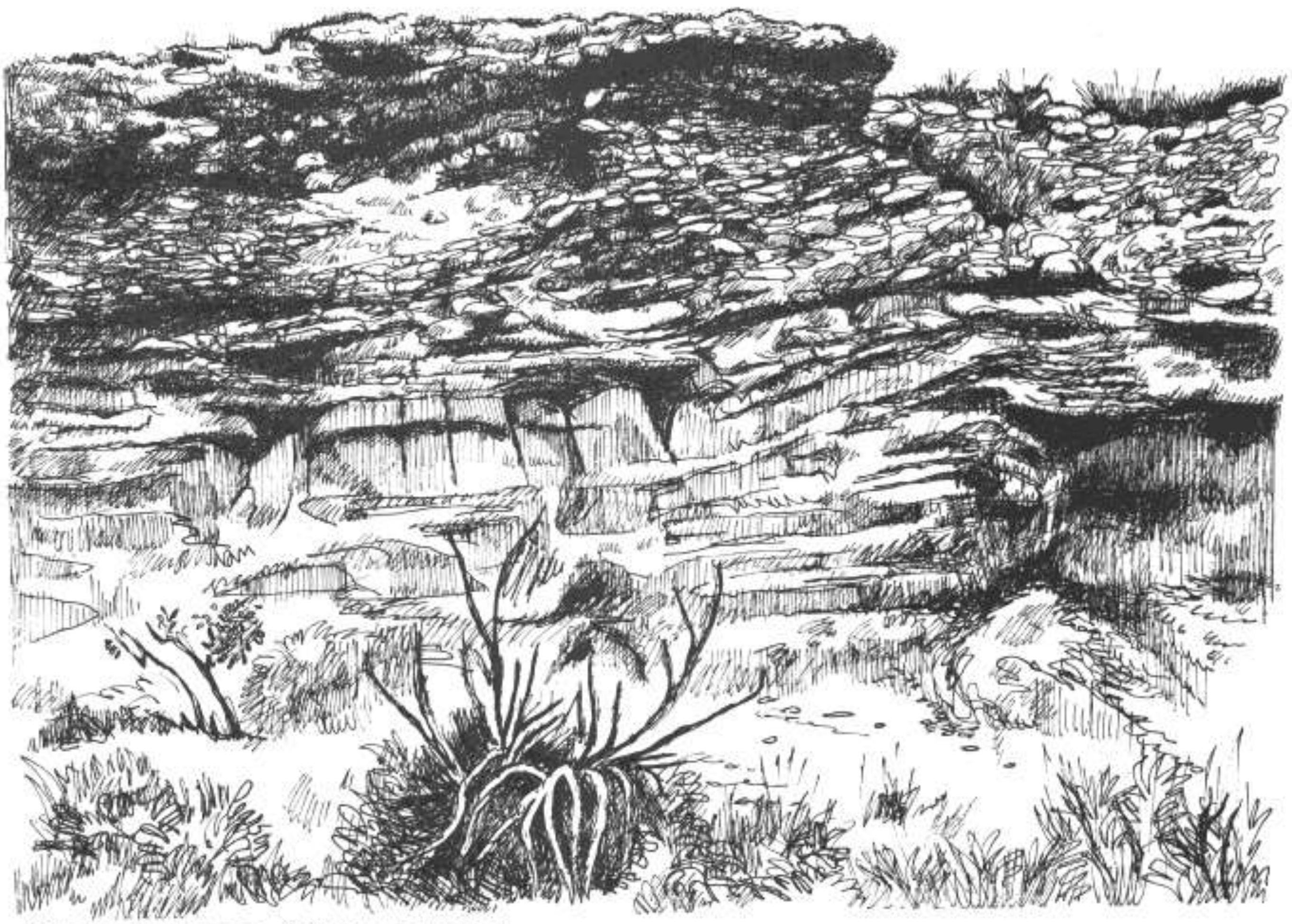
Circular 161 1978

Paleontolology of Ogallala Formation, northeastern New Mexico

by A. Byron Leonard and John C. Frye



KIMBALL MEMBER OF OGALLALA FORMATION, CLAYTON SOUTH SEC, UNION COUNTY

New Mexico Bureau of Mines & Mineral Resources

A DIVISION OF
NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY

Circular 161

New Mexico Bureau of Mines & Mineral Resources

A DIVISION OF
NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY

Paleontology of Ogallala Formation, northeastern New Mexico

by A. Byron Leonard and John C. Frye

SOCORRO 1978

First printing, 1978

Published by Authority of State of New Mexico, NMSA 1953 Sec. 63-1-4
Printed by University of New Mexico Printing Plant, March 1978

Available from New Mexico Bureau of Mines & Mineral Resources, Socorro, NM 87801 Price $3.00

