cascade Mountains to the Atlantic Ocean; Alaska and Hudson Bay southward to vicinity of the Ohio River. I have no records of its living in the midcontinent region. *Aplexa hypnorum* is an inhabitant of stagnant ponds and ephemeral pools, often in association with *Physa*, *Helisoma*, and *Sphaerium*.

Description.—Shell sinistral, elongate, thin, imperforate; whorls 6 or more in number, spire long and pointed, body whorl compressed and elongate; suture narrowly but well impressed; aperture length half that of shell, narrowly elongate, outer edge flattened; lip thin, simple, lacking an internal callus, inner lip tightly appressed to umbilical region; surface polished, growth striae scarcely visible even with considerable magnification, spiral lines absent; total height, 10 to 16 mm.

Remarks.—This shell is readily recognized by its elongate shape, sinistral spirals, and polished surface. The illustration (Pl. 2, fig. 4) is that of a shell which was coated with an opaque film, since the surface polish made a satisfactory photograph otherwise impossible.

FAMILY CARYCHIIDAE JEFFREYS, 1829

GENUS *CARYCHIUM* MÜLLER, 1774

Carychium is a genus of minute terrestrial snails, derived from an early branch of primitive auriculid stock, which acquired the small size and terrestrial habits of the Pupillidae. The family is first recognizable in Jurassic faunas, but species became numerous only in early Tertiary time. *Carychium*, one of four genera in the family, is holarctic in distribution, one genus became extinct in Pliocene time, and the remaining two genera are sporadically distributed over the world. *Carychium* is the only remaining genus having a wide distribution.

Carychium perexiguum BAKER

Plate 1, figure D

Carychium perexiguum BAKER, 1938, Nautilus, vol. 51, p. 128; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Knox and Harlan Counties, Nebraska (locs. 5, 9); Jewell, Gove, Russell, Dickinson, and Meade Counties, Kansas (locs. 13, 20, 22, 25, 34); Woodward and Washita Counties, Oklahoma (locs. 39, 43).

Type locality.—Rexroad deposits (Aftonian), SW $\frac{1}{4}$ Sec. 22, T. 33 S., R. 29 W.; 9 miles south and 7 miles west of Meade, Meade County, Kansas.

Vertical distribution.—Afton to Yarmouth.

Areal distribution and ecology.—The known distribution of this extinct species extends from northern Nebraska across Kansas and northwestern Oklahoma to northwestern Texas. The ecological requirements of the species can only be inferred; its nearest relatives live in extremely moist situations, beneath sticks, stones, and various debris at water's edge, where they must actually be submerged. However, they are not found in open water.

Description.—Shell minute, scarcely over 2 mm. in length, elongate-conical, whorls 5 in number, suture deeply impressed; aperture slightly more than one third the length of shell, peristome reflected and heavily thickened, bearing a conspicuous callosity just above the middle of outer lip; a lamella on columella, appearing tubercular from external view, but actually ascending axis as spiral fold.

Remarks.—This tiny snail, which superficially resembles the Pupillidae, is a member of a group which lives largely along ocean shores or in salt marshes. The family Carychiidae is, however, restricted to land and freshwater habitats.

FAMILY SUCCINEIDAE MÖRCH

GENUS OXYLOMA WESTERLUND, 1885

Oxyloma is a genus of stalked-eyed snails, having thin, fragile shells, and more or less amphibious habits, although they are pulmonates. The genus is distributed throughout the northern continents and is known in South Africa. It may be more widespread than is now known. The group is not well known, either in regard to natural relationships of the species or paleontologic record of the genus. The family Succineidae is known from Eocene time in North America.

Oxyloma navarrei, new species

Plate 4, figure H

Occurrence.—Ottawa, Dickinson, and Clark Counties, Kansas (locs. 24, 25, 33).

Holotype.—University of Kansas Museum of Natural History, No. 5128.

Horizon and type locality.—Yarmouth interglacial deposits, SW $\frac{1}{4}$ Sec. 35, T. 15 S., R. 2 E., 4 miles west of Navarre, Dickinson County, Kansas.

Diagnosis.—Shell elongate, narrow, depressed, whorls 3 in number, spire small, acute, body whorl enlarging slowly; surface sculpture consisting of fine growth striae and coarse ridges, the latter evident within the shell; height, 12 to 14 mm.

Description of holotype.—Shell narrow, elongate, dextral, depressed; spire acute, about one ninth total

height of shell; body whorl elongate, slowly enlarging toward aperture; aperture two thirds total length of shell, narrow, elongate, outer lip of peristome effuse above, straight below; peristome arched upward (as seen in profile view); inner lip strongly inflexed, especially near columella; nuclear whorl finely granular, second whorl bearing fine, crowded growth striae, body whorl embellished with fine, crowded growth striae and coarse, irregularly spaced ridges and furrows, the latter plainly visible on interior of shell. Total height of shell, 13.5 mm.; height of spire, 1.4 mm.; height of aperture, 8.5 mm.; greatest width of aperture, 4 mm.; dorsoventral diameter of shell, 4 mm.

Comparisons.—Seemingly, *Oxyloma navarrei* is related to *O. retusa*. It differs from the latter in having a heavier shell, coarser ridges, relatively narrower aperture, and more slender, elongate body whorl.

GENUS SUCCINEA DRAPERNAUD, 1881

Succinea is a genus of pulmonate snails having shells like those of *Oxyloma*, and having similar habits; the animals of the two genera differ in anatomical details. The genus, which is world-wide in distribution, occupies a number of habitat types, but most species live in moist, shaded situations, near water, but not commonly in it. The shells are thin and fragile, generally amber-colored and more or less translucent. The genus is known from Eocene time.

Succinea avara SAY

Plate 4, figure G

Succinea avara SAY, 1824, Appendix, Keating's Narrative, Major Long's Second Expedition, vol. 2, p. 260, pl. 15, fig. 6; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Meade and Seward Counties, Kansas (locs. 34, 37).

Type locality.—Not known; somewhere along the route of Major Long's second expedition to the Northwest Territory.

Vertical distribution.—Yarmouth to Recent. The species is abundantly present in lower zones of the Peoria silt in Kansas, and is living even in the more arid portions of the midcontinent region.

Areal distribution and ecology.—Newfoundland; Ontario northward to James and Hudson Bays, southward to Florida and northern Mexico. It has been reported from every State in the United States, but some West Coast records are doubtful. *Succinea avara* is a snail of wide range in habitat preferences; it lives in low swampy areas, crawling about on mud or living among shore debris. It is found also in upland habitats, living under leaves, fallen logs, or beneath stones, often in association with various Pupillidae. The upland forms are invariably smaller

and less robust than the lowland examples; the upland snails are sometimes called "hunger forms," because their dwarfed size is thought to reflect less favorable conditions for living. The fossils from the Peoria silt are largely of this type.

Description.—Shell slender, length nearly twice the diameter; whorls 3 or a little more in number; surface irregularly wrinkled, having coarse growth lines on the body whorl; suture deeply impressed; aperture ovate, up to two thirds the length of the shell; lip thin, simple; shell thin and fragile; total length, 7 to 11 mm.

Remarks.—The lowland form of the species has been described as a race, *Succinea avara vermeta*; PILSBRY (1948, p. 834) regards the differences between the lowland and upland examples as due to direct influences of environment, and does not recognize the name *vermeta* as having racial significance.

Succinea grosvenori LEA

Plate 4, figure I

Succinea grosvenori LEA, 1864, Proc. Acad. Nat. Sci. Philadelphia, p. 109, April 12; —, FRYE, LEONARD & HIBBARD, 1943, Jour. Geol., vol. 51, p. 41; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Harrison and Monona Counties, Iowa (loc. 3); Knox and Harlan Counties, Nebraska (locs. 5, 9); Jewell, Gove, Russell, Lincoln, Clark, Meade, and Seward Counties, Kansas (locs. 13, 20, 22, 23, 33, 34, 35, 36, 37); Beaver, Woodward, and Washita Counties, Oklahoma (locs. 38, 39, 43); Roberts and Hartley Counties, Texas (locs. 45, 46).

Type locality.—"Santa Rita Valley, Kansas (?), Mr. H. C. GROSVENOR, and Alexandria, Louisiana, J. HALE, M. D." (LEA, 1864, p. 9). There is obviously some confusion about the Kansas locality, as there is no such place in Kansas, as far as I can learn.

Vertical distribution.—Afton to Recent. The species occurs locally in large numbers in certain faunal zones of the Peoria silt; it is living in the Plains region in favorable situations.

Areal distribution and ecology.—Ontario, southward to Louisiana, westward to North Dakota, southwestward to New Mexico. *Succinea grosvenori* is a successful species, tolerant of a wide range of temperature and other factors of environment, but thrives where there is considerable moisture during

some seasons of the year. It is frequently found on mud flats near ponds, but I have seen thousands of them active in semiarid situations at seasons of recurring rains, in localities where the predominant vegetation is sagebrush and yucca. At the approach of dry seasons, these animals burrow a short distance into the earth at the base of shrubs, but they avoid timbered areas. SHIMEK (1935, p. 7-10) has discussed the habitat preferences of the species, showing that it is a basically xerophilous animal.

Description.—Shell asymmetrically conical, whorls 3 to 3½ in number, spiral whorls short, body whorl large, all convex; suture deeply incised; aperture ovoid, peristome thin, simple; surface sculpture consisting of irregularly developed growth striae; total height of shell, 12 to 15 mm.

Remarks.—The Succineidae are a difficult group, but those in this fauna may be distinguished by size and general shape. *Succinea grosvenori* is similar to *S. ovalis* in general form, but is considerably smaller; it differs from *S. avara* in its larger size and much more obese whorls.

Succinea ovalis SAY

Plate 4, figure J

Succinea ovalis SAY, 1817, Jour. Acad. Nat. Sci. Philadelphia, vol. 1, p. 15; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Clark County, Kansas (loc. 33); Beaver County, Oklahoma (loc. 38).

Type locality.—Philadelphia, Montgomery County, Pennsylvania.

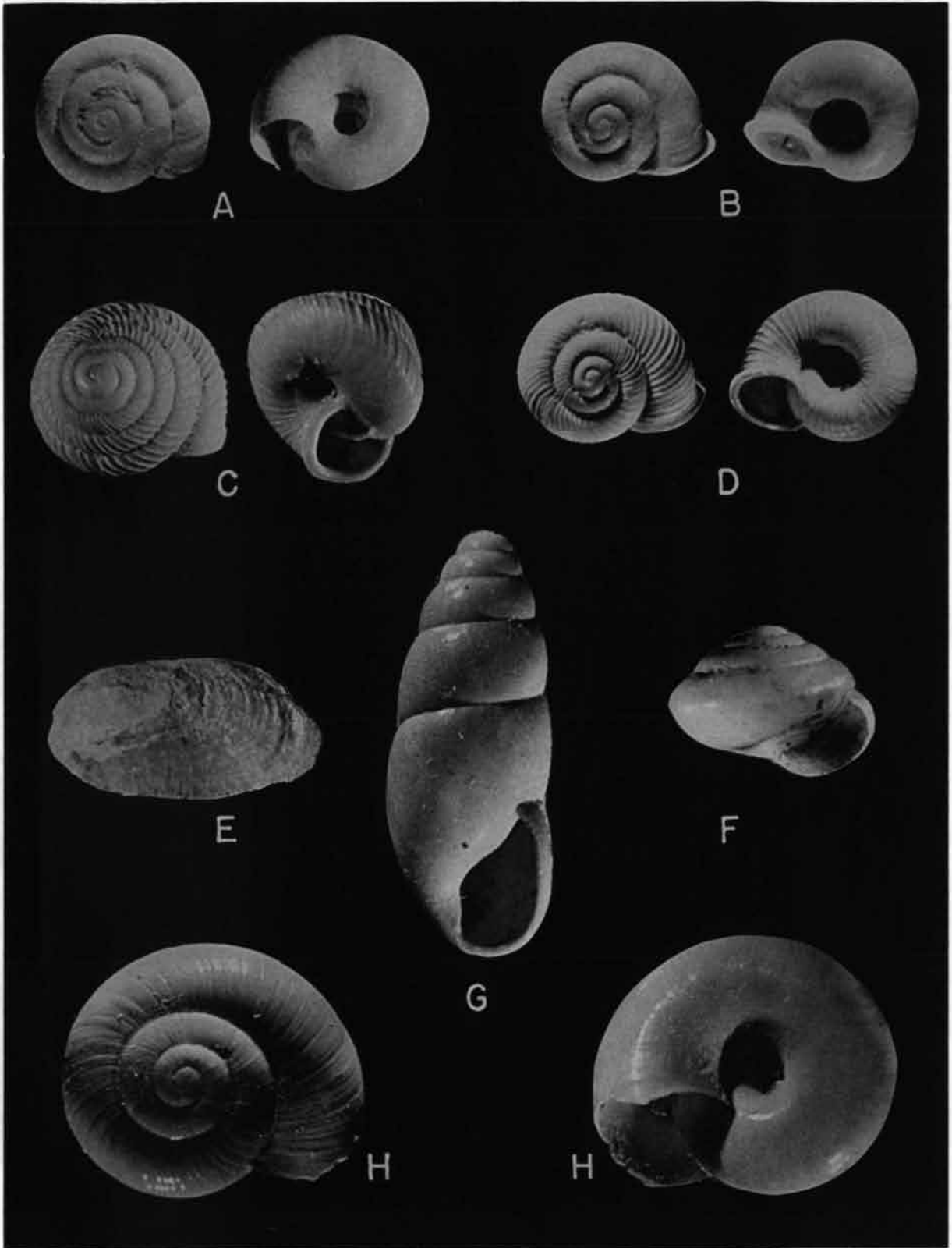
Vertical distribution.—Yarmouth to Recent. *Succinea ovalis* is a much less common fossil in the mid-continent region than is *S. grosvenori*, although it is locally abundant in the Peoria and Bignell silts in the eastern portion of the region.