Contents

FIGURES

PLATES

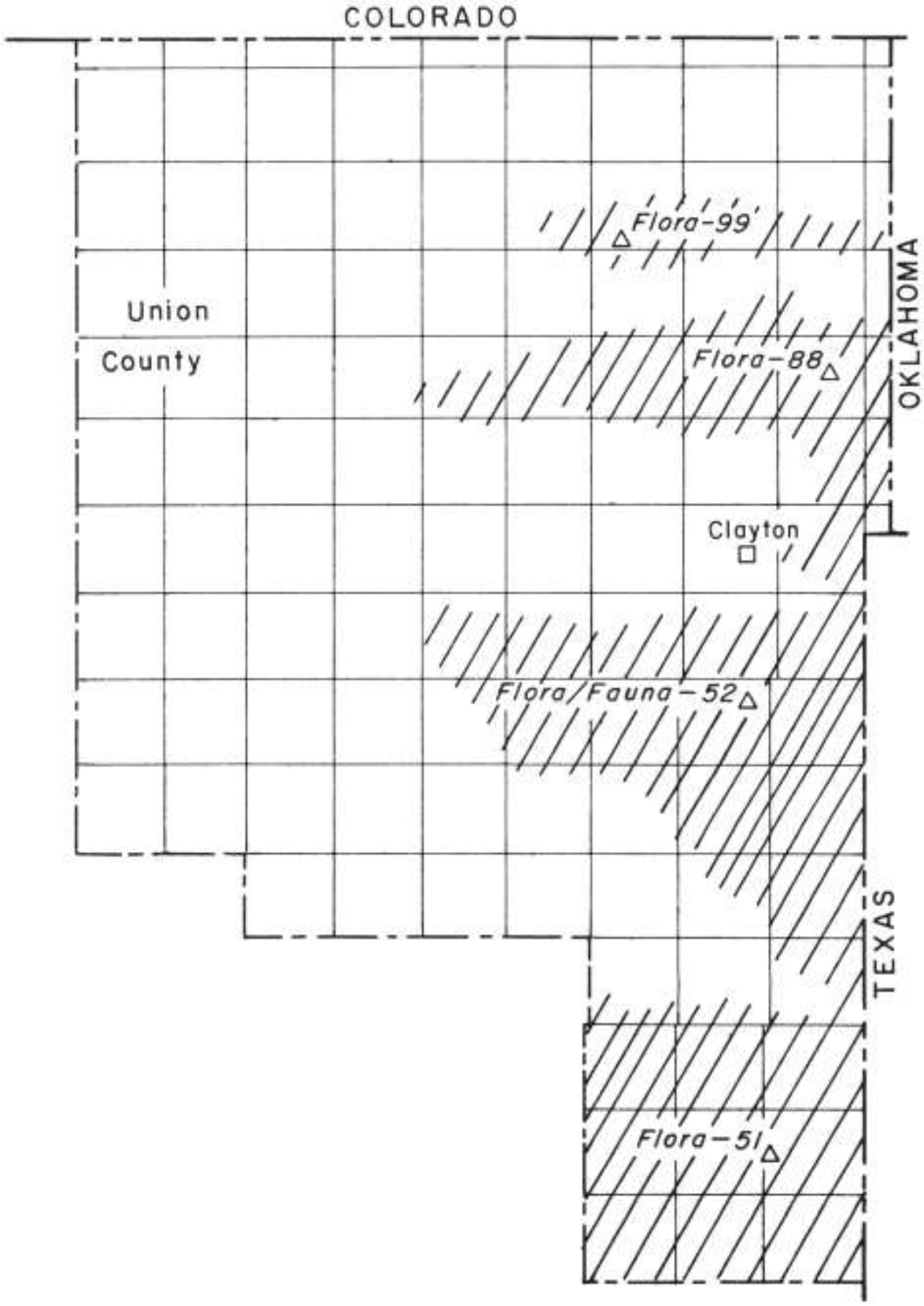


FIGURE 1—LOCATION MAP OF FOUR FLORAS AND MOLLUSCAN FAUNA DESCRIBED. Hachures show general distribution of Ogallala Formation in eastern Union County.

Abstract

Two outstandingly productive sections in northeastern New Mexico yielded fossil seed floras that confirm the correlation between clay-mineral zonation in the Ogallala Formation and that based on fossil floras. The fossil seed floras place the sections in the Ash Hollow and lower Kimball members. The Kimball Clayton South section is remarkable for the substantial seed flora it contains and is unique for the well-preserved molluscan fauna of 26 taxa, three of which have been described as new. The Seneca Northeast section not only contains a distinctive seed flora but is outstanding for the occurrence of three species of hackberry: *Celtis hatcheri* Chaney, hitherto known only from Oligocene sediments; *C. willistoni* (Cockerell) Berry, the common and widespread hackberry in the Ogallala Formation; and C. cf. *reticulata* Torrey, a species living in the area today. Ecological implications of the Clayton South molluscan fauna indicate no remarkable difference from present climate, except for lesser temperature extremes and rainfall sufficient to maintain natural marshes and/or (possibly ephemeral) ponds.