Areal distribution and ecology.—Newfoundland to North Dakota, Nebraska, and northeastern Kansas, southeastward to Alabama. *Succinea ovalis* is an inhabitant of moist situations near ponds, swamps, and streams, often among trees or shrubs. It is abundant along the flood plain of the Missouri River in western Iowa, eastern Nebraska, and northeastern Kansas, where it lives among grasses and hedges on mud flats, but often ascends the wooded bluffs where moisture is abundant. Its preference for moist en-

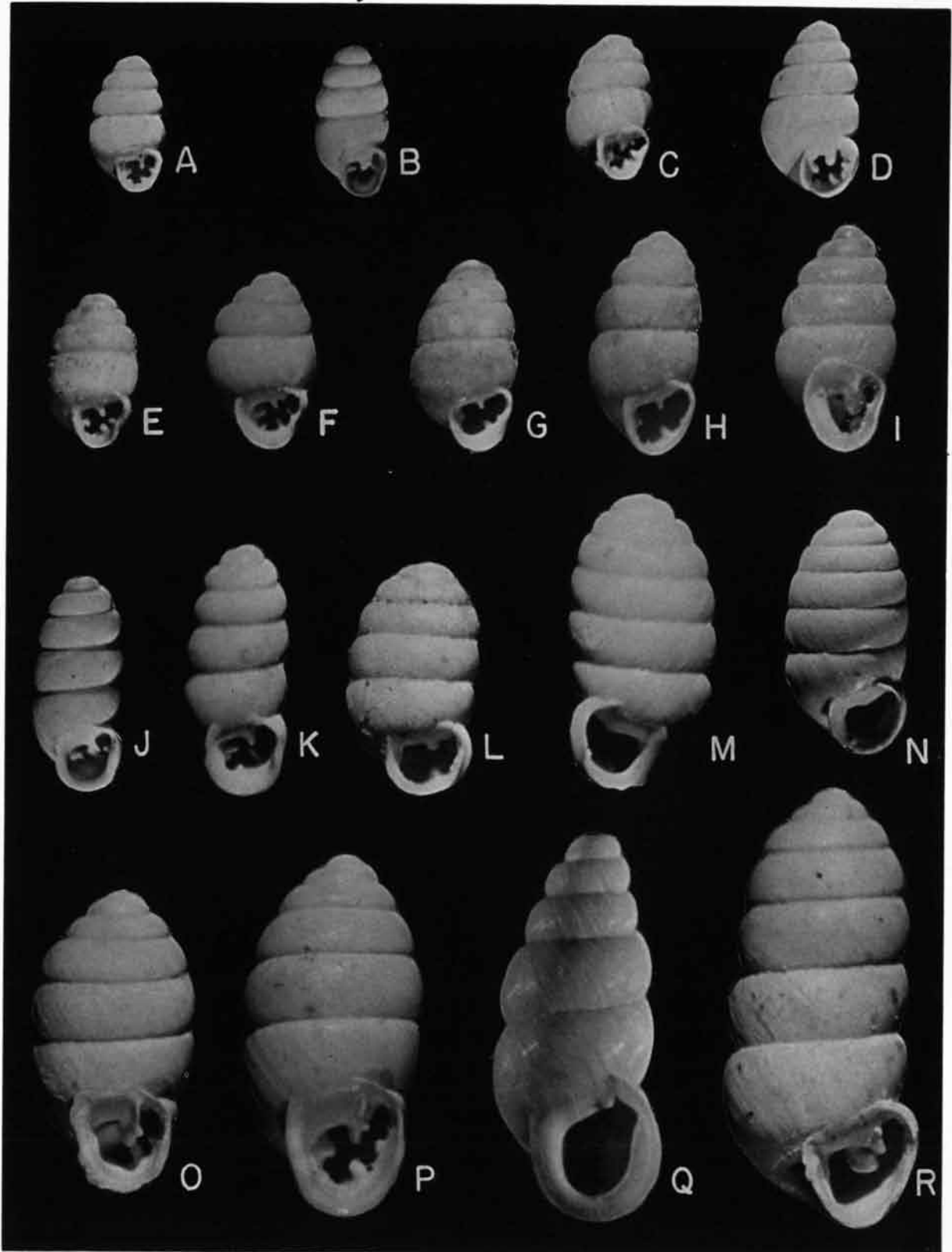
EXPLANATION OF PLATE 5

(All figures 11 times natural size. Figures A-D, inclusive, and H, illustrate spiral view at left, and umbilical view at right)

FIGURE	PAGE	FIGURE	PAGE
A.— <i>Hawaia miniscula</i> (BINNEY).....	36	E.— <i>Deroceras aenigma</i> , n. sp., holotype, from Rexroad Ranch deposits, Aftonian; 9 mi. S, 7 mi. W of Meade, Meade County, Kansas.....	38
B.— <i>Vallonia pulchella</i> (MÜLLER).....	33	F.— <i>Euconulus fulvus</i> (MÜLLER).....	37
C.— <i>Strobilops sparsicosta</i> BAKER.....	34	G.— <i>Cionella lubrica</i> (MÜLLER).....	25
D.— <i>Vallonia gracilicosta</i> REINHARDT.....	33	H.— <i>Retinella electrina</i> (GOULD).....	36



LEONARD—Pleistocene Mollusca



LEONARD—Pleistocene Mollusca

vironments is so characteristic that its distribution on a wooded slope may be suddenly truncated above a horizon where contact springs emerge. The Beaver County, Oklahoma, record is the most westerly locality of occurrence yet reported.

Description.—Shell oval, inflated; whorls 3 to 3½ in number; spire small, body whorl large, inflated, convex throughout; aperture ovate, about three fourths the length of shell; sculpture of fine growth striae; total length, 14 to 16 mm.

Remarks.—BAKER (1927, p. 117) has described a Pleistocene race of this species, *Succinea ovalis pleistocenica*, said to differ from the typical form in its rounder aperture, proportionately longer spire, and slightly smaller size. In Doniphan County, Kansas, where this snail occurs in the Peoria and Bignell silts, and where it may be found living nearby on the Missouri River flood plain, I can find no significant differences between the living and fossil shells.

FAMILY CIONELLIDAE KOBOLT, 1880

GENUS CIONELLA JEFFREYS, 1829

Cionella is a holarctic genus. It contains one holarctic species and a few others of east Asiatic distribution. In Europe, several fossil species are known, the oldest dating from Eocene time. The shells are simply formed and most bear a characteristic high gloss. The animals live in woodlands, associated with such genera as *Triodopsis*, *Mesodon*, *Anguispira*, and others whose habitat preferences are similar.

Cionella lubrica (MÜLLER)

Plate 5, figure G

Helix lubricus MÜLLER, 1774, Vermium Terrestrium et Fluvium, vol. 2, p. 104.

Cionella lubrica (MÜLLER) PILSBRY, 1948, Land Mollusca North America, vol. 2, pt. 2, p. 1047, fig. 560 a.b.; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Cochlicopa lubrica (MÜLLER) FRYE, LEONARD & HIBBARD, 1943, Jour. Geol. vol. 51, p. 41.

Occurrence.—Harrison and Monona Counties, Iowa (loc. 3); Gove, Russell, Clark, and Meade Counties, Kansas (locs. 20, 22, 33, 34, 35).

Type locality.—Denmark.

Vertical distribution.—Yarmouth to Recent. It is not a common species in Pleistocene faunas in the midcontinent region, but it does occur locally in the Peoria silt.

Areal distribution and ecology.—Point Barrow, Alaska, and Queen Charlotte Islands to Labrador and Newfoundland, southward to Washington, D. C., Missouri and Kansas; in all western and mountain states except California; to the Mexican border in Arizona; in the Sierra Madre of western Chihuahua. *Cionella lubrica* lives among damp leaves or in decaying wood in densely shaded situations. It is found in eastern Kansas, eastern Nebraska, and Iowa, but is absent from the Plains Border and Plains Provinces.

Description.—Shell elongate spiral; spire tapering gradually to an obtuse apex; whorls 5½ to 6 in number, moderately convex, suture sharply but not deeply incised; surface polished; aperture subvertical, ovate, simple; outer lip thickened, arcuate, inner lip straight; length of shell, 5.5 to 6.5 mm.

Cionella lubrica is readily recognized by its size, shape, and polished surface; no other snail in this region is similar to it.

Remarks.—At one time it was suggested that *Cionella lubrica* was an early importation, perhaps by the Norse explorers; its wide distribution and occurrence in deposits of Yarmouthian age invalidate this idea. American shells are indistinguishable from European ones. *C. lubrica* is said to occur locally in dense populations, but this does not seem to be true of Yarmouthian populations.

FAMILY PUPILLIDAE TURTON, 1831

GENUS VERTIGO MÜLLER, 1774

Vertigo is a genus of minute terrestrial snails, widely distributed in the holarctic realm, from near sea level to an altitude of 10,000 feet. At least 80

EXPLANATION OF PLATE 6

(All figures 14 times natural size)

FIGURE	PAGE	FIGURE	PAGE
A.— <i>Gastrocopta holzingeri</i> STERKI.....	31	J.— <i>Gastrocopta procera</i> (GOULD).....	32
B.— <i>Gastrocopta falcis</i> LEONARD.....	31	K.— <i>Gastrocopta cristata</i> (PILSBRY & VANATTA).....	32
C.— <i>Vertigo milium</i> (GOULD).....	26	L.— <i>Pupilla blandi</i> MORSE.....	28
D.— <i>Gastrocopta tappaniana</i> (C. B. ADAMS).....	31	M.— <i>Pupilla muscorum sinistra</i> FRANZEN.....	28
E.— <i>Vertigo gouldi</i> (BINNEY).....	27	N.— <i>Pupilla muscorum</i> (LINNE).....	28
F.— <i>Vertigo ovata</i> SAY.....	26	O.— <i>Gastrocopta proarmifera</i> LEONARD.....	30
G.— <i>Vertigo tridentata</i> WOLF.....	26	P.— <i>Gastrocopta armifera</i> (SAY).....	29
H.— <i>Vertigo modesta</i> (SAY).....	27	Q.— <i>Pupoides albilabris</i> (C. B. ADAMS).....	29
I.— <i>Gastrocopta contracta</i> (SAY).....	30	R.— <i>Gastrocopta tridentata</i> (LEONARD).....	30

living species are recognized, as well as a number of extinct species, the oldest in North America dating from Eocene time. The shell commonly is characterized by a biarcuate indentation of the outer lip of the peristome, and in all species the aperture bears a number of denticles. The animals are generally found on and under dead wood and fallen leaves in humid situations, but some species live among grasses in marshes or pond borders. In mountainous states they are found in aspen groves, but this is to be expected, since snails generally avoid coniferous forests.

Vertigo milium (GOULD)

Plate 6, figure C

Pupa milium GOULD, 1840, Boston Jour. Nat. Hist., vol. 3, p. 402.

Vertigo milium (GOULD) BINNEY, 1878, *Terrestrial Mollusca*, vol. 5, p. 215, pl. 71, fig. 1 (in vol. 3); —, FRYE, LEONARD & HIBBARD, 1943, Jour. Geol., vol. 51, p. 41; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Harrison and Monona Counties, Iowa (loc. 3); Harlan County, Nebraska (loc. 9); Gove, Lincoln, Dickinson, and Meade Counties, Kansas (locs. 20, 23, 25, 36); Woodward and Washita Counties, Oklahoma (locs. 39, 43).

Type locality.—Oak Island, Chelsea, near Boston, Massachusetts.

Vertical distribution.—Afton to Recent; it is a common fossil in the Peoria silt.

Areal distribution and ecology.—Ontario; Maine to Florida, westward to South Dakota and Kansas, southwestward to Arizona and Mexico. *Vertigo milium* is an inhabitant of humid situations, such as those afforded by marshes, and wooded slopes near streams. It is absent from regions characterized by low humidity or by high extremes of summer temperature, which means that it does not occur in the Plains Border and High Plains Provinces.

Description.—Shell small, always less than 2 mm. in height, ovate to ovoid-cylindrical, rimate; whorls $4\frac{1}{2}$ to 5 in number, convex but not inflated, finely striate, gradually and regularly increasing in size; body whorl large, more than half height of shell, contracted at base and expanded toward aperture; aperture ovate, oblique, strongly biarcuate, expanded; peristome slightly everted, lip thin and sharp, terminations approaching; denticles 6 in number; an elongate, lamelliform parietal, a smaller, more deeply immersed angular lamella; an elongate upper palatal fold; a more deeply immersed, elongate lower palatal, curved strongly toward the columella; a low, somewhat elongated basalar, and a short, crescentic columellar lamella.

Vertigo milium is the smallest member of the genus in this fauna.

Remarks.—*Vertigo milium*, unlike *V. ovata*, which has similar ecological requirements, does not occur

in the Great Plains Province, even under locally favorable conditions, such as that provided by marshes near artesian springs.

Vertigo ovata SAY

Plate 6, figure F

Vertigo ovata SAY, 1822, Jour. Acad. Nat. Sci. Philadelphia, vol. 2, p. 375; —, FRANZEN & LEONARD, 1947, Univ. Kansas Sci. Bull., vol. 31, p. 354, pl. 19, fig. 6; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol. vol. 56, fig. 2.

Occurrence.—Harrison and Monona Counties, Iowa (loc. 3); Knox County, Nebraska (loc. 5); Jewell, Dickinson, Clark, Meade, and Seward Counties, Kansas (locs. 13, 25, 33, 34, 36, 37); Washita County, Oklahoma (loc. 43); Roberts and Hartley Counties, Texas (locs. 45, 46).

Type locality.—Philadelphia, Pennsylvania.

Vertical distribution.—Lower Pliocene to Recent.

Areal distribution and ecology.—Labrador, Ontario, and Alaska, southward to Alabama, westward to Texas, Arizona and Mexico; West Indies. *Vertigo ovata* is commonly distributed in the northern and eastern parts of its range, sporadic in occurrence in the southern and western parts. A limiting ecological factor seems to be moisture; in Kansas, for example, it thrives in locally favorable situations, such as marshes near springs, in areas where it is not generally present.

Description.—Shell of average size for the genus, spire obtusely conical; whorls 5 in number, increasing rapidly in size, the last much the largest, a strongly developed crest occurring behind and near the peristome; aperture characterized by well-developed sinulus defined by an indented point on the outer lip, which is thin and expanded; denticles 9, including 3 parietal lamellae, a low, tubercular infraparietal, a high, elongate parietal lamella, and a low, tubercular angular; 5 folds on a palatal callus, including a low tubercular suprapalatal, situated just above the indenture of the outer lip, an elongate upper palatal, a similar lower palatal, a low infrapalatal, and a low, slightly elongate basal fold; columellar lamella elongate, ascending inwardly along the axis; peristome narrowly reflected, lip thin, acute; height of shell, 1.8 to 2.7 mm.

Remarks.—The shape of the shell is somewhat variable, but characteristically developed; the number of denticles is variable, the infraparietal, suprapalatal, and infrapalatal being variable in size, commonly reduced, and in some shells wanting, so that the minimum number of denticles is 6.

Vertigo tridentata WOLF

Plate 6, figure G

Vertigo tridentata WOLF, 1870, Amer. Jour. Conchology, vol. 5, p. 198, pl. 17, fig. 1; —, FRANZEN & LEONARD, 1947, Univ. Kansas Sci. Bull., vol. 31, p. 361, pl. 20, fig. 5; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Dickinson County, Kansas (loc. 25).

Type locality.—Canton, Fulton County, Illinois.

Vertical distribution.—Yarmouth to Recent, but rare as a Pleistocene fossil.

Areal distribution and ecology.—Quebec, Maine, New York, southwestward to Missouri and eastern Kansas. HANNA (1905, p. 95) reports it as the "commonest *Vertigo*" in eastern Kansas, but it is rarely found there at the present time. *Vertigo tridentata* is an inhabitant of wooded areas; WOLF found them crawling about in large numbers on herbaceous plants, scarcely ever on the ground. It is not a common species, and little is known of its ecological requirements.

Description.—Shell ovate to tapering oblong, whorls $4\frac{3}{4}$ to $5\frac{1}{2}$ in number, the last flattened externally over the lower palatal fold, and bearing a crest behind the subarcuate peristome; lamellae 3 to 4, including a high short parietal lamella, a blunt downward directed columellar lamella, and a strongly developed lower palatal fold; upper palatal fold weak or wanting; angular lamella and basal fold lacking; total height of shell, 1.85 to 2.2 mm.

Remarks.—The small size, tapering form, and absence of basal and angular denticles distinguish this species from other representatives of *Vertigo* in our fauna. This is the first report of the species as a Pleistocene fossil.

Vertigo gouldi (BINNEY)

Plate 6, figure E

Pupa gouldi BINNEY, 1843, Proc. Boston Soc. Nat. Hist., vol. 1, p. 105.

Vertigo gouldi (BINNEY), 1878, Terrestrial Mollusca, vol. 5, p. 214, pl. 71, fig. 2 (in vol. 3); —, FRANZEN & LEONARD, 1947, Univ. Kansas Sci. Bull., vol. 31, p. 358, pl. 21, fig. 3; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Gove, Lincoln and Meade Counties, Kansas (locs. 20, 23, 34, 36.)