Introduction

This study is part of a larger investigation of Pliocene and Pleistocene geology and paleontology in northeastern New Mexico being reported in Circular 160 (Frye, Leonard, and Glass, 1978), but because of the uniqueness of the fossil floras in this part of New Mexico and the rarity of the molluscan assemblage found in lower Kimballian sediments at the Clayton South section, a separate report on the paleontology of the Ogallala Formation here has been prepared.

The 26 species of mollusks described from the Clayton South locality include 11 species of aquatic habitat and 15 kinds of terrestrial gastropods. These numbers compare with 22 aquatic and 25 terrestrial species reported from east-central New Mexico (Leonard and Frye, 1975) and 15 aquatic and 15 terrestrial mollusks described from southeastern New Mexico (Leonard, Frye, and Glass, 1975). Among the mollusks described in this report, 5 aquatic species and 10 terrestrial gastropods occur in common with the assemblages from the east-central segment of the state; 3 aquatic mollusks and 6 gastropods of terrestrial habit occur also in the southeast part of New Mexico. In general, the kinds of mollusks common to all three areas are those hardy kinds capable of survival in spite of climatic fluctuations. The aquatic mollusks common to all three areas include *Gyraulus circumstriatus, Gyraulus parvus,* and *Physa anatina.* Six terrestrial species are common to all three areas: *Gastrocopta cristata, Hawaiia minuscula, Pupilla blandi, Pupoides albilabris, Succinea grosvenori,* and *Succinea gelida.* Most of these hardy mollusks still survive in eastern New Mexico but in extremely sparse populations.

ACKNOWLEDGMENTS—The field work for this study was supported by the New Mexico Bureau of Mines and Mineral Resources, Dr. Frank E. Kottlowski, Director, and for whose great personal interest in these investigations we herewith express our sincere thanks. We are also indebted to Dr. John Hawley, New Mexico Bureau of Mines and Mineral Resources, for having critically read the manuscript. Dr. Kottlowski and Dr. Hawley reviewed much of the pertinent geology in the field; we are grateful for their constructive comments made at that time.

Stratigraphic zonation of Ogallala sediments

The Ogallala Formation extends from South Dakota to the southern border of New Mexico and the adjacent part of Texas. The physical stratigraphy has been discussed in many papers since Darton (1899) first introduced the term. Floral zones in western Texas, east of the part of New Mexico in this study (fig. 1), were described (Frye and Leonard, 1957) and correlated northward with floral zones and members in northwestern Kansas (Frye, Leonard, and Swineford, 1956) and with the typical sections in western Nebraska (Frye and Leonard, 1959). Correlations were based on physical stratigraphy and floral zones, with assistance at a few localities from assemblages of vertebrate fossils and from fossil mollusks. On the basis of contained fossil vertebrates and the correlation of younger sediments of the region with the Pleistocene glacial sequence of the midwest (Frye, Swineford, and Leonard, 1948), the Ogallala Formation has been considered Pliocene, with the probability that the lowermost part is Miocene.

Work on the Ogallala of eastern New Mexico prior to this study has failed to develop distinctive paleozoological or paleobotanical collections that could serve as a basis for correlating the various units in New Mexico with the regionally recognized zones to the east and north. In the absence of faunal and floral zones, the Ogallala Formation of eastern New Mexico has been divided into zones on the basis of the composition of the contained clay minerals (Frye, Glass, Leonard, and Coleman, 1974). These clay-mineral zones are distinctive and have been recognized from the southeastern part of the state (Leonard, Frye, and Glass, 1975) northward to northeastern New Mexico. The occurrence in this northeastern area of distinctive floral and molluscan assemblages, which can be correlated with the regionally described fossil zones to the east and north and placed in the sequence of clay-mineral zones traceable throughout eastern New Mexico, provides a basis for integration of the two methods of subdivision and correlation.

The clay-mineral zones are described as Zone I at the base of the formation, including at least the lower half, which is characterized by high percentages of montmorillonite (generally more than 90 percent of the total clay minerals). Zone II, above, is characterized by the presence of attapulgite (palygorskite), which typically increases in percentage upward. In a full Ogallala sequence, Zone II is not as thick as Zone I, but in thin sections Zone II may rest directly on bedrock below the Ogallala. Zone III commonly ranges in thickness from 1 or 2 ft up to 10-15 ft and is distinguishable by the presence of sepiolite, generally accompanied by attapulgite in the lower part, along with montmorillonite and minor amounts of illite and kaolinite. Although locally quite thick, in Clayton South section Zone II commonly is 3-6 ft thick.