Type locality.—New England States.

Vertical distribution.—Yarmouth to Recent. *Vertigo gouldi* is known from the Peoria silt of northern Kansas.

Areal distribution and ecology.—Quebec and Ontario, Maine to Missouri, southward to Harlan County, Kentucky, Tennessee, and northern Alabama. It has been reported from British Columbia and Montana; I have not seen these specimens, but PILSBRY (1948, p. 792) doubts these records. Ecological data on this species are not available, beyond the fact that it requires a moderate amount of moisture, and does not easily survive periods of high temperature and low humidity.

Description.—Shell ovate to cylindrical in shape, whorls $4\frac{1}{2}$ to 5 in number, convex, suture deeply impressed; sculpture consisting of fine, sharply in-

cised, transversely oblique growth striae; body whorl more than half height of shell; aperture slightly oblique, biarcuate; denticles 5 or 6, including a short, lamelliform parietal on the center of the parietal wall, two palatal folds, the lower somewhat the longer, a tubercular basal fold, and a low, columellar fold, appearing tubercular from without but actually ascending inward; a small tubercular sub-columellar fold present in some shells; denticles not on a callus; lip thin, not reflected outward; crest behind peristome, separated from it by a groove; height of shell, 1.8 to 2 mm.

Remarks.—A race of this species, *Vertigo gouldi paradoxa*, occurs in the Peoria silt in northern Kansas.

Vertigo modesta (SAY)

Plate 6, figure H

Pupa modesta SAY, 1824, Keating's Narrative, Major Long's Second Expedition Northwest Terr., Appendix, p. 259, pl. 15, fig. 5.

Vertigo modesta (SAY) PILSBRY & VANATTA, 1900, Proc. Acad. Nat. Sci. Philadelphia, p. 600, pl. 23, fig. 2, 3, 6; —, FRANZEN & LEONARD, 1947, Univ. Kansas Sci. Bull., vol. 31, p. 363, pl. 20, fig. 6; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Harrison and Monona Counties, Iowa (loc. 3); Russell County, Kansas (loc. 22).

Type locality.—Northwest Territory . . . "somewhere in northern Minnesota, southern Manitoba, or near the western end of Lake Superior, on the route of Major LONG's second expedition" . . . (PILSBRY & VANATTA, 1900, p. 601).

Vertical distribution.—Yarmouth to Recent; it is a common *Vertigo* in the Peoria silt of northern Kansas.

Areal distribution and ecology.—Labrador to Victoria and Nanaimo, Alaska; Maine, Vermont and Connecticut; a number of weakly differentiated races have been described from the Rock Mountain region. *Vertigo modesta* thrives in climates which are cooler and more humid than that now prevailing in the midcontinent region; it is abundantly present in Alaska.

Description.—Shell ovately conical; summit convex; rimate; suture deeply incised; whorls $4\frac{1}{2}$ to 5 in number, convex; nuclear whorl finely granular, remaining whorls coarsely and irregularly striate; body whorl more than half total height of shell; aperture ovate, outer peristome scarcely indented; denticles 3 or 4, including a low slightly elongate parietal lamella, a low tubercular upper palatal fold (commonly present), a larger and somewhat more elongate lower palatal fold, and a low short horizontally disposed columellar fold; palatal folds not on a callus; peristome not everted, margins slightly rounded; low crest behind peristome occurs in some shell; height of shell, 1.98 to 2.6 mm.

Remarks.—I know of no record of *Vertigo mod-*

esta from the midcontinent region; since Yarmouthian time it has retreated to higher latitudes or altitudes.

GENUS PUPILLA LEACH, 1828

Pupilla is a genus of minute ground snails, distributed in North America, Eurasia, Africa, and Australia, almost wholly in temperate and cold climates. The animals live on or near the ground in decaying wood or among leaves, and on or beneath stones in moderately humid situations.

The shells are ovoid to cylindrical, and the number and size of the apertural denticles is generally reduced.

Pupilla blandi MORSE

Plate 6, figure L

Pupilla blandi MORSE, 1865, Ann. Lyceum Nat. Hist. New York, vol. 8, p. 5, fig. 8; ———, FRANZEN & LEONARD, 1947, Univ. Kansas Sci. Bull., vol. 31, p. 378, pl. 22, fig. 1; ———, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Meade County, Kansas (loc. 36); Woodward County, Oklahoma (loc. 39).

Type locality.—Fort Berthold Indian Reservation, northwestern North Dakota.

Vertical distribution.—Yarmouth to Recent; it is not uncommon in the Peoria silt in northern Kansas.

Areal distribution and ecology.—The known distribution of this species includes the Rocky Mountain region from Montana and Red Deer, Alberta, southward to New Mexico, westward to Nevada, and eastward to North Dakota. It has disappeared from the Great Plains province, and occurs in regions of higher humidity and lower mean temperature. In the southern part of its range it lives at altitudes up to 10,000 feet, especially in aspen groves.

Description.—Shell ovately cylindrical, whorls 6 in number, suture deeply impressed; apex obtuse; the last whorl descending at base; aperture expanded; a heavy callus behind the peristome, separated from it by a groove; aperture nearly circular, bearing three obtuse denticles of about equal size, of which one occurs on the parietal margin, one on the columellar margin, and one within and at the base of the aperture; height, little more than 3 mm.

Remarks.—In Yarmouthian time, *Pupilla blandi* was associated with *P. muscorum* in the molluscan fauna of the midcontinent region.

Pupilla muscorum (LINNÉ)

Plate 6, figure N

Turbo muscorum LINNÉ, 1758, Systema Naturae, 10th ed., p. 767.

Pupilla muscorum (LINNÉ) PILSBRY, 1921, Manual Conchology, vol. 26, p. 156, pl. 18, figs. 12-15; ———, FRANZEN & LEONARD, 1947, Univ. Kansas Sci. Bull., vol. 31, p. 375, pl. 22, fig. 2; ———, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Harrison and Monona Counties, Iowa (loc. 3); Jewell, Gove, Russell, Lincoln, and Meade Counties, Kansas (locs. 13, 20, 22, 23, 34, 35, 36); Beaver and Woodward Counties, Oklahoma (locs. 38, 39); Roberts and Hartley Counties, Texas (locs. 45, 46).

Type locality.—Europe.

Vertical distribution.—Yarmouth to Recent. This species is abundant in the Peoria silt of northern Kansas, but is absent from the Bignell silt.

Areal distribution and ecology.—Holarctic realm, southward to northern Africa and Persia; eastern North America from Anticosti Island southward to New Jersey, westward in northern tier of States and Canada, northward to Alaska; Rocky Mountain region from Colorado southward to New Mexico and Arizona. In North America *Pupilla muscorum* is more closely restricted to the Canadian and Transition faunas than in the Old World. It lives under leaves and grass in rather humid situations. The species is extinct in the midcontinent region; the mountains of Colorado and New Mexico are the places nearest the midcontinent region in which it now lives.

Description.—Shell large for a pupillid snail, cylindrically ovate, whorls 6 to 7 in number, convex but not inflated; rimate, suture deeply incised; the 1½ nuclear whorls finely granular, remaining whorls finely striate; body whorl less than half height of shell, contracted at base and expanded near aperture; a prominent crest paralleling the peristome, removed from it by deep groove; aperture truncately oval, slightly oblique, typically edentulous, though a poorly developed parietal tooth may be present; peristome sharply everted, margins acute, terminations approaching; height 2.9 to 3.9 mm.

Remarks.—*Pupilla muscorum* is locally abundant in Yarmouth deposits, and dense populations occur in the Peoria silt. It seems to have been a migrant arriving by way of the Siberian-Alaskan route, which has not yet become adapted in North America to warmer habitats.

Pupilla muscorum sinistra FRANZEN

Plate 6, figure M

Pupilla muscorum sinistra FRANZEN, 1946, Nautilus, vol. 60, p. 24; ———, FRANZEN & LEONARD, 1947, Univ. Kansas Sci. Bull., vol. 31, p. 377, pl. 22, fig. 4; ———, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Gove, Russell, Clark, and Meade Counties, Kansas (locs. 20, 22, 33, 34).

Type locality.—Pyle Ranch deposits (Yarmouth), NE¼ Sec. 11, T. 30 S., R. 23 W.; 13 miles east and one half mile south of Minneola, Clark County, Kansas.

Vertical distribution.—Known only from the Yarmouth interglacial beds.

Areal distribution and ecology.—The known distribution is limited to central and southwestern Kansas. The ecological requirements can only be inferred from the known habitat preferences of *Pupilla muscorum*, which this race closely resembles, except for sinistral torsion.

Description.—The shell is similar to *Pupilla muscorum*, except for the sinistral torsion. It is the only commonly sinistral pupillid in our fauna.

Remarks.—At locality 33 in Clark County, Kansas, *Pupilla muscorum sinistra* occurs in a pure population; at the other localities it occurs with the typical *P. muscorum*.

Seemingly, the mutant genes responsible for the reversed torsion have been lost or submerged, since no living sinistral races are known.

GENUS PUPOIDES PFEIFFER, 1854

Pupoides is a genus of small snails, differing from *Pupilla* in internal anatomical characters. The shell which is more tapering has more elongate, loosely coiled whorls and a longer aperture which also has a more oblique parietal margin. The genus is world-wide in distribution, save for Europe. *Pupoides* dates from the Oligocene in North America.

Pupoides albilabris (C. B. ADAMS)

Plate 6, figure Q

Cyclostoma marginata SAY, 1821, Jour. Acad. Nat. Sci. Philadelphia, vol. 2, p. 172 (*non Cyclostoma marginatum* Fischer).

P(upa) albilabris C. B. ADAMS, 1841, "Ward's letter," Amer. Jour. Sci., vol. 40, p. 271 (new name for *Cyclostoma marginata* SAY).

Pupoides albilabris (C. B. ADAMS) PILSBRY, 1948, Land Mollusca North America, vol. 2, pt. 2, p. 921, fig. 499.

Pupoides marginatus (SAY) FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Knox and Harlan Counties, Nebraska (locs. 5, 9); Gove, Clark, and Meade Counties, Kansas (locs. 20, 33, 36); Woodward and Washita Counties, Oklahoma (locs. 39, 43); Roberts and Hartley Counties, Texas (locs. 45, 46).

Type locality.—Upper Missouri River.

Vertical distribution.—Lower Pliocene (Laverne formation) to Recent.

Areal distribution and ecology.—Maine and Ontario, Canada, southward to the Gulf of Mexico, westward to the Dakotas and Arizona; West Indies. *Pupoides albilabris* is tolerant of a wide range in environmental conditions; it thrives in woodlands under leaf mold, loosened bark of dead trees, beneath stones, and in prairies in dead grass, or even in shortgrass pastures in unshaded situations. Populations are usually more dense in limestone areas than elsewhere. It does not ascend to high elevations in mountains.

Description.—Shell elongate, tapering from the last whorl to the obtuse apex, rimate, whorls $4\frac{1}{2}$ to $6\frac{1}{2}$, body whorl more than half height of shell; $1\frac{1}{2}$ nuclear whorls granular, remaining whorls finely striate; aperture roundly ovate, oblique, having sinulus at upper corner of outer lip; peristome reflected, heavily thickened within; height, 3.7-5.6 mm.

Remarks.—The shells of this species are variable in height, breadth, and in the degree of reflection and thickening of the peristome. None of these variations seems racially significant, although there is a tendency for western examples to possess a heavier thickening within the peristome. Once known, *Pupoides albilabris* is readily recognized, since there are no similar snails in this fauna.

GENUS GASTROCOPTA WOLLASTON, 1878

Gastrocopta is a genus of small to minute snails, widely distributed over the world, but absent from the Recent fauna of Europe, where it is known from Tertiary sediments, however. For reasons not understood, it is absent from the West Coast of North America.

The shells of this genus are ovoid to cylindrical, and the aperture is characteristically provided with a heavy armature of denticles.

Gastrocopta armifera (SAY)

Plate 6, figure P

Pupa armifera SAY, 1821, Jour. Acad. Nat. Sci. Philadelphia, vol. 2, p. 162.

Gastrocopta armifera (SAY) PILSBRY, 1916, Manual Conchology, vol. 24, p. 15, pl. 1, figs. 1-4; —, FRYE, LEONARD & HIBBARD, 1943, Jour. Geol., vol. 51, p. 41; —, FRANZEN & LEONARD, 1947, Univ. Kansas Sci. Bull., vol. 31, p. 328, pl. 17, figs. 3-5; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Knox County, Nebraska (loc. 5); Dickinson and Meade Counties, Kansas (locs. 25, 36); Roberts and Hartley Counties, Texas (locs. 45, 46).

Type locality.—Germantown, Pennsylvania, designated by PILSBRY (1948, p. 875).

Vertical distribution.—Yarmouth to Recent; the species is present throughout the Peoria silt in northern Kansas.

Areal distribution and ecology.—Eastern United States and Canada; Quebec to northern Florida, westward to Red Deer, Alberta, southward to Texas and New Mexico. *Gastrocopta armifera* probably occurs over most of the midcontinent region, but in the Great Plains province, it is limited to timber or brushy situations along stream courses, or to thick grass near by. It thrives best in limestone districts, where it may occur in dense populations. The species is found in leaf mold, dead leaves and grass, or beneath stones.

Description.—Shell elongate oval, rimate, summit obtusely conical; whorls $6\frac{1}{2}$ in number, moderately convex, surface marked with oblique striae; aperture irregularly rounded; peristome thin, well expanded, margins approaching, typically connected across parietal wall by a callus; denticles 6, including a fused angulo-parietal, a conspicuous subhorizontal columellar, a low inconspicuous basal, and two palatal folds.

Remarks.—*Gastrocopta armifera* is one of the largest of the pupillid snails, and easily distinguished from other species of the genus, with possible exception of *G. proarmifera*, which has a characteristically different columellar lamella. Several subspecies names have been assigned to variations of *G. armifera*, but since these do not seem to represent geographical races, I have abandoned the use of subspecific designations applied to this species.

Gastrocopta proarmifera LEONARD

Plate 6, figure O

Gastrocopta proarmifera LEONARD, 1946, Nautilus, vol. 60, p. 21, pl. 3, figs. 3-5; —, FRANZEN & LEONARD, 1947, Univ. Kansas Sci. Bull., vol. 31, p. 326, pl. 17, figs. 1, 2; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Harrison and Monona Counties, Iowa (loc. 3); Gove, Russell, Lincoln, Clark, Meade, and Seward Counties, Kansas (locs. 20, 22, 23, 33, 34, 35, 36, 37); Beaver and Woodward Counties, Oklahoma (locs. 38, 39); Roberts and Hartley Counties, Texas (locs. 45, 46).

Type locality.—Tobin deposit (Yarmouth), Sec. 35, T. 14 S., R. 11 W.; approximately 6 miles southeast of Dorrance, Russell County, Kansas.

Vertical distribution.—Known only from the Yarmouth interglacial beds.

Areal distribution and ecology.—Distributed as a Yarmouthian fossil from western Iowa, across Nebraska, Kansas, and northwestern Oklahoma to northwestern Texas. The ecological requirements of *Gastrocopta proarmifera* are unknown, but it may be inferred not unreasonably that they were like those of *G. armifera*, although such an assumption would not account for the extinction of the species.

Description.—Shell rimate, ovate-oblong, apex obtusely conical; whorls 6 or a little more, the first $1\frac{1}{2}$ finely granular, the remaining finely and diagonally striate; whorls only slightly inflated, the last compressed around the axis, subangulate below; aperture irregularly oval; peristome flared; lip thin, simple; lamellae 7, including a bifurcate angulo-parietal, a large, lamellar, vertically disposed columellar, a basal, and lower, upper, and suprapalatal folds.

The shape, disposition and massiveness of the columellar lamella readily distinguishes this species from *G. armifera*.

Remarks.—At the time that *Gastrocopta proarmifera* was described from Pleistocene deposits in southwestern Kansas, I held the opinion that *G. armifera* was a later migrant into the midcontinent region. This idea has been shown to be incorrect, since at localities 20, 36, 45, and 46, the two species occur together. *G. armifera*, moreover, persisted through the remainder of Pleistocene time to the Recent, while *G. proarmifera* became extinct at the close of Yarmouthian time.

Gastrocopta tridentata (LEONARD)

Plate 6, figure R

Columella tridentata LEONARD, 1946, Nautilus, vol. 60, p. 20, pl. 3, figs. 1, 2; —, FRANZEN & LEONARD, 1947, Univ. Kansas Sci. Bull., vol. 31, p. 381, pl. 22, fig. 6; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Gastrocopta tridentata (LEONARD) PILSBRY, 1948, Land Mollusca North America, vol. 2, pt. 2, p. 880, fig. 473.

Occurrence.—Russell County, Kansas (loc. 22).

Type locality.—Tobin deposit (Yarmouth), Sec. 35, T. 14 S., R. 11 W.; approximately 6 miles southeast of Dorrance, Russell County, Kansas.

Vertical distribution.—Yarmouth beds in the type locality.

Areal distribution and ecology.—Known only from type locality; ecological requirements unknown.

Description.—Shell largest known of the genus, elongate, cylindrical, whorls $7\frac{1}{2}$, convex; suture well impressed; sculpture consisting of closely spaced diagonal growth striae; peristome roundly triangular, narrowest below; denticles 3, including a fused angulo-parietal and a deeply immersed, rounded columellar lamella.

Remarks.—*Gastrocopta tridentata* is known only from the type, and as suggested by PILSBRY, it may represent a case of gigantism within the species *G. proarmifera*, which occurs with it. Further collecting may clarify the status of this enigmatic shell.

Gastrocopta contracta (SAY)

Plate 6, figure I

Pupa contracta SAY, 1822, Jour. Acad. Nat. Sci. Philadelphia, vol. 2, p. 374.

Gastrocopta contracta (SAY) PILSBRY, 1916, Manual Conchology, vol. 24, p. 22, pl. 2, figs. 9-12; —, FRYE, LEONARD & HIBBARD, 1943, Jour. Geol., vol. 51, p. 41; —, LEONARD & FRANZEN, Univ. Kansas Sci. Bull., vol. 31, p. 330, pl. 18, fig. 9; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Lincoln and Dickinson Counties, Kansas (locs. 23, 25); Washita County, Oklahoma (loc. 43).

Type locality.—Occoquan, Prince Williams County, Virginia.

Vertical distribution.—Yarmouth to Recent.

Areal distribution and ecology.—Eastern United States and Canada, southward to Florida and Vera Cruz, Mexico; westward to central Kansas and east-central Oklahoma. A recognizable race, *Gastrocopta contracta climeana*, replaces the typical form on the Gulf Coastal Plain from Alabama to Texas, and lowlands of the Mississippi River northward to Arkansas. *Gastrocopta contracta* is an inhabitant of wooded slopes, where it lives under leaf mold, the bark of fallen logs, or stones. It is locally more abundant where loose limestone rock provides cover.

Description.—Shell ovate-conical tapering from the body whorl to obtuse apex, rimate; surface bearing fine, transversely oblique growth striae; whorls a little more than 5 in number, convex, last half of body whorl straightened, pinched at base, impressed over the lower palatal folds, and on both sides of a low ridge which stands a short distance behind the peristome; aperture trianguloid, almost closed by large denticles; a large, fused, anguloparietal lamella, of complex structure; a tubercular upper palatal, a slightly elongate lower palatal fold, a large columellar ascending inwardly; peristome reflected, thin, continuous, adnate upon the preceding whorl, margin, sharp; height of shell, 2 to 3 mm.

Remarks.—This small shell is readily recognized by its conic shape, and triangular aperture, which appears to be nearly obstructed by the large denticles.

Gastrocopta holzingeri (STERKI)

Plate 6, figure A

Pupa holzingeri STERKI, Nautilus, 1889, vol. 3, p. 37.
Gastrocopta holzingeri (STERKI) PILSBRY, 1916, Manual Conchology, vol. 24, p. 25, pl. 2, figs. 4-5; —, FRANZEN & LEONARD, 1947, Univ. Kansas Sci. Bull., vol. 31, p. 333, pl. 18, fig. 2; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Gove County, Kansas (loc. 20); Woodward County, Oklahoma (loc. 39).

Type locality.—Winona, Winona County, Minnesota.

Vertical distribution.—Afton to Recent. *Gastrocopta holzingeri* is not an important component of any Pleistocene molluscan fauna of the midcontinent region.

Areal distribution and ecology.—Ontario, Canada, and western New York, westward to Montana; southward to Illinois, Kansas, and eastern New Mexico. It is essentially a northern species, but tolerant of high summer temperature, which it must endure in the southern part of its range. The species lives in woodlands, among leaves and under logs.

Description.—Shell small, not exceeding 2 mm. in height, ovoid, rimate; whorls $4\frac{1}{2}$ to 5, regularly increasing in size; $1\frac{1}{2}$ nuclear whorls finely granular, remaining whorls finely striate; body whorl less than half height of shell; aperture rounded, exceeding

one-half height of body whorl; denticles 7, including a fused angulo-parietal, which converges inward like a mirror image of the letter "Y," 4 palatal folds on a heavy callus; and a horizontal columellar lamella which turns downward within; peristome narrowly reflected, terminations approaching; a high rounded callus ridge on body whorl, separated from peristome by a wide groove; height, 1.6 to 1.9 mm.

Remarks.—The two most readily usable characters for recognition of this species are its small size and the peculiar shape of the fused angulo-parietal lamella.

Gastrocopta falcis LEONARD

Plate 6, figure B

Gastrocopta falcis LEONARD, 1946, Nautilus, vol. 60, p. 22, pl. 3, fig. 6; —, FRANZEN & LEONARD, 1947, Univ. Kansas Sci. Bull., vol. 31, p. 332, pl. 18, fig. 2; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Clark and Meade Counties, Kansas (locs. 33, 35).

Type locality.—Cudahy volcanic ash mine, Sec. 2, T. 31 S., R. 28 W.; 6 miles north of Meade, Meade County, Kansas.

Vertical distribution.—Known only from deposits of Yarmouthian age.

Areal distribution and ecology.—*Gastrocopta falcis* is at present known only from Meade and Clark Counties, Kansas. The ecological requirements of the species are unknown.

Description.—Shell small, about 1.7 mm. in height, cylindrical, whorls 5 in number, denticles 7, including strongly divergent angular and parietal lamellae, the latter curving toward periphery, columellar lamella arising low in orifice, extending toward parietal, and then reflexed toward the periphery, reaching nearly to the free lip, basal fold transverse in cavity, lower palatal large, entering, elongate, curved toward periphery, upper and suprapalatal folds tubercular, the latter the smaller.

Remarks.—*Gastrocopta falcis* is a little-known species; more material is needed to clarify its status.

Gastrocopta tappaniana (C. B. ADAMS)

Plate 6, figure D

Pupa tappaniana C. B. ADAMS, 1842, (in) Thompson's History of Vermont, p. 158.

Gastrocopta tappaniana PILSBRY, 1916, Manual Conchology, vol. 24, p. 33, pl. 3, fig. 9; —, FRYE, LEONARD & HIBBARD, 1943, Jour. Geol., vol. 51, p. 42; —, FRANZEN & LEONARD, 1947, Univ. Kansas Sci. Bull., vol. 31, p. 336, pl. 18, fig. 8; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Harrison and Monona Counties, Iowa (loc. 3); Knox and Harlan Counties, Nebraska (loc. 5, 9); Jewell, Gove, Lincoln, Ottawa, Dickinson, Clark, Meade, and Seward Counties, Kansas (locs. 13, 20, 23, 24, 25, 33, 36, 37); Woodward and

Washita Counties, Oklahoma (locs. 39, 43); Roberts and Hartley Counties, Texas (locs. 45, 46).

Type locality.—Vermont.

Vertical distribution.—Afton to Recent; it is a common species in the Peoria silt of northern Kansas.

Areal distribution and ecology.—Ontario, Canada, and Maine, southward to Virginia and Alabama, westward to South Dakota and Kansas, southwestward to Arizona. *Gastrocopta tappaniana* may be found most frequently in leaf mold and under sticks, logs and stones on wooded slopes and poorly drained flood plains, but it has been taken among grass roots on open slopes. Its wide latitudinal range indicates that annual mean temperature is not a primary factor in its distribution.

Description.—Shell small, elongate, conical, spire blunt; whorls $4\frac{1}{2}$ to 5, obese, suture deeply impressed; sculpture consisting of fine, transverse growth striae; a heavy callus on body whorl paralleling the subrectangular aperture, separated from the rim of the peristome by a narrow groove; peristome, reflected; denticles 6 to 9, including a low, tubercular infraparietal (rarely present), a completely fused high angulo-parietal on the center of parietal wall, and as many as 6 equally immersed palatal folds situated on a heavy callus; peristome reflected, thin, margin acute; height of shell, 1.5 to 2.5 mm.

Gastrocopta procera (GOULD)

Plate 6, figure J

Pupa procera GOULD, 1840, Boston Jour. Nat. Hist., vol. 3, p. 401.

Gastrocopta procera (GOULD) PILSBRY, 1916, Manual Conchology, vol. 24, p. 62, pl. 12, figs. 1-5; —, FRYE, LEONARD & HIBBARD, 1943, Jour. Geol., vol. 51, p. 41, 42; —, FRANZEN & LEONARD, 1947, Univ. Kansas Sci. Bull., vol. 31, p. 341, pl. 18, figs. 3, 6; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Lincoln County, Kansas (loc. 23); Beaver, Woodward, and Washita Counties, Oklahoma (locs. 38, 39, 43).

Type locality.—Baltimore, Baltimore County, Maryland.

Vertical distribution.—Afton to Recent; it is more or less commonly distributed throughout the Pleistocene deposits of the midcontinent region.

Areal distribution and ecology.—Eastern United States, southward to Alabama, westward to South Dakota, Kansas; southwestward to New Mexico and Arizona. *Gastrocopta procera* is typically an inhabitant of timbered slopes near streams, where it lives in leaf mold, beneath fallen logs or loosened bark, or beneath stones, but it sometimes is found living in meadows in dead grass. Its wide distribution indicates an ability to tolerate wide extremes of temperature and humidity.

Description.—The shell is cylindrical in form, rimate, moderate in size for the genus; whorls 5 to $6\frac{1}{2}$ in number, convex, regularly increasing in size toward aperture; body whorl constricted at base, expanded toward aperture, marked with linear impressions of palatal and basal folds, and with a crest parallel and approximate to peristome; lip variable from thin to heavy, invariably more or less reflected; denticles 6, including a bifid angulo-parietal, an immersed, tubercular upper palatal, an immersed, elongate, obliquely situated lower palatal, a low basal fold, a horizontal columellar lamella, and a low, tubercular, subcolumellar lamella; height of shell, 2 to 3 mm.

Remarks.—*Gastrocopta procera* is commonly associated with *G. cristata* in Aftonian faunas, and the two are found living together in the southwestern portion of the midcontinent region; strangely, *G. cristata* does not occur in the known Peoria silt faunas.

Gastrocopta cristata (PILSBRY & VANATTA)

Plate 6, figure K

Bifidaria procera cristata PILSBRY & VANATTA, 1900, Proc. Acad. Nat. Sci. Philadelphia, p. 595, pl. 22, figs. 4, 5.

Gastrocopta cristata (PILSBRY & VANATTA) PILSBRY, 1916, Manual Conchology, vol. 24, p. 68, pl. 13, figs. 6, 8-12; —, FRANZEN & LEONARD, 1947, Univ. Kansas Sci. Bull., vol. 31, p. 344, pl. 19, fig. 1; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Harrison and Monona Counties, Iowa (loc. 3); Meade and Seward Counties, Kansas (locs. 34, 37); Woodward and Washita Counties, Oklahoma (locs. 39, 43); Roberts and Hartley Counties, Texas (locs. 45, 46).

Type locality.—Camp Verde, Yavapai County, Arizona.

Vertical distribution.—Afton to Recent. *Gastrocopta cristata* was a more important component of molluscan faunas in the midcontinent region during Aftonian time than subsequently; it ranged much farther north during Yarmouthian time than it does at present.

Areal distribution and ecology.—Northern Kansas, Oklahoma, and Texas, westward to New Mexico and Arizona. This species is an inhabitant of wooded slopes near streams, where it lives in leaf mold, beneath bark and fallen logs, often associated with *G. procera*, but it has been found in the grass of low-lying meadows where moisture conditions were favorable and stable.

Description.—Shell cylindrical, rimate, with $5\frac{1}{4}$ to $6\frac{1}{2}$ whorls; apex obtuse, body whorl more than half height of shell, constricted at base and expanded toward aperture, the position of the basal and palatal folds marked by linear impressions; aperture rounded, oblique, peristome expanded, terminations approaching; margin acute, thin; denticles 6, in-

cluding a fused anguloparietal, tubercular upper palatal, an elongate curved lower palatal, basal fold immersed, columellar fold elongate, horizontal, sub-columellar nodose, situated immediately below the columellar; height of shell, 2.5 to 3.5 mm.

Remarks.—*Gastrocopta cristata* is related to *G. procera* which it resembles, but it may be distinguished from the latter by the almost complete fusion of its anguloparietal lamella, and the stronger, more distantly removed crest behind the peristome.

FAMILY VALLONIIDAE PILSBRY, 1900

GENUS VALLONIA RISSO, 1826

The genus *Vallonia* comprises some 25 species of minute snails which are distributed north of Mexico in North America, Europe, northern and central Asia, and Japan. These snails are known from the Paleocene, Eocene, Miocene, and Pliocene of Europe, and from the Pleistocene of Europe and America. The group apparently developed during Mesozoic time, and has changed little since the Eocene.

Vallonia pulchella (MÜLLER)

Plate 5, figure B

Helix pulchella MÜLLER, 1774, *Vermium Terrestrium et Fluvium*, vol. 2, p. 30 (Denmark).

Vallonia pulchella (MÜLLER) BINNEY, 1878, *Terrestrial Mollusca*, vol. 5, p. 344, pl. 17, fig. 1 (in vol. 3); —, FRYE, LEONARD & HIBBARD, 1943, *Jour. Geol.*, vol. 51, p. 41; —, FRYE, SWINEFORD & LEONARD, 1948, *Jour. Geol.*, vol. 56, fig. 2.

Occurrence.—Harrison and Monona Counties, Iowa (loc. 3); Lincoln, Dickinson, Clark, and Meade Counties, Kansas (locs. 23, 25, 33, 34); Beaver County, Oklahoma (loc. 38); Roberts and Hartley Counties, Texas (locs. 45, 46).

Type locality.—Denmark.

Vertical distribution.—Yarmouth to Recent. It is not as common as *Vallonia gracilicosta* at any interval of occurrence.