Zone III is overlain by two thin but persistent clay-mineral zones. Zone IV lacks both attapulgite and sepiolite and contains well-crystallized montmorillonite, illite, kaolinite, and (in some places) chlorite. Zone IV generally contains abundant calcium carbonate but not to the extent that it occurs in the uppermost Zone V. Zone V, which includes the dense pisolitic limestone in its upper part, is generally only 1-3 ft thick, is the uppermost zone of the Ogallala Formation, and is characterized by weathered montmorillonite, chlorite, kaolinite, and relatively abundant illite.

The clay-mineral zones, as they occur in the sections from which faunas and floras were collected, are shown graphically in figs. 2 and 3 for the Clayton South and Seneca Northeast sections, respectively. As shown in the diagram, at Clayton South the stratigraphic position of the Fauna and Flora No. 52 is within clay-mineral Zone

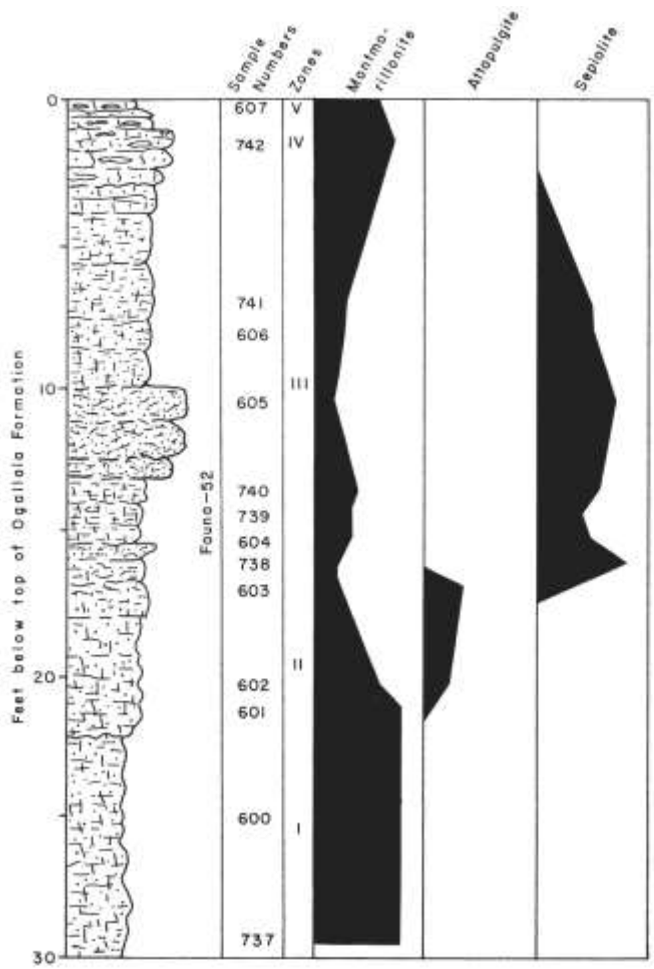


FIGURE 2—Ogallala Formation at the Clayton South section, SW¼SW¼ sec. 2, T. 24 N., R. 35 E., Union County. The three primary clay minerals are shown by percentage. Illite, kaolinite, and chlorite were also determined. The width of each mineral column represents 100 percent of the clay minerals present, and the position of Fauna 52 is shown in the lower part of Zone III. The flora (F-52) is correlated with lowest Kimball Floral Zone to the east and north. Kaolinite plus chlorite exceed 7 percent only in the upppermost sample, Zone V, where they total 12 percent. These clay-mineral zones occur in the Ogallala Formation throughout eastern New Mexico, but in this section sepiolite (Zone III) is exceptionally abundant, and attapulgite (Zone II) is exceptionally thin.