Areal distribution and ecology.—North Africa, Europe, Siberia eastward to the Amur River, North America east of the Rocky Mountains from Nova Scotia southward to Sedalia, Missouri, and Bowling Green, Kentucky. It has been widely introduced with potted plants and shrubbery, and in addition to flourishing in greenhouses, often becomes feral in the vicinity. It lives under dead grass, in crevices in stones, in moss, under stones, boards and dead wood, and after a rain, often appears in enormous numbers in localities where it has become established. It probably lives in the northern part of the midcontinent region, but it is not known south of northern Kansas, except for introduced colonies in Texas.

Description.—Shell small (not over 2.5 mm. in diameter), depressed spiral, with $3\frac{1}{2}$ whorls, separated by deep suture; umbilicus narrow, deep; surface silky in texture, lacking costae; aperture oblique, peristome abruptly expanded forming five sixths of a circle, thickened within.

The reflected and inwardly thickened peristome, small size, characteristic shape, and lack of costae are principal distinguishing characters of *Vallonia pulchella*.

Remarks.—The genus *Vallonia* is represented in Aftonian time by *V. gracilicosta*, but *V. pulchella* is now known as a fossil before Yarmouthian time.

Vallonia gracilicosta REINHARDT

Plate 5, figure D

Vallonia gracilicosta REINHARDT, 1883, *Sitzungs-Ber. Ges. Naturforsch., Freunde Berlin*, p. 42; —, FRYE, SWINEFORD & LEONARD, 1948, *Jour. Geol.*, vol. 56, fig. 2.

Vallonia costata FRYE, LEONARD & HIBBARD, 1943, *Jour. Geol.*, vol. 51, p. 41, 42.

Occurrence.—Harrison and Monona Counties, Iowa (loc. 3); Jewell, Gove, Russell, Lincoln, Dickinson, Clark, Meade, and Seward Counties, Kansas (locs. 13, 20, 22, 23, 25, 33, 34, 35, 36, 37); Beaver, Woodward, and Washita Counties, Oklahoma (locs. 38, 39, 43); Roberts and Hartley Counties, Texas (locs. 45, 46).

Type locality.—Near Little Missouri River, at Medora, Billings County, North Dakota.

Vertical distribution.—Afton to Recent. *Vallonia gracilicosta* is frequently abundant in the Peoria silt of northern Kansas. I have taken as many as 3,000 individuals from a 100-pound sample of this silt.

Areal distribution and ecology.—Rocky Mountain States, the Dakotas, Nebraska, California. *Vallonia gracilicosta* is an inhabitant of situations where leaf mold, stones, and dead grass offer protection. The animals burrow into the earth where the soil is not too compact; I have found them at least an inch below the surface in loose soil. In the Rocky Mountains, *V. gracilicosta* has been found at altitudes up to 10,000 feet.

Description.—Shell small, almost flat spiral, whorls $3\frac{1}{2}$ in number, convex, separated by deep suture; surface sculpture consisting of riblets placed obliquely transverse to whorls; last whorl enlarging rapidly near aperture, descending; peristome reflected, thickened, the termini approaching, connected by a callus; diameter of shell, 2.5 mm. or a little more.

Remarks.—*Vallonia gracilicosta* is readily distinguished from *V. pulchella* by the presence of the costae on the former. *V. costata*, which somewhat resembles *V. gracilicosta*, is not known from the midcontinent region.

FAMILY STROBILOPSIDAE HANNA, 1922

GENUS STROBILOPS PILSBRY, 1893

The genus *Strotilops* comprises small snails which live on decaying logs and dead leaves in moderately humid forests. It is distributed in North America from the 100th meridian eastward; it ranges from Ontario, Canada, on the north to Guatemala. In Europe, a number of fossil species are known from Eocene to Pliocene, when the genus became extinct there. The genus is sporadically distributed over the world elsewhere. In North America, *Strotilops* appears first in Aftonian faunas.

***Strotilops sparsicosta* BAKER**

Plate 5, figure C

Strotilops sparsicosta BAKER, 1938, *Nautilus*, vol. 51, p. 127; ———, FRYE, SWINEFORD & LEONARD, 1948, *Jour. Geol.*, vol. 56, fig. 2.

Occurrence.—Harrison and Monona Counties, Iowa, (loc. 3); Jewell and Meade Counties, Kansas (locs. 13, 34); Woodward and Washita Counties, Oklahoma (locs. 39, 43); Roberts and Hartley Counties, Texas (locs. 45, 46).

Type locality.—Rexroad deposits (Aftonian), SW $\frac{1}{4}$ Sec. 22, T. 33 S., R. 29 W.; 9 miles south and 7 miles west of Meade, Meade County, Kansas.

Vertical distribution.—Afton and Yarmouth deposits.

Areal distribution and ecology.—The known range of this extinct species extends from western Iowa across Kansas and northwestern Oklahoma to northwestern Texas. It is much more abundant in the southern deposits. Nothing is known of its ecological requirements.

Description.—Shell obtusely conical, resembling an old-fashioned beehive; whorls convex, 5 $\frac{1}{2}$ in number, the first 1 $\frac{1}{2}$ smooth, remaining whorls embellished with distinct riblets, widely spaced, a faint riblet being developed in the intervals; body whorl angled at periphery; base nearly smooth or bearing a few faint riblets; aperture expanded, peristome thickened and bearing heavy callus; two lamellae on parietal wall within aperture. These lamellae are actually long folds which extend far within the shell, where there are other complexly developed lamellae. The reader is referred to standard works (such as PILSBRY, 1948, p. 849) for detailed information regarding the anatomy, terminology, and use of these lamellae in the systematic treatment of species of *Strotilops*. For present purposes, the shape of the shell, the course riblets, and the smooth base will serve as identifying characters.

Remarks.—Its distribution and similarity to *Strotilops texasiana* indicate that *S. sparsicosta* is essentially a southwestern species; it is remarkable that its range should have extended to western Iowa.

FAMILY ENTODONTIDAE PILSBRY, 1894

GENUS HELICODISCUS MORSE, 1864

Helicodiscus is a genus of small snails, with disc-shaped shells, generally distributed over North America from eastern Mexico to Canada. Its geologic history is not well known, but I find no records of occurrence earlier than Yarmouthian.

***Helicodiscus parallelus* (SAY)**

Plate 4, figure A

Planorbis arallelus SAY, 1821, *Jour. Acad. Nat. Sci. Philadelphia*, vol. 2, p. 164 (corrected to *parallelus* in index).

Helicodiscus parallelus (SAY) PILSBRY, 1906, *Proc. Acad. Nat. Sci. Philadelphia*, p. 156; ———, FRYE, LEONARD & HIBBARD, 1943, *Jour. Geol.*, vol. 51, p. 41, 42; ———, FRYE, SWINEFORD & LEONARD, 1948, *Jour. Geol.*, vol. 56, fig. 2.

Occurrence.—Russell, Lincoln, Dickinson, and Clark Counties, Kansas (locs. 22, 23, 25, 33); Beaver, Woodward, and Washita Counties, Oklahoma (locs. 38, 39, 43).

Type locality.—SAY indicated no type locality, but PILSBRY (1948, p. 627) has designated Council Bluffs, Iowa, as the type locality.

Vertical distribution.—Yarmouth to Recent; this species occurs commonly in the Peoria silt and is widely distributed over the midcontinent region at the present time.

Areal distribution and ecology.—*Helicodiscus parallelus* ranges from Newfoundland southward to Alabama and westward to Nebraska, Kansas, Oklahoma, and Texas. It is replaced in the Rocky Mountains by *H. eigenmanni*, but it lives up to 5,000 feet elevation in the Appalachians. This species is an inhabitant of leaf mold, moss, and decaying wood in rather humid situations, although it ranges into the Plains Border province where timber is sparse.

Description.—A small, coin-shaped shell, the upper surface plane to slightly convex, umbilicus broad and shallow; whorls 4 to 4 $\frac{1}{2}$ in number, the first 1 $\frac{1}{2}$ marked by faint spiral striations, remaining whorls embellished with numerous spiral raised lines, narrower than interval between them; diameter, a little over 3 mm.

The small size, discoid shape, and above all, the spiral striations, serve to identify this shell, which is unlike any other in our fauna.

Remarks.—The last whorl bears small conical teeth, generally two pairs; these are deep within the whorl and not visible from without.

GENUS DISCUS FITZINGER, 1833

Discus is a genus of small but not minute snails having depressed, rib-striate shells. The living species are generally distributed through the holarctic realm; in America, fossil species have been reported from Upper Cretaceous, Eocene and Miocene deposits.

Discus cronkhitei (NEWCOMB)

Plate 4, figure C

Helix cronkhitei NEWCOMB, 1868, Proc. California Acad. Sci., vol. 3, p. 180.

Discus cronkhitei (NEWCOMB) PILSBRY, 1948, Land Mollusca North America, vol. 2, pt. 2, p. 600, fig. 328; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Harrison and Monona Counties, Iowa (loc. 3); Harlan County, Nebraska (loc. 9); Jewell, Gove, Russell, Lincoln, and Meade Counties, Kansas (locs. 13, 20, 22, 23, 34, 35, 36); Beaver and Woodward Counties, Oklahoma (locs. 38, 39).

Type locality.—Klamath Valley, Oregon.

Vertical distribution.—Yarmouth to Recent. In the Peoria silt of northern Kansas, *Discus cronkhitei* is largely replaced by *D. shimeki*.

Areal distribution and ecology.—*Discus cronkhitei* occurs as a living snail from Labrador, Newfoundland, and Maine, in the east, westward to Alaska, and southward to Arizona and New Mexico. In the southern part of its range, it lives at altitudes of 7,000 to 8,000 feet. "In the east it lives in humid forests, under dead wood, and among rotting leaves and grass in rather wet situations. It is a common snail in the Canadian and Transition faunas, and occurs sporadically in the Carolinian" (PILSBRY, 1948, p. 604). This species does not live within the midcontinent region.

Description.—Shell composed of approximately 4 whorls, depressed, spire low conoid, umbilicus open, exhibiting all whorls; whorls convex, suture deeply impressed; 1½ nuclear whorls smooth, remaining ones transversely rib-striate, the riblets extending on to the base of shell; aperture rounded, a little larger than umbilicus; peristome simple, thin, dilated toward umbilical insertion; diameter of shell, 5 to 6.5 mm.

Remarks.—*Discus cronkhitei* is similar in size and shape to *D. shimeki*, but in the latter, the riblets do not extend on to the base of the shell. *D. shimeki* is not known to occur in Yarmouthian faunas, at least not in the midcontinent region. This species, which bears a general resemblance to *Discus patulus* and *D. shimeki*, is usually listed in older literature under the name *Pyramidula*.

FAMILY POLYGYRIDAE PILSBRY, 1930

GENUS POLYGYRA SAY, 1818

Snails of the genus *Polygyra* are animals of humid climates; with few exceptions, they are absent where the average annual rainfall is below 30 inches, and most species occur where annual precipitation exceeds this amount. The genus is distributed in southern United States east of the 100th meridian, and in Mexico, except much of the central plateau region. Several species are known from the Miocene of North America.

Polygyra texasiana (MORICAND)

Plate 4, figure E

Helix texasiana MORICAND, 1883, Mem. Soc. Phys. Hist. Nat. de Genève, vol. 6, p. 538, pl. 1, fig. 2.

Polygyra texasiana (MORICAND) BINNEY, 1878, Terrestrial Mollusca, vol. 5, p. 270, pl. 6, fig. g (in vol. 3); —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Woodward County, Oklahoma (loc. 39).

Type locality.—Vicinity of Brownsville, Cameron County, Texas.

Vertical distribution.—Yarmouth to Recent. It is not known from later Pleistocene deposits in the midcontinent region nor is it found living there.

Areal distribution and ecology.—Texas, Louisiana, southern Arkansas, and southern and central Oklahoma. *Polygyra texasiana* lives in timbered areas, under leaves, logs, and stones. It is one of the few species in the Pearlette ash fauna which has a restricted southern distribution.

Description.—Shell strongly depressed, perforate, umbilicus about one fourth diameter of shell; embryonic whorls nearly smooth, remaining whorls coarsely striate, last two whorls rib-striate above, base nearly smooth; peristome forming two thirds of a circle, reflected and thickened, its inner margin bearing 2 palatal teeth rather close together; parietal callus bearing a two-branched denticle; diameter of shell, 7 to 10 mm.

Remarks.—A related species of *Polygyra* ranged northward to southern Kansas in Aftonian time.

GENUS STENOTREMA RAFINESQUE, 1819

Stenotrema is a genus closely related to *Polygyra* but most shells are easily distinguishable. The shell of *Stenotrema* differs in having papillose or striate nuclear whorls, and by the forms of the apertural teeth. The genus is found in humid forests, but its range extends into prairie or plains areas along streams which support timber. No fossil species older than Aftonian are known.

Stenotrema monodon (RACKETT)

Plate 4, figure D

Helix monodon RACKETT, 1821, Trans. Linnaean Soc. London, vol. 13, p. 42, pl. 5, fig. 2.

Stenotrema monodon (RACKETT) BINNEY, 1878, Terrestrial Mollusca, vol. 5, p. 299, pl. 41, middle figures (in vol. 5, p. 41); —, FRYE, LEONARD & HIBBARD, 1943, Jour. Geol., vol. 51, p. 41; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Jewell, Russell, Clark, and Meade Counties, Kansas (locs. 13, 22, 33, 34, 35); Beaver County, Oklahoma (loc. 38).

Type locality.—Alpena County, Michigan.

Vertical distribution.—Yarmouth to Recent. A small form of *Stenotrema monodon* from the Peoria silt of Illinois has been described as *S. monodon peoriensis*. It does not seem to differ from small examples of living *S. monodon*.

Areal distribution and ecology.—Ontario, New York, southward to Missouri and westward to Nebraska. It has been reported from Kansas, but the living species is a distinguishable race, *Stenotrema monodon aliciae*; the same may be true of the Nebraska examples, which I have not seen. *Stenotrema monodon* thrives in rather humid forests, and may be found on low terraces and flood plains of streams, under leaves, logs, and stones.

Description.—Shell depressed globose, almost imperforate, spire convexly conical, whorls $5\frac{1}{2}$ to 6, closely coiled; surface bearing closely set hairlike excrescences, which are almost invariably absent from fossil shells, leaving the surface with numerous small pits; lip thickened and reflected; parietal tooth short, straight, typically not prolonged toward the columella; diameter of shell, 7 to 9 mm.

Remarks.—*Stenotrema monodon* has been replaced in the midcontinent region by *S. monodon aliciae* and by *S. fraternum*, both of which live in a somewhat drier habitat. The former has been found in dense growths of grass in ravines in the High Plains region.

FAMILY ZONITIDAE PFEIFFER

GENUS HAWAIIA GUDE, 1911

Hawaiiia is an American genus of minute snails comprising a single species and several races. The singularly inappropriate generic name is explained by the fact that the snail was introduced in Hawaii and later named as a native form by an author who was unaware of its long history in scientific literature.

Hawaiiia miniscula (BINNEY)

Plate 5, figure A

Helix miniscula BINNEY, 1840, Boston Jour. Nat. Hist., vol. 3, p. 435, pl. 22, fig. 4.

Hawaiiia miniscula (BINNEY) H. B. BAKER, 1941, B. F. Bishop Mus. Bull., p. 322, pl. 61, figs. 13-15; —, FRYE, LEONARD & HIBBARD, 1943, Jour. Geol., vol. 51, p. 41, 42; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Harrison and Monona Counties, Iowa (loc. 3); Knox and Harlan Counties, Nebraska (locs. 5, 9); Gove, Lincoln, Dickinson, Clark, Meade, and Seward Counties, Kansas (locs. 20, 23, 25, 33, 34, 36, 37); Beaver, Woodward, and Washita Counties, Oklahoma (locs. 38, 39, 43); Roberts and Hartley Counties, Texas (locs. 45, 46).