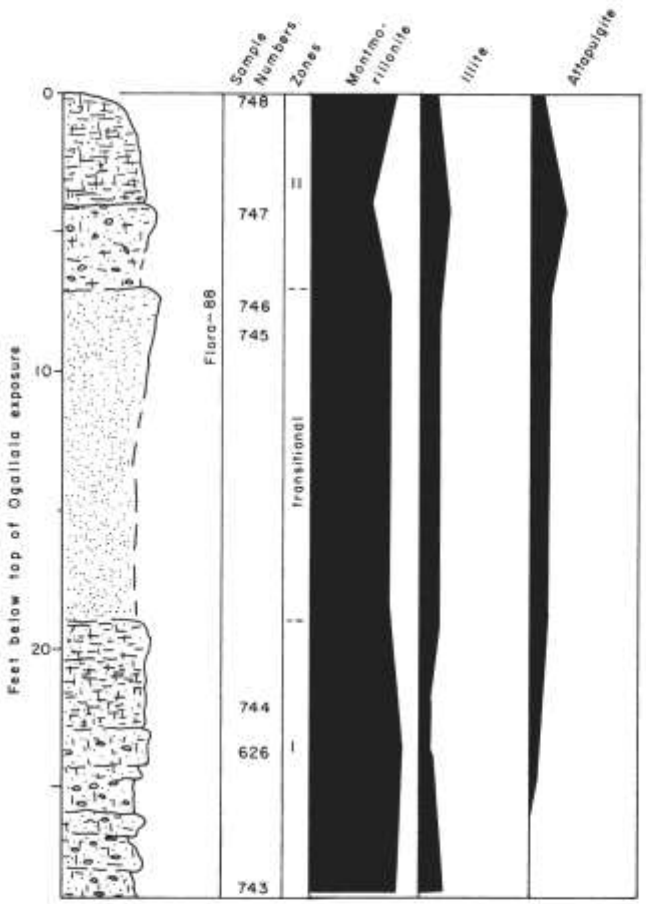


FIGURE 3—OGALLALA FORMATION AT THE SENECA NORTHEAST SECTION, SE¼NE¼ SEC. 15, T. 28 N., R. 36 E., UNION COUNTY. The position of Flora 88 is shown in the lower part of clay-mineral Zone II. The flora (F-88) is correlated with the mid-part of the Ash Hollow Floral Zone to the east and north. Sepiolite does not occur, and kaolinite plus chlorite ranges from 2-6 percent.

III, which is characterized by abundant sepiolite. The fauna and flora at this locality correlate with the lower part of the Kimball Floral Zone of western Texas and northward. Clay-mineral Zones III, IV, and V of eastern New Mexico are classed as equivalent to the Kimball Floral Zone and recognized throughout the extent of the Ogallala Formation.

Floral Assemblage No. 88, from the Seneca Northeast section (fig. 3), supports such a correlation because this flora is correlated with the mid-part of the Ash Hollow Floral Zone and falls stratigraphically within clay-mineral Zone II.

Paleontological evidence adequate for the correlation with the regional floral zones has not yet been obtained from clay-mineral Zone I in eastern New Mexico. However, as the mid-range of the Ash Hollow Floral Zone seems to occur in the lower part of clay-mineral Zone II, it is probably reasonable to extrapolate that the boundary between the Ash Hollow and Valentine Floral Zones should occur in the upper part of clay-mineral Zone I. Although this zone is well developed farther south in New Mexico, in the northeastern area of the state it is generally quite thin or absent (Frye, Leonard, and Glass, 1978).

The establishment of a correlation of the clay-mineral zones of eastern New Mexico with the previously established and widespread floral zones now gives a basis for the correlation of stratigraphic subdivisions throughout the extent of the Ogallala Formation, approximately 900 mi north-south and nearly 300 mi east-west.

Vertebrate fossils have provided the means of intercontinental correlation of Pliocene and other Tertiary units and, to a large extent, regional correlation of the Ogallala Formation (Pliocene). However, in many places vertebrate fossils are absent or at least not yet known, making it impossible to correlate local Ogallala exposures on the basis of vertebrate fossils. Our explorations of the Ogallala Formation in northeastern New Mexico have revealed nothing more than occasional chips of bone in Ogallala deposits, and we know of no local vertebrate faunal assemblages in the region.

Elias (1942) noted that fossil seeds of grasses and other plants form assemblages of stratigraphic significance; Frye, Leonard, and Swineford (1956) refined the techniques of Elias and subsequently utilized fossil seed zones to recognize horizons within the Ogallala Formation along the High Plains escarpment in Texas (1957). For reasons not yet understood, we have not found fossil seeds in the Ogallala along the escarpment of the High Plains east of the Pecos River in New Mexico, although careful searches have been conducted from Quay County to Lea County, where the escarpment loses its identity. The lone exception to the failure to find fossil seeds in this long stretch of generally excellent exposures of Ogallala sediments has been the discovery of an occasional hackberry seed, *Celtis willistoni*.

Floral assemblages

Two exposures of Ogallala sediments in Union County, the Clayton South (Flora/Fauna 52) and Seneca Northeast (Flora 88) sections, have yielded floral assemblages of fossil seeds that are sufficiently characteristic to be useful in the stratigraphic zonation of these outcrops. Two other exposures of promise are the Guy Southeast (Flora 99) and Amistad South (Flora 51) sections, where only seeds of *Celtis willistoni* were taken, but with more careful study of the outcrops, there is a probability of additional kinds of seeds being found at both of these localities.

CLAYTON SOUTH SECTION—At this exposure the fossils occur in a fine, calcite-cemented light-tan quartz sand and were recovered with some difficulty since the sand does not break down easily. Because the seeds are silicified, acid can be used to liberate them; however, this technique destroys the calcareous shells of mollusks. The flora (as now known) at this site is composed of five taxa:

Panicum elegans Elias, a millet grass
Biorbia microendocarpica (Brooks) Leonard, a borage
Biorbia levis Segal, a borage
Biorbia papillosa Leonard, a southern borage
Celtis willistoni (Cockerell) Berry, a hackberry

Although small, the floral assemblage is of interest. The occurrence of *Panicum elegans* places the assemblage in the *Panicum elegans* Floral Zone that equates with lowermost Kimball or with the transition zone in the uppermost Ash Hollow. Other evidence, primarily the stratigraphic relation to the pisolitic limestone that distinguishes the top of the formation, serves to place the exposure in lowermost Kimball. It has never been found so far north, nor in association with other species of *Biorbia*. The occurrence of *B. papillosa* in the Clayton South section clearly points to a southern climatic influence at the time of deposition.