Type locality.—Ohio.

Vertical distribution.—Lower Pliocene to Recent. This species is common in all deposits containing a terrestrial molluscan fauna throughout the Pleistocene of the midcontinent region, but it is not yet known from the Ogallala formation (Pliocene) of the plains country.

Areal distribution and ecology.—Alaska and Maine, southward to Florida and West Indies, and westward to Arizona and southern California. It has been widely introduced in Pacific islands, Japan, and in Europe through articles of commerce, such as potted plants. *Hawaiiia miniscula* is an inhabitant of humid situations, where it lives in leaf mold, on and beneath the bark of trees, among mosses, and beneath fallen logs, or beneath stones. It is capable, in spite of its habitat preferences, of withstanding long periods of drought and high temperature.

Description.—Shell minute, umbilicate, the umbilicus about one third the diameter of the shell; spire low, convex; whorls 4, strongly convex, slowly enlarging in size toward the aperture; embryonic whorls smooth, remaining whorls unevenly striate above, almost smooth below; aperture nearly round, lip of peristome thin, simple; diameter of shell, 2.2 to 2.8 mm.

Remarks.—The shells of *Hawaiiia miniscula* vary so considerably that it seems inadvisable to assign the Pearlette specimens to any named race.

GENUS RETINELLA SHUTTLEWORTH, 1877

Retinella is a genus widely distributed in the holarctic realms, but the systematic relations of many Old World species are not well known. There are about 20 American species, distributed from the Arctic to southern Mexico, the greatest number occurring in and around the Appalachian region. The shells borne by living snails are translucent, clear to amber colored, and they have a more or less glossy surface. The animals of this genus are inhabitants of relatively humid woodlands.

Retinella electrina (GOULD)

Plate 5, figure H

Helix electrina GOULD, 1841, Invertebrata of Massachusetts, p. 183, fig. 111.

Retinella electrina (GOULD) BAKER, 1939, Manual 2, Illinois Nat. Hist. Survey, p. 69, fig. a; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Harrison and Monona Counties, Iowa (loc. 3); Gove, Lincoln, Ottawa, Clark, and Meade Counties, Kansas (locs. 20, 23, 24, 33, 34, 35, 36); Beaver and Woodward Counties, Oklahoma (locs. 38, 39); Roberts and Hartley Counties, Texas (locs. 45, 46).

Type locality.—Cambridge, Massachusetts.

Vertical distribution.—Aftonian to Recent. The species is much more common in Aftonian and Yarmouthian deposits known to me than it is in later Pleistocene sediments.

Areal distribution and ecology.—Eastern Canada, Maine, southward to Virginia, westward to Montana, Oregon and Alaska, and southward to New Mexico and Arizona. *Retinella electrina* is an inhabitant of woodlands where it lives in decaying leaves, beneath loosened bark on dead trees and under sticks and fallen logs. It is frequently associated with another woodland snail (*Zonitoides arboreus*) of similar size and superficial appearance. *R. electrina* is common in the woodlands of eastern Kansas, where the annual rainfall is generally more than 35 inches but it declines in frequency of occurrence toward the more arid Plains Border province, and is unknown in the Plains province, even where timber is locally available.

Description.—Shell depressed, deeply umbilicate; sculpture consisting of numerous, radial grooves, which are wanting on first whorl and on base of the shell; surface shining; whorls $3\frac{3}{4}$ to $4\frac{1}{4}$, the last convex below; aperture ovoid-lunate; peristome thin, simple, not reflected; diameter of shell, 4.5 to 5.5 mm.

Remarks.—*Retinella electrina* may be confused with *Zonitoides arboreus*, since the shells of the two are similar in size and shape, but the latter has more tightly wound, more convex whorls, and the surface is embellished with raised growth lines, rather than grooves.

GENUS ZONITOIDES LEHMANN, 1862

Zonitoides is holarctic in distribution, occurring in most temperate parts of the northern continents. The paleontology of the genus is not well known, but several species have been reported from the Tertiary of Europe. In America, I know of no authentic records of occurrence earlier than Yarmouthian time, but PILSBRY (1946, p. 475) speaks of *Zonitoides arboreus* being "present throughout the Pleistocene." Better evidence of the antiquity of the species in question is that it has become adapted to a wide range of habitat situations, from subarctic to tropical, throughout its great range.

Zonitoides arboreus (SAY)

Plate 4, figure B

Helix arboreus SAY, 1816, in Nicholson's Encyclopedia, 1st Amer. Ed., vol. 2, article "conchology," pl. 4, fig. 4 (no pagination).

Zonitoides arboreus (SAY) HENDERSON, 1924, Univ. Colorado Studies, vol. 13, p. 147; —, FRYE, LEONARD & HIBBARD, 1943, Jour. Geol., vol. 51, p. 41; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., fig. 2.

Occurrence.—Russell, Lincoln, Dickinson, Clark, and Meade Counties, Kansas (locs. 22, 23, 25, 33, 36); Beaver County, Oklahoma (loc. 38).

Type locality.—Probably near Philadelphia, Pennsylvania.

Vertical distribution.—Yarmouth to Recent, but rare in the later loesses.

Areal distribution and ecology.—British America as far north as Great Slave Lake, all of the United States, Mexico, Central America and the West Indies. *Zonitoides arboreus* occurs in woodlands, living under loosened bark, leaves, and stones, and other cover affording protection from the sun, and providing at least moderate moisture. I have found the species within the Plains province in situations where trees were locally available.

Description.—Shell depressed spiral, openly umbilicate, with $4\frac{1}{2}$ convex, regularly enlarging whorls; sculpture consisting of transverse growth striae; aperture lunate, lip simple, thin; diameter of shell, about 5.5 mm.

Remarks.—Although this species lives in or near woodlands, its tolerance of a wide range of ecological conditions reduces its usefulness for the purpose of reconstructing former environmental situations.

GENUS EUCONULUS REINHARDT, 1883

Euconulus comprises a group of small woodland snails, which bear conical shells, as the name of the genus suggests. It is widespread in the holarctic realm, particularly in high latitudes. Little is known of the paleontological history of the genus, but in America, *Euconulus* is first known from Aftonian deposits.

Euconulus fulvus (MÜLLER)

Plate 5, figure F

Helix fulva MÜLLER, 1774, Vermium Terrestrium et Fluvium, vol. 2, p. 56.

Euconulus fulvus (MÜLLER) PILSBRY, 1908, Nautilus, vol. 22, p. 25.

Euconulus chersinus FRYE, LEONARD & HIBBARD, 1943, Jour. Geol., vol. 51, p. 41; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Jewell, Gove, Russell, Lincoln, Dickinson, and Meade Counties, Kansas (locs. 13, 20, 22, 23, 25, 34, 35, 36); Beaver and Woodward Counties, Oklahoma (locs. 38, 39).

Type locality.—The type locality of the species is Fridrichsdal, Denmark. Dyea Valley, Alaska, is the type area of the subspecies *alaskensis*, which shells here treated most closely resemble.

Vertical distribution.—Yarmouth to Recent in North America; the species has been reported from the middle Pliocene, Montpellier, France, but some doubt remains regarding the age of these beds.

Areal distribution and ecology.—*Euconulus fulvus* is holarctic in distribution, but is wanting in the Gulf and southern Atlantic States from North Carolina to Texas. *E. fulvus alaskensis* ranges from Kamchatka Peninsula to Alaska, southward through the

Coastal Ranges and Rocky Mountains, but in the southern part of its range, it is invariably found at altitudes above 7,000 feet. Both *E. fulvus fulvus* and the race *E. fulvus alaskensis* live among damp leaves or other vegetation in well-shaded situations.

Description.—A small, thin, shell of about 4½ whorls; surface silky or shining; conical in profile view, body whorl much enlarged; suture not deeply impressed; peristome, thin sharp, simple; aperture lunate; diameter of shell, about 3.2 mm.

Remarks.—Most of the individuals examined in the present study possess a rounded angle at the periphery of the body whorl, perhaps slightly more distinct than in *Euconulus fulvus alaskensis*; otherwise our specimens closely resemble that race.

FAMILY LIMACIDAE GRAY, 1824

GENUS DEROCERAS RAFINESQUE, 1820

Deroceras is a genus of small gastropods in which the reduced shell is carried as an internal, flattened plate; accordingly, the naked animals are often called "slugs." The genus is widely distributed in palearctic regions and in both Americas; over 60 species have been named, but many of them are based on color variations or are otherwise unrecognizable. Little is known of the paleontological history of these animals; the occurrence of the species described below in Aftonian deposits of southwestern Kansas constitutes the earliest known record for the genus.

Deroceras aenigma, new species

Plate 5, figure E

Limax (?), FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Harrison and Monona Counties, Iowa (loc. 3); Knox County, Nebraska (loc. 5); Jewell, Gove, Russell, Clark, and Meade Counties, Kansas (locs. 13, 20, 22, 33, 34, 35); Beaver, Woodward, and Washita Counties, Oklahoma (locs. 38, 39, 43); Roberts and Hartley Counties, Texas (locs. 45, 46).

Holotype.—University of Kansas Museum of Natural History, No. 5127.

Horizon and type locality.—Rexroad Ranch deposits, Aftonian; SW¼ Sec. 22, T. 33 S., R. 29 W.; 9 miles south and 7 miles west of Meade, Meade County, Kansas.

Yarmouthian examples of the species are indistinguishable from those found in Aftonian deposits; the species is not known from later Pleistocene intervals.

Diagnosis.—The species is known only from the internal shell, which is elongate, roundly oblong, heavy, bearing concentric growth striae which emanate from a subterminal nucleus displaced toward the left.

Description of holotype.—Shell elongate, roundly oblong, relatively thick and heavy; left border convex, right border slightly concave, anterior and posterior borders convex; dorsal surface arched, nucleus subterminal displaced toward the left; growth striae fine, crowded; growth rests making distinct ridges, parallel with striae, 3 in number; ventral surface of shell slightly concave, marked by irregular shallow grooves and rounded ridges, which are roughly parallel to long axis. Total length, 4.0 mm; greatest width, 2.5 mm.; thickness, 1.1 mm.

Comparisons.—The shell of *Deroceras aenigma* is much larger and heavier than that of *D. laeve*, the living representative of the genus in the midcontinent region. The living animal of *D. laeve* is about an inch long when the animal is extended, narrow and wormlike in superficial appearance. From comparative sizes of the shells of the two species, it may be inferred that *D. aenigma* was considerably larger than *D. laeve*. The latter lives in humid situations, on floodplains and low terraces of streams, and in or near marshes, under logs, twigs, leaves, grasses, or among mosses and other vegetation. It may reasonably be inferred that the ecological requirements of *D. aenigma* were generally like those of *D. laeve*.

FAMILY HELICINIDAE GUILDING, 1828

GENUS HENDERSONIA A. J. WAGNER, 1905

Hendersonia is sporadically distributed in the holarctic realm; the living members of the genus seem to represent the survivors of a once more widespread population. The genus is represented in the Paleocene and Miocene of North America, but the only living North American species—the one reported below—is known first from Yarmouthian beds. American *Hendersonia* are snails of low, humid woodlands, usually very close to streams.

Hendersonia occulta (SAY)

Plate 4, figure F

Helicina occulta SAY, 1831, Transylvania Jour. Med., vol. 4, p. 528.

Hendersonia occulta H. B. BAKER, 1922, Proc. Acad. Nat. Sci., Philadelphia, vol. 74, p. 41; —, FRYE, LEONARD & HIBBARD, 1943, Jour. Geol., vol. 51, p. 41; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Occurrence.—Harrison and Monona Counties, Iowa (loc. 3); Russell County, Kansas (loc. 22).

Type locality.—Loess south of New Harmony, Indiana.

Vertical distribution.—Yarmouth to Recent. It is rare in the Peoria silt west of the Missouri River, but common in the Peoria east of that river.

Areal distribution and ecology.—This snail was first described as a fossil, but a number of scattered

localities, distributed widely in the upper Mississippi Valley eastward to the Alleghany Mountains in Pennsylvania and North Carolina, support living colonies; none are known to be located within the midcontinent region. The ecological requirements of *Hendersonia occulta* have been the subject of many discussions, one of the most valuable of which is that by VAN DER SCHALIE (1939, p. 1-8) which summarizes previous discussions, and assembles data to show that this species is confined to habitats near water, along streams and lakes, often in positions that allow submergence at times of high water.

Description.—Shell somewhat depressed, but having a conical spire, rather solid, about 5, nearly flat whorls; suture scarcely impressed; surface dull, bearing fine transverse growth striae; periphery more or less keeled; aperture oblique, subtriangular to semicircular; peristome narrowly expanded, strongly thickened, edge rounded; diameter variable, 5 to 7.25 mm.

Remarks.—*Hendersonia occulta* is a common fossil in the Bignell silt in extreme northeastern Kansas; it occurs in the Peoria silt of Kansas as far west as Republic County.