SENECA NORTHEAST SECTION—The floral assemblage at this exposure includes seven taxa:

Stipidium grande Elias, a grass related to *Stipa*
Berriochloa amphoralis Elias, a grass
Biorbia microendocarpica (Brooks) Leonard, a borage
Biorbia papillosa Leonard, a southern borage
Celtis hatcheri Chaney, a hackberry, common in certain Oligocene deposits
Celtis willistoni (Cockerell) Berry, common Pliocene hackberry
Celtis cf. *reticulata* Torrey, a living hackberry

This floral assemblage also has useful characteristics. The two grasses, *Stipidium grande* and *Berriochla amphoralis* serve to place the flora in the Ash Hollow Flora Zone and the containing deposits in the Ash Hollow member of the Ogallala Formation. This placement is confirmed by topographic and stratigraphic setting and by clay-mineral assemblages.

An annotated checklist of the nine taxa of fossil plants known from the Ogallala Formation in northeastern New Mexico follows:

Class ANGIOSPERMAE

Subclass MONOCOTYLEDONAE

Family GRAMINEAE

Tribe STIPEAE

GENUS ***STIPIDIUM*** Elias

Stipidium grande Elias

Stipidium grande Elias, 1942, Geological Society of America, Spec. Paper No. 41, pl. 14, fig. 508.

All specimens of *S. grande* taken at the Seneca Northeast section were fragmentary, but the surface sculpture, size, and shape of some fragments were clear evidence of the identity of the fossil grass hulls. *S. grande* is known only from Ash Hollow deposits, where it is often found in association with other species of the genus *Stipidium, as* well as species of *Biorbia, Berriochloa* (especially *B. amphoralis), Celtis willistoni,* and sometimes with species of *Cryptantha (Krinitzkia). S. grande* is, therefore, not only an indicator of the Ash Hollow Floral Zone, but also a member of the rich prairie flora that flourished during Ash Hollow (Middle Pliocene) time.

GENUS ***BERRIOCHLOA*** Elias

Berriochloa amphoralis Elias

Berriochloa amphoralis Elias, 1942, Geological Society of America, Spec. Paper No. 41, p. 97, pl. 13, figs. 1-4.

The genus *Berriochloa* is similar in general characteristics to genus *Stipidium*, but the fruits tend to be much more inflated; the two genera also differ in the minute anatomy of the seed hulls. The specimens of *B. amphoralis* recovered from the Seneca Northeast section were fragmentary, but specific characters were preserved sufficiently well as to leave no doubt about the identity of the taxon. *B. amphoralis* was described from deposits called Middle Pliocene by Elias, now referred to as Ash Hollow Floral Zone or member.

Tribe PANICEAE

GENUS ***PANICUM*** Linne

Panicum elegans Elias

Panicum (sensu lato) *elegans* Elias, 1931, University of Kansas, Sci. Bull., v. 38, p. 342, pl. 28, fig. 2a-c.

P. elegans is a millet grass, characteristic of the uppermost Ash Hollow and lowermost Kimball Floral Zones or members. Elias (1942, p. 102) recognized an "early mutation," which he called *nebraskense,* but this form seems not to occur south of Nebraska. Leonard (1958, p. 1398) described a millet grass of southern distribution, which he called ***P.*** *eliasi.*

Subclass DICOTYLEDONAE

Family BORAGINACEAE

GENUS ***BIORBIA*** Elias

Biorbia microendocarpica **(Brooks) Leonard**

Biorbia microendocarpica (Brooks) Leonard, 1977, Southwestern Naturalist, v. 22, no. 4.

This new name combination that replaces the more familiar *Biorbia fossilia* is made necessary by the fact that Berry (1928) described several varieties of a species he called *Lithospermum fossilium,* without having described the species *(fossilium).* According to the International Botanical Code, Art. 43, neither the specific epithet nor the varieties described are valid under these circumstances. The first available name (somewhat unfortunately) is *microendocarpica* of Brooks (1928), who invented the name because she thought she was dealing with a hackberry *(Celtis),* presumably because the nutlets were rugose. Leonard (1977a) has documented the history of the valid name combination.

B. microendocarpica is a common seed in the Ogallala Formation, most abundant in the Ash Hollow but having feeble beginnings in the Valentine member and extending into the lowermost part of the Kimball Floral Zone.

Biorbia levis **Segal**

Biorbia levis Segal, 1966, University of Kansas, Sci. Bull., v. 46, p. 499, figs. 2-3.

As the name suggests, this is a smooth form of *Biorbia,* the seeds being generally similar in size and shape to *B. microendocarpica,* but without the rugose surface sculpture of that species. It frequently occurs with *microendocarpica.* Segal (1966) also has described varieties of *levis* and *microendocarpica* on the basis of size, but in our judgment these are not real entities.

Biorbia papillosa **Leonard**

Biorbia papillosa Leonard, 1958, University of Kansas, Sci. Bull., v. 38, p. 1396, pl. 1, figs. 1-3.

B. papillosa replaces *microendocarpica* in the southern Great Plains; the two have never before been discovered together. This fact probably indicates that southern climatic influences were being felt in the area of what is now Union County, New Mexico, at the time the sediments were deposited at the Seneca Northeast and Clayton South sections. As the name suggests, *B. papillosa* has a surface sculpture that is papillose rather than rugose. Only a few specimens were found in the sections mentioned, but preservation was excellent.

Family ULMACEAE

GENUS *CELTIS* Linne

Celtis hatcheri **Chaney**
pl. 1, fig. 12

Celtis hatcheri Chaney, 1925, Carnegie Institution of Washington, Contributions to Paleontology, p. 54, fig. 8.

C. hatcheri has a smaller fruit than that of the common *C. willistoni,* which is found throughout the Ogallala Formation. *C. hatcheri* was described from Oligocene beds near Scenic, South Dakota (Chaney, 1925), but the species is known also from beds of similar age exposed in Toadstool Park, Sioux County, Nebraska.

The endocarps of *C. hatcheri* are smaller than those of *C. willistoni* and are prolate (rather than spherical) and somewhat flattened; the tip is drawn to a point, but the base is rounded and almost featureless. The surface sculpture of the specimens from the Seneca Northeast section is distinctly rugose; individuals are silicified but otherwise similar to the original fruit. Those from the two Oligocene exposures are replaced by calcite and are probably casts of hollow molds because surface sculpture is more or less preserved. Like other *Celtis* fruits, both fossil and recent, the suture divides the endocarps into symmetrical halves.

It is entirely unexpected to find endocarps of C. *hatcheri* in a late Pliocene deposit, but the four specimens are in an excellent state of preservation; one is split along the suture and reveals the interior of the seed.

Celtis willistoni **(Cockerell) Berry**
pl. 1, fig. 13

Celtis willistoni (Cockerell) Berry, 1928, American Museum Novitates, no. 298, p. 1-5, figs. 1-6.

The endocarps of *Celtis willistoni* are locally abundant and/or sparingly distributed throughout the Ogallala Formation. In fact, the fossils are so widely dispersed (both horizontally and vertically) that the endocarps have very little value for stratigraphic interpretations. The fossils do identify the Ogallala Formation, however, since only an occasional reworked seed has been found in Pleistocene deposits. Endocarps of C. *willistoni* are almost perfectly spherical, but are distinctly smaller than the fruits of the various living species of *Celtis* in the Great Plains region. Large, rather compact, aggregations of fruits of *C. willistoni* are often seen in Ogallala deposits, giving rise to various speculations concerning the origin of such masses; storehouse accumulations made by rodents or fecal deposits made by rhinoceroses are two common explanations.

Celtis cf. reticulata **Torrey**

Celtis reticulata Torrey, Stevens, 1973, University Press of Kansas, Woody Plants of North Central Plains, p. 144, figs. 1-10.

At the Seneca Northeast site, large spherical endocarps of a *Celtis* were recovered. The size and surface sculpture suggests *C. reticulata* because these fossils are too large to fall within the size range of *C. willistoni.* Their specific identity remains in doubt, especially because the taxonomy of *Celtis* is, as botanists are fond of saying, in a state of confusion. Similar seeds have not been previously recognized in Ogallala deposits. Five well-preserved seeds of C. cf. *reticulata* were recovered at the Seneca Northeast site.

In summary, the floral assemblage from the two sites in Union County consists of three grasses, *Stipidium grande, Berriochloa amphoralis,* and *Panicum elegans;* three boraginaceous plants, *Biorbia microendocarpica,* *B. Levis,* and *B. papillosa;* and three taxa of *Celtis, C. hatcheri, C. willistoni,* and C. cf. *reticulata.*

The remarkable occurrence of three species of *Celtis,* one an Oligocene species, *C. hatcheri;* one a typical Pliocene species, *C. willistoni;* and one a modern species, C. cf. *reticulata,* is the first record of *C. hatcheri* in deposits younger than Oligocene, the first record of a modern species in the Pliocene, and the first record of these three species in deposition together.