KEY TO YARMOUTHIAN GASTROPOD SPECIES OF THE MIDCONTINENT REGION

1. Shell having spiral whorls..... 5
2. Shell not obviously formed of spiral whorls..... 3
3. Shell limpet-like..... *Ferrissia parallela*
4. Shell a flattened plate..... *Deroceras aenigma*
5. Spire elevated above body whorl..... 7
6. Spire depressed below level of body whorl..... 97
7. Whorls sinistrally spiraled..... 9
8. Whorls dextrally spiraled..... 15
9. Aperture length more than half that of shell..... 11
10. Aperture length less than half that of shell..... 13
11. Whorls of spire almost flat; little change of slope at body whorl..... *Physa elliptica*
12. Whorls of spire convex; distinct change of slope at body whorl..... *Physa anatina*
13. Aperture elongate, attenuated above, spire acute..... *Aplexa hypnorum*
14. Aperture rounded, spire obtuse..... *Pupilla muscorum sinistra*
15. Diameter of shell less than height of shell..... 17
16. Diameter of shell more than height of shell..... 19
17. Aperture denticulate..... 69
18. Aperture not denticulate..... 45
19. Shell imperforate..... 21
20. Shell perforate..... 23
21. Peristome reflected, thickened..... *Hendersonia occulta*
22. Peristome thin, simple..... *Euconulus fulvus*
23. Peristome thin, simple..... 33
24. Peristome reflected, thickened, or denticulate..... 25
25. Aperture denticulate..... 27
26. Aperture not denticulate..... 31
27. Parietal tooth disappearing within body whorl..... *Strobilops sparsicosta*
28. Parietal tooth not disappearing within body whorl, 29
29. Parietal tooth straight..... *Stenotrema monodon*
30. Parietal tooth bifid..... *Polygyra texasiana*
31. Surface of whorls costate..... *Vallonia gracilicosta*
32. Surface of whorls not costate..... *Vallonia pulchella*
33. Whorls carinate..... *Valvata tricarinata*
34. Whorls not carinate..... 35
35. Surface bearing raised, spiral lines..... *Helicodiscus parallelus*
36. Surface lacking raised, spiral lines..... 37
37. Surface polished, marked by radial grooves..... *Retinella electrina*
38. Surface lacking radial grooves..... 39
39. Surface rib-striate..... *Discus cronkhitei*
40. Surface not rib-striate..... 41
41. Spire turbinate..... *Valvata lewisi*
42. Spire not turbinate..... 43
43. Whorls at least 4, diameter of shell not more than 3 mm..... *Hawaia miniscula*
44. Whorls at least 4, diameter not less than 5 mm..... *Zonitoides arboreus*
45. Peristome reflected..... *Pupoides marginatus*
46. Peristome not reflected..... 47
47. Outer lip of peristome rounded on edge..... *Cionella lubrica*
48. Outer lip of peristome sharp..... 49
49. Umbilicus open, peristome continuous..... 51
50. Umbilicus closed or rimate, peristome not continuous..... 53
51. Spire elevated conical, whorls 5..... *Pomatiopsis cincinnatiensis*
52. Spire obtusely conical, whorls 4..... *Amnicola limosa parva*
53. Whorls not more than 4..... 55
54. Whorls more than 4..... 61
55. Aperture elongate, somewhat retuse..... *Oxyloma navarrei*
56. Aperture oval, not retuse..... 57
57. Height of shell not more than 11 mm..... *Succinea avara*
58. Height of shell more than 12 mm..... 59
59. Diameter of aperture less than two-thirds length of aperture..... *Succinea ovalis*
60. Diameter of aperture at least two-thirds length of aperture..... *Succinea grosvenori*
61. Whorls more than 4, less than 6..... 63
62. Whorls more than 6..... 67
63. Length of shell less than 8 mm..... *Lymnaea parva*
64. Length of shell more than 9 mm..... 65
65. Diameter of shell less than half the height of shell..... *Lymnaea caperata*
66. Diameter of shell at least half the height of shell..... *Lymnaea bulimoides*
67. Whorls flatly rounded, 7, aperture attenuate above..... *Lymnaea reflexa*
68. Whorls obese, 7, aperture not attenuate above..... *Lymnaea palustris*
69. Columellar lamella only denticle visible..... *Carychium perezignum*
70. Columellar lamella not only denticle visible..... 71
71. Both angular and parietal teeth present but fused.. 73
72. Angular and parietal teeth both not present or if both present, not fused..... 89
73. Height of shell more than 3 mm..... 75
74. Height of shell less than 3 mm..... 79
75. Palatal folds wanting..... *Gastrocopta tridentata*
76. Palatal folds present..... 77
77. Columellar lamella large, flattened, vertical in position..... *Gastrocopta proarmifera*
78. Columellar lamella small, horizontal in position..... *Gastrocopta armifera*
79. Anguloparietal tooth forked in front..... 81
80. Anguloparietal tooth not forked in front..... 83
81. Angular lamella continuous with outer lip of peristome..... *Gastrocopta falcis*
82. Angular lamella not continuous with outer lip of peristome..... *Gastrocopta holzingeri*
83. Anguloparietal tooth bent at right angles toward the periphery within..... *Gastrocopta contracta*
84. Anguloparietal tooth not bent toward periphery within..... 85
85. Five or more folds on basal and palatal wall of aperture..... *Gastrocopta tappaniana*

86. Three folds on basal and palatal wall of aperture. 87
 87. Anguloparietal tooth bifid at summit
 Gastrocopta procera
 88. Anguloparietal tooth not bifid at summit
 Gastrocopta cristata
 89. Outer lip of peristome biarcuate. 91
 90. Outer lip of peristome not biarcuate. *Vertigo modesta*
 91. Denticles 3 to 4 in number. *Vertigo tridentata*
 92. Denticles 5 or more in number. 93
 93. Denticles 7 to 9; parietal lamellae 3. *Vertigo ovata*
 94. Denticles less than 7 in number. 95
 95. Lower palatal fold curved toward columella
 Vertigo milium
 96. Lower palatal fold not recurved toward columella
 Vertigo gouldii
 97. Umbilicus funnel-shaped; whorls flat on umbilical surface 99
 98. Umbilicus various, not funnel-shaped, whorls not flat on umbilical surface. 105
 99. Aperture inflated to bellshape; whorls usually carinate above or below, or both. *Helisoma anceps*
 100. Aperture not inflated; whorls not carinate. 101
 101. Conspicuous crest behind peristome
 Planorbula nebraskensis
 102. Crest behind peristome wanting or inconspicuous. 103
 103. Ventral angle of penultimate whorl partially concealed by body whorl. *Planorbula vulcanata*
 104. Ventral angle of penultimate whorl exposed for full volution. *Planorbula vulcanata occidentalis*
 105. Entire umbilical surface plane. *Gyraulus pattersoni*
 106. Entire umbilical surface not plane. 107
 107. Body whorl drawn to sharp angle at periphery
 Menetus pearlettei
 108. Body whorl not drawn to sharp angle at periphery, 109
 109. Body whorl subangulate at periphery
 Promenetus umbilicatellus
 110. Body whorl round at periphery. 111
 111. Sculpture of coarse transverse striae, and spiral striae, at least on early whorls. *Helisoma trivolvis*
 112. Sculpture consisting of fine growth lines only. 113
 113. Lip of peristome continuous across parietal wall
 Gyraulus labiatus
 114. Lip of peristome not continuous across parietal wall, or if apparently so, thinner. *Gyraulus similaris*

CLASS PELECYPODA

FAMILY SPHAERIIDAE DAHL, 1895

GENUS SPHAERIUM SCOPOLI, 1777

The Sphaeriidae are small bivalves, mostly less than an inch in length, generally much smaller, which are of widespread occurrence over the world. They brood the developing young in a branchial pouch, and hence are not dependent upon fish during development, as are the larger unionid mussels. For this reason, and the fact that these animals are able to survive the absence of open water in drying ponds, they are often numerous in small streams and ponds, even in semi-arid regions. Unfortunately, the nomenclature of these animals is in a chaotic condition, which is not remarkable, for they are a difficult group, taxonomically speaking. The inherent difficulty with systematic arrangement of these animals lies in their small size, variability in relation to ecological conditions, general similarity, and lack of distinct anatomical differences at the species level. These difficulties have so impressed

students in general, that the group has been grossly neglected. There is reason to believe that with a workable system of nomenclature, the Sphaeriidae may prove to be as useful for stratigraphic correlations as other mollusks. In the meantime, however, these organisms are almost entirely useless for present purposes, since species limitations are often in grave doubt. For this reason I have not emphasized the presence of shells of these animals in the Yarmouthian fauna described here.

I am greatly indebted to Mr. H. B. HERRINGTON, of Newburgh, Ontario, for identifying the sphaeriids named below; he is studying the collections of these shells from the Yarmouthian and other Pleistocene deposits of the midcontinent region.

A common form of *Sphaerium* is illustrated from an external view of the right valve, Plate 1, figure J. This or similar kinds occur at localities 23, 24, 34, 45, and 46. Mr. HERRINGTON informs me (*personal communication*, 13 October 1948) that a great many of the shells seem to be intergrades between *Sphaerium striatinum*, *S. stamineum*, and *S. solidulum*, and he suggests that eventually these named species may be shown to be a single species made up of several races, but the indication is that these shells are closest to *S. solidulum* PRIME. Of the ecological requirements of this species BAKER (1928, p. 323) reports them from "shallow water, bottom gravel with some sand, good current, water clear."

GENUS PISIDIUM C. PFEIFFER, 1821

The genus *Pisidium* is comprised of very small animals; most shells are only a few millimeters in length. These animals occur in a wide range of habitat situations, in shallow muddy water, on aquatic vegetation, in streams, and in lakes to depths of 25 meters. A few species are distinctive and readily recognized; among them is *Pisidium compressum*, widely distributed in Yarmouthian deposits in the midcontinent region.

Pisidium compressum PRIME

Plate 1, figure H

Pisidium compressum PRIME, 1851, Proc. Boston Soc. Nat. Hist., vol. 4, p. 164; —, FRYE, LEONARD & HIBBARD, 1943, Jour. Geol., vol. 51, p. 40, 42; —, FRYE, SWINEFORD & LEONARD, 1948, Jour. Geol., vol. 56, fig. 2.

Type locality.—Fresh Pond, near Cambridge, Massachusetts.

Vertical distribution.—Yarmouth to Recent.

Areal distribution and ecology.—Entire United States, Alaska, Canada, and Mexico. *Pisidium compressum* is an inhabitant of streams, rather than ponds, but is occasionally found in the latter. It has been taken in lakes at depths up to 20 feet or more, on mud or clay bottoms. This species flourishes in a brook fed by artesian springs in Meade County, Kansas; here it lives in fine to coarse sand

Species		Locality Numbers																			
		within glaciated region			outside glaciated region																
		2	3	5	9	13	20	22	23	24	25	33	34	35	36	37	38	39	43	45	46
Yarmouthian to Recent	<i>Pisidium compressum</i> Prime.....65	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	<i>Pupilla muscorum</i> (Linné).....64	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	<i>Discus cronkhitei</i> (Newcomb).....63	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	<i>Lymnaea palustris</i> (Müller).....62	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	<i>Euconulus fulvus</i> (Müller).....61	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	<i>Promenetus umbilicatellus</i> (Cockerell).....60	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	<i>Gyraulus similaris</i> (Baker).....59	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	<i>Vallonia pulchella</i> (Müller).....58	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	<i>Cionella lubrica</i> (Müller).....57	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	<i>Gastrocopta armifera</i> (Say).....56	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	<i>Valvata tricarinata</i> (Say).....55	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	<i>Helisoma cf. wisconsinensis</i> Winslow.....54	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	<i>Amnicola limosa parva</i> Lea.....53	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	<i>Hendersonia occulta</i> (Say).....52	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	<i>Vertigo modesta</i> (Say).....51	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	<i>Polygyra texasiana</i> (Moricand).....50	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	<i>Helicodiscus parallelus</i> (Say).....49	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	<i>Stenotrema monodon</i> (Rackett).....48	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	<i>Helisoma trivolvis</i> (Say).....47	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	<i>Sphaerium</i> sp.....46	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
<i>Zonitoides arboreus</i> (Say).....45	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
<i>Aplexa hypnarum</i> (Linné).....44	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
<i>Physa elliptica</i> Lea.....43	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
<i>Vertigo gouldi</i> (Binney).....42	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
<i>Gastrocopta contracta</i> (Say).....41	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
<i>Lymnaea caperata</i> (Say).....40	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
<i>Pomatiopsis cincinnatensis</i> (Lea).....39	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
<i>Lymnaea bulimoides</i> Lea.....38	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
<i>Pupilla blandi</i> Morse.....37	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
<i>Succinea avara</i> Say.....36	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
<i>Succinea ovalis</i> Say.....35	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
<i>Valvata lewisi</i> Currier.....34	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
<i>Vertigo tridentata</i> Wolf.....33	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
Restricted to Yarmouthian	<i>Gyraulus labiatus</i> Leonard.....32	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
	<i>Gastrocopta proarmifera</i> Leonard.....31	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	<i>Menetus pearlettei</i> Leonard.....30	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	<i>Gyraulus pattersoni</i> Baker.....29	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	<i>Ferrissia parallela</i> (Haldeman).....28	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	<i>Planorbula nebraskensis</i> Leonard.....27	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	<i>Physa</i> , indet.....26	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	<i>Planorbula v. occidentalis</i> Leonard.....25	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	<i>Pupilla muscorum sinistra</i> Franzen.....24	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	<i>Oxyloma navarrei</i> , new species.....23	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
<i>Gastrocopta falcis</i> Leonard.....22	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
<i>Planorbula vulcanata</i> Leonard.....21	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
<i>Gastrocopta tridentata</i> (Leonard).....20	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
Aftonian to Yarmouthian	<i>Deroceras ainigma</i> , new species.....19	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
	<i>Carychium perexiguum</i> Baker.....18	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	<i>Strobilops sparsicosta</i> Baker.....17	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Aftonian to Recent	<i>Succinea grosvenori</i> Lea.....16	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	<i>Vallonia gracilicosta</i> Reinhardt.....15	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	<i>Gastrocopta tappaniana</i> (C.B. Adams).....14	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	<i>Retinella electrina</i> (Gould).....13	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	<i>Vertigo milium</i> (Gould).....12	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	<i>Gastrocopta cristata</i> (Pilsbry and Vanatta).....11	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	<i>Lymnaea parva</i> Lea.....10	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
<i>Gastrocopta procera</i> (Gould).....9	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	
<i>Lymnaea</i> , indet.....8	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	
<i>Lymnaea reflexa</i> Say.....7	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	
<i>Gastrocopta halzingeri</i> Sterki.....6	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	
Lower Pliocene to Recent	<i>Hawaii minuscula</i> (Binney).....5	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	<i>Vertigo ovata</i> Say.....4	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	<i>Pupoides albilabris</i> (C.B. Adams).....3	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	<i>Physa anatina</i> Lea.....2	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
<i>Helisoma anceps</i> (Menke).....1	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	
Total numbers of species		8	23	17	16	13	20	27	25	11	22	30	29	19	28	18	26	27	21	24	24

●●●● abundant ●●●● common ●●●● rare

FIGURE 4.—Chart showing distribution and occurrence of the 65 species comprising the Yarmouthian molluscan fauna associated with the Pearlette volcanic ash in the midcontinent region.

in swiftly flowing water, though it may also be found creeping about on aquatic vegetation.

Description.—Shell solid, inflated, strongly inequipartite, trigonal; anterior end rounded; posterior end roundly truncate; total height, 3 to 4 mm.

The hinge teeth are diagnostic, but the use of them requires experience and skill. The trigonal shape, and relatively heavy shell are fairly reliable identifying characters of this species.

Remarks.—In addition to *Pisidium compressum*, which is so widespread in this fauna, Mr. HERRINGTON has recognized a number of other species of

this genus and other sphaeriids. For example, at locality 46, Hartley County, Texas, the following kinds occur: *Sphaerium solidulum* (?), *Musculium transversum* SAY, *Pisidium compressum* PRIME, *P. variabile* PRIME, *P. pauperculum nylanderii* STERKI, *P. walkeri* STERKI, and *P. abditum* HALDEMAN. That the sphaeriid fauna is variable from place to place is indicated by the list of species from locality 23, Lincoln County, Kansas, where those recognized include: *Pisidium compressum*, *P. variabile*, *P. pauperculum* STERKI, *P. adamsiifine* STERKI, and *P. nitidum* JENYNS.

DISTINCTIVE FEATURES OF THE YARMOUTHIAN MOLLUSCAN FAUNA

Little attention has been given by others to Pleistocene molluscan faunas in the midcontinent region. The most notable exceptions to this are the studies by the late F. C. BAKER, reported by LUGN (1935, p. 183-212). There seems little doubt that several of the listed faunas assigned to Yarmouthian time are actually of this age, but others are assigned to this part of the Pleistocene Epoch on evidence which in my judgment is very tenuous. For example, LUGN (1935, p. 190-191) states that BAKER expressed the opinion that snails from beds on the Dismal River, 12 miles south of Mullen, Hooker County, Nebraska, are Yarmouthian in age, which by implication, at least, indicates that the age was determinable from the fauna. The snails concerned are: *Lymnaea caperata*, *Gyraulus* sp., *Succinea grosvenori*, and *Vallonia gracilicosta*; the three specifically determined forms do occur in Yarmouthian faunas, but they may be found also in later Pleistocene deposits in the general region. While the age of these beds may have been correctly determined by other means, obviously it could not have been judged correctly from the evidence presented by the fossil mollusks. In addition, LUGN frankly admits lack of certainty regarding the age of many exposures from which mollusks are listed, which makes comparisons of them with the Pearlette fauna impracticable. Because of this fact, I exclude from this study data on specimens from localities which I have not personally examined.

The distinctive features of the Yarmouthian molluscan fauna listed in this paper have been previously discussed (FRYE, SWINEFORD & LEONARD, 1948, p. 514-517) but a few characteristics of the fauna may be reemphasized. In the chart (fig. 4) showing occurrence and distribution of the Pearlette molluscan fauna, species are divided into five categories: (1) Species ranging from lower Pliocene to Recent; (2) species ranging from Aftonian to Recent; (3) species ranging from Aftonian to Yarmouthian but not found in later Pleistocene deposits; (4) species restricted to Yarmouthian sediments; (5) species which make their first known

appearance in Yarmouthian beds, but which are living somewhere in North America, if not in the midcontinent region. In each category, species are listed according to frequency of occurrence.

The following observations seem pertinent. (1) The five species which range from lower Pliocene to Recent are of little value for stratigraphic correlation, but the wide range of three of these species serves to support the concept of widespread uniformity of ecological conditions during Yarmouthian time. (2) The eleven species which range from Aftonian to Recent are likewise of little use for purposes of stratigraphic correlation, but the widely distributed species are ecologically significant. (3) The three species which range from Aftonian to Yarmouthian are useful as stratigraphic indicators only when an Aftonian age can be excluded. (4) Thirteen species or subspecies are restricted to Yarmouthian deposits, which makes them of particular significance; more than half of them occur in the nonglaciaded plains region and the glaciaded region as well. (5) The largest group of species (no. 33-65, fig. 4) are not known before Yarmouthian time, but they range upward to Recent. They serve to indicate an age no older than Yarmouthian, but will not serve, of course, to limit the age of a deposit otherwise. Fifteen species in this group are distributed on either side of the glacial border in the midcontinent region. In all, 35 species, comprising more than half the total number found in the Yarmouthian faunal assemblage of our region, are widely distributed and are found both within glaciaded territory and outside the glacial border. The large number of species involved, the wide distribution of many species, together with the fact that no less than 20 percent of the species are restricted to the Pearlette faunal zone, give this molluscan fauna particular distinctive qualities that serve to prove the essential contemporaneity of the sediments from which they come. These conclusions are confirmed by similar conclusions based on petrographic evidence (FRYE, SWINEFORD & LEONARD, 1948, p. 507-514) and stratigraphic data (*ibid.*, p. 517, ff.).

PALEOECOLOGY OF YARMOUTHIAN TIME IN THE MIDCONTINENT REGION

Attempts to reconstruct the ecological conditions prevalent in times past, based on judgments inferred from fossil remains, are always beset with difficulties and uncertainties, and this is no less true in studies of mollusks than in work on other fossils. The basic difficulty arises from the lack of knowledge concerning real limiting factors in the environmental complex in which these animals live. For example, if a certain species of mollusk is restricted in distribution to northern States, it does not necessarily follow that its restriction is due entirely to temperature factors; as a matter of fact, the chemical composition of the country rock, with its resulting effect on the chemistry of ground waters, the composition of the flora, the mean annual rainfall and its seasonal distribution, the presence or absence of certain predatory animals, parasites, diseases, and many other more or less unknown elements in the environment, all play variable roles in determining the areal distribution of any particular species. The reproductive index, relative aggressiveness, modes of dispersal, ability or lack of ability of a species to adjust itself to variations in the environment, and many other factors affect distributional range of the species. To a very large extent, the manner and extent of influence of these many complex elements of environment are unknown. It follows, therefore, that inferences regarding climatic and other environmental conditions in times past must be somewhat tentative. However, in the light of our present knowledge, be it ever so deficient, certain conclusions may be drawn, as I propose to do here.

AQUATIC GASTROPODS

Leaving aside indeterminate forms, there are 23 species of aquatic gastropods known from Yarmouthian deposits in the midcontinent region. Of these, 8 species are living in the region today, but among them, only 3 species, *Lymnaea parva*, *Helisoma trivolvis*, and *Physa anatina* are known to be distributed widely. The remaining species in this category, *Lymnaea reflexa*, *L. caperata*, *L. palustris*, *Helisoma anceps*, and *Promenetus umbilicatellus*, are restricted to the extreme northern portion (being unknown south of central Nebraska) or to the more humid eastern border (*Helisoma anceps*).

Nine of the 23 species are extinct in the midcontinent region but living elsewhere. These include *Valvata tricarinata*, *V. lewisi*, *Amnicola limosa parva*, *Pomatiopsis cincinnatiensis*, *Lymnaea bulimoides*, *Gyraulus similis*, *Ferrissia parallela*, *Physa elliptica*, and *Aplexa hypnorum*. All of these gastropods are now living in regions north and east of the midcontinent region, except *Aplexa hypnorum*, which is widely distributed in the northern

part of the continent, and *Gyraulus similis*, which is found in high mountain lakes in Colorado.

The remaining 6 species of aquatic gastropods in this fauna, *Planorbula vulcanata*, *P. v. occidentalis*, *P. nebraskensis*, *Menetus pearlettei*, *Gyraulus pattersoni*, and *G. labiatus* are entirely extinct; their ecological requirements can only be inferred from related species and by their associations.

A consideration of aquatic gastropods listed here brings to a focus several facts and deductions concerning the paleoecology of Yarmouthian time in the midcontinent region.

(1) The Yarmouthian age was characterized by conditions generally more favorable for aquatic gastropods than are conditions at present; this is exemplified by the relatively large number of genera and variety of species known, by the wider range of species now restricted to northern or extreme eastern parts of the region, and by the large number of species now extinct in the region, but found living in more humid climates elsewhere.

(2) Specifically, permanent bodies of water must have been more widely prevalent, especially in the southern half of the region, than is the case now; the wide occurrence, and dense populations of such branchiate snails as *Valvata tricarinata* point to this, as well as the wide occurrence of such pulmonates as *Ferrissia*, *Planorbula*, *Menetus*, and *Gyraulus*, which are more or less dependent upon permanent water. *Lymnaea*, *Physa*, *Helisoma*, and even *Amnicola* and *Pomatiopsis* are less significant, for all are known to be able to endure long periods without open water, although moisture is essential for survival.

(3) The absence of the larger branchiates, such as *Pleurocera*, *Goniobasis*, *Campeloma*, and *Vivipara*, is evidence opposed to a concept of a profoundly different environment than that prevalent at the present time. This idea is buttressed by the fact that all the Yarmouthian genera, except *Valvata*, have representatives in the region today, although many of them are restricted to extremely local situations where conditions are favorable. Cases in point are the presence of *Menetus* and *Gyraulus* in ponds fed by artesian springs in southwestern Kansas, and of *Pomatiopsis* in a marsh, also produced by artesian springs, in northeastern Kansas.

(4) Annual mean temperature was possibly somewhat lower than at present, an inference which might be deduced from the number of species, once living in the midcontinent region, now found north and east of their former range. The same results doubtless could have been produced by a more equitable climate, without much if any lowering of annual mean temperatures; such a climate, lacking the extreme summer highs of temperature fluctuation and severe

droughts, which characterize the climate of much of the midcontinent region today, probably would account for observed characters of the Yarmouthian molluscan assemblage. I am inclined to adopt this latter view, which I hope to strengthen by deductions based upon distribution of terrestrial gastropods in Yarmouthian time.

Present knowledge of Recent, as well as Yarmouthian sphaeriid species in the midcontinent region militates against any attempt to utilize these animals either for stratigraphic correlation or for the reconstruction of probably ecological conditions in Yarmouthian time. The reasons for this have been mentioned.

TERRESTRIAL GASTROPODS

Thirty-six species of terrestrial gastropods are known in the Yarmouthian molluscan fauna reported here. Of these, nineteen species are living somewhere in the region today, nine species are extinct in the region but living elsewhere in North America, and eight species are entirely extinct.

Among the nineteen species living in the midcontinent region, six are rather generally distributed; these include *Succinea avara*, *Pupoides albilabris*, *Gastrocopta armifera*, *G. procera*, *G. tappaniana*, and *Hawaiiia minuscula*. All these snails are able to survive high temperature and drought for considerable periods, and thus are able to live on the plains, but at the same time they are found in the more humid woodlands of the eastern border of the region. Ten of the endemic species are more or less limited to eastern and northern woodlands where moisture conditions are more stable than on the plains; these are *Succinea ovalis*, *Cionella lubrica*, *Vertigo milium*, *V. tridentata*, *Gastrocopta contracta*, *Helicodiscus parallelus*, *Stenotrema monodon*, *Retinella electrina*, *Zonitoides arboreus*, and *Vallonia gracilicosta*. The three remaining species are *Gastrocopta cristata*, which enters our fauna from the south, *Succinea grosvenori*, which in this region, at least, is western in range, and *Vertigo ovata*, sporadically distributed in locally favorable situations, such as marshy ground near permanent ponds and lakes.

The nine species which are extinct in the midcontinent region but living elsewhere, include *Vertigo gouldi*, *V. modesta*, *Pupilla blandi*, *P. muscorum*, *Vallonia pulchella*, *Discus cronkhitei*, *Polygyra texasiana*, *Euconulus fulvus*, and *Hendersonia occulta*. All these species, except *Polygyra texasiana*, which is limited to the southern States, now live east or north of the midcontinent region, or at higher altitudes.

The eight entirely extinct species are *Carychium perexiguum*, *Oxyloma navarrei*, *Pupilla muscorum sinistra*, *Gastrocopta proarmifera*, *G. tridentata*, *G. falcis*, *Strobilops sparsicosta*, and *Deroceras aenigma*.

An analysis of the ecological requirements of the terrestrial gastropods listed here, confirms the

deduction that Yarmouthian time was characterized in the midcontinent region by a more stable climate; there was more equitable distribution of rainfall throughout the year, if not more rainfall, for all of the nine species extinct in the area, now live in regions where the climate is not subject to extreme high summer temperature, nor ordinarily to extreme drought. Thirteen of the nineteen species living within the limits of the region here concerned are not generally distributed, but confined to the more humid eastern or northern portions, or to locally favorable situations, and only six species in this category are at all generally distributed.

Among the entirely extinct species, half of them, *Carychium perexiguum*, *Oxyloma navarrei*, *Strobilops sparsicosta* and *Deroceras aenigma* are hydrophilous species, if we may judge them by the moisture requirements of their relatives.

On the other hand, nothing learned from analysis of the terrestrial fauna suggests that the greater part of the area was timbered, as has been suggested. It is true that *Stenotrema*, *Cionella*, *Retinella*, *Zonitoides*, *Strobilops*, *Euconulus*, *Hendersonia*, and other genera are primarily woodland animals, but they are known to thrive in narrow bands of timber along streams in terrain that is otherwise treeless. More important in this connection, I judge, is the absence of the true forest genera, such as *Triodopsis*, *Mesodon*, *Allogona*, *Anguispira*, and *Mesomphix* among others, which are entirely unknown from the fossil assemblages of the region considered here.

The entire faunal assemblage listed here, both aquatic and terrestrial species, points to an equitable climate over the midcontinent region, for inspection of the distribution of species by localities (fig. 4) reveals that nearly half the total number are distributed from within the glaciated parts of northern Nebraska and western Iowa to the plains of northwestern Oklahoma and Texas. Such a range of distribution, when ecological requirements of the various species are considered, points conclusively toward widely favorable conditions for mollusks during Yarmouthian time.

In summary, the climate over the midcontinent region during Yarmouthian time is judged to have been not unlike that of the present, with the following qualifications: (1) The Plains Border and Plains Provinces were better watered than at present, at least permanent ponds and lakes were more widely prevalent than now. (2) Trees were more plentiful along stream courses, but there is no evidence of widespread forests on what is now the Plains Border and Plains Provinces. (3) Annual mean temperature was perhaps a little lower (or higher?) than now, but there is no evidence of great deviation from present annual means, although there is good reason for believing that seasonal extremes, especially summer highs, were reduced.

It is not my purpose here to review the extensive work on Pleistocene mollusks done by BOHUMIL

SHIMEK of Iowa and FRANK COLLINS BAKER of Illinois, whose work has contributed so much to knowledge of the paleontology of these animals. A study by BAKER (1931, p. 148-155) is particularly significant, however, because he compares the Pleistocene and Recent faunas of Fulton County, west central Illinois; this study in relation to similar comparisons in the midcontinent area serves to point up the arguments advanced above. BAKER reports 44 living species from Fulton County, Illinois, but only 20 from the Yarmouthian deposits. Of these 20 species, 9 are extinct, 3 are extralimital, 2 of these living outside the State, and one outside the county. Only 8 of the 44 species in the Recent fauna are found in the Yarmouthian deposits. BAKER (*loc. cit.*) concludes:

The present molluscan fauna of Fulton County is far richer in species than any fauna of the interglacial intervals, containing sixteen species not found in any of the Pleistocene series, excepting a few in Late Wisconsin. The fauna is seen to gradually increase in number of species from the Yarmouth interval. A feature of special interest is that the greater number of the extinct and extralimital species persist until Early Wisconsin time, when they disappear from the fauna of the county.

These results and observations differ radically from those obtained from studies in southwestern Kansas. A report by ALICE E. LEONARD (1943, p. 226-240) lists the living molluscan fauna of Meade and Clark Counties, which excluding pelycypods (and including *Succinea grosvenori*, subsequently found in this area), comprises 21 species. This number is probably higher than normal for the southwestern Kansas region, because Meade County contains artesian springs and permanent ponds, which furnish an unusual environment for a semi-arid region. This faunal assemblage is listed below; names marked with an asterisk indicate species

which are not found in the Yarmouthian deposits of the two counties.

Living gastropod species in Meade and Clark Counties, Kansas. (An asterisk indicates species which occur also in Yarmouthian deposits of these counties.)

* <i>Lymnaea bulimoides</i>	<i>Hawaiiia miniscula</i>
<i>techella</i>	<i>Helicodiscus parallelus</i>
* <i>Lymnaea bulimoides</i>	<i>Gastrocopta armifera</i>
<i>cockerelli</i>	<i>Gastrocopta tappaniana</i>
<i>Lymnaea parva</i>	<i>Gastrocopta cristata</i>
* <i>Lymnaea humilis rustica</i>	<i>Vertigo ovata</i>
* <i>Lymnaea dalli</i>	<i>Pupoides marginatus</i>
<i>Helisoma trivolvis</i>	* <i>Vallonia parvula</i>
* <i>Menetus exacuus</i>	* <i>Succinea concordalis</i>
* <i>Gyraulus parvus</i>	* <i>Succinea haydeni</i>
* <i>Physa hawni</i>	<i>Succinea grosvenori</i>
	* <i>Deroceras gracilis</i> (= <i>D. laeve</i>)

The Yarmouthian molluscan fauna of Meade and Clark Counties may be compiled from the list of species reported from localities 33, 34, 35, and 36 (fig. 4). Forty-five species are included in this Yarmouthian assemblage, which is more than twice the number of molluscan species in the living fauna of the two counties. Eleven species in the living fauna are not found in the Yarmouthian beds and the remaining ten species are common to both. Thirty-five Yarmouthian species, a number considerably greater than that species living in the area, are extinct or extralimital; they are not found in the two counties, and most of them are not known within the State. These observations strengthen the concept of prevalent favorable conditions for molluscan life in Yarmouthian time in the midcontinent region, and are widely at variance with relative conditions of Yarmouthian and present time in Illinois. If conditions in Meade and Clark Counties are representative, the molluscan fauna of the midcontinent region has been decreasing in number of species since Yarmouthian time, rather than increasing, as has been the case in Illinois, according to BAKER.

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