The molluscan fauna

Previous reports of molluscan assemblages from the Ogallala Formation are not numerous. Frye, Leonard, and Swineford (1956) reviewed the scant literature on the subject and described fossil assemblages from northwestern Kansas; all (except one from a single locality in Wallace County where a few species of well-preserved shells were found) were represented by hollow molds of shells, many of which were cast in plastic with sufficient success at identification. While most of the species reported by Frye, Leonard, and Swineford are different from those in the Clayton South deposit, the significant difference between the two areas is that in northwestern Kansas, branchiate snails belonging to the genus *Calipyrgula* are common, while branchiates in the Clayton assemblage are absent. Taylor (1960) reported a molluscan faunal assemblage from the Buis Ranch deposits of Hemphillian age from southwestern Kansas; he reported no branchiate gastropods from the Buis Ranch local fauna nor from other assemblages thought to be of the same age.

The deposits of early Kimballian age at the Clayton South section are strikingly unusual because they contain, in a zone of calcite-cemented fine sand, a diagnostic flora represented by fossil seeds and an abundant molluscan fauna of well-preserved shells. Although Ogallala deposits sometimes display molds of molluscan species, very few occurrences of well-preserved molluscan shells are known in the Ogallala Formation. In the Clayton South section, 26 taxa of mollusks have been recovered; these include one sphaeriid clam, 10 aquatic gastropods, and 15 taxa of terrestrial gastropods. Each kind of mollusk is listed below in systematic order, together with pertinent notes. Synonymies are limited to a citation of the original description and one modern work in which an illustration of the species occurs.

Class PELECYPODA

Order TELEODESMACEA

Family SPHAERIIDAE

GENUS *PISIDIUM* Pfeiffer 1821

Pisidium casertanum (Poli)
pl. 1, fig. 1

Cardium casertanum Poli, 1791, Test, utr. Sicilia, p. 65, pl. 16, fig. 1.
Pisidium casertanum (Poli) Herrington, 1962, Rev. Sphaeriidae of North America, p. 33, pl. 4, fig. 1; pl. 7, fig. 7.

Pisidium casertanum is a clam only a few millimeters long of cosmopolitan distribution and varied habitat. It is the most common among the Eurasian pisidia and has been recorded from Australia, New Zealand, and Tasmania. In Africa it occurs as far south as Rhodesia; in the western hemisphere it has been recorded in Canada as far north as the Arctic Circle, and it is widespread in the United States, Puerto Rico, Central America, and South America. As a fossil it has been found in the Laverne Formation (Late Miocene) of Beaver County, Oklahoma; Herrington (1962) characterized these specimens as "quite modern looking." *P. casertanum* occurs in bogs, ponds, and swamps that may dry up for part of the year, and in the outlets of springs, in creeks, rivers, and lakes, including the Great Lakes. It is, therefore, scarcely a surprise to find this little clam in the Clayton South deposits. About 30 valves were recovered.

Class GASTROPODA

Order PULMONATA

Suborder BASOMMATOPHORA

Family LYMNAEIDAE

GENUS *LYMNAEA* Lamarck 1799

The members of the genus *Lymnaea* are so variable and so responsive to local ecological conditions that the systematics of the genus has long been in a state of considerable confusion. F. C. Baker, in his monumental work on the family Lymnaeidae of North America (1911), recognized several genera in the genus *Lymnaea* and literally hundreds of species, subspecies, and varieties. On the other hand, Hubendick (1951) reduced the number of recognized taxa to a small part of those recognized by Baker. Fossil specimens introduce another complication: the lack of the soft anatomy upon which various genera in the family Lymnaeidae are based. Therefore, not only in the Lymnaeidae, but also in other groups of aquatic and even terrestrial gastropods, it is necessary to use "form species" by matching fossil shells with those of their modern counterparts where these exist. The following accounts of species use this procedure.

Lymnaea dalli F. C. Baker
pl. 1, fig. 4

Lymnaea dalli Baker, 1907, Nautilus, 20:125
Lymnaea dalli Baker, Leonard and Frye, 1975, New Mexico Bureau of Mines and Mineral Resources, Mem. 30, p. 24, pl. 2, fig. 20.

Hubendick (1951, p. 185) synonymizes *L. dalli* with *L. humilis,* a treatment with which we are inclined to agree; but since this tiny gastropod is so widely recognized, we continue to treat it as a distinct species. *L. dalli* is an animal that frequents the borders of marshes and ponds and is more often out of water than in it. It is widely distributed in North America except on the east and west coastal regions. *L. dalli* is closely related to *L. parva* but differs from it by its smaller size and the character of its whorls.

Lymnaea parva Lea
pl. 1, fig. 3

Lymnaea parva Lea, 1841, American Philosophical Society, Proc., 2:33.
Lymnaea parva Lea, Leonard and Frye, 1975, New Mexico Bureau of Mines and Mineral Resources, Mem. 30, p. 24, pl. 2, fig. 18.

Only about 10 examples of *L. parva* were recovered from the sediments of the Clayton South section; about five examples of *L. dalli* were found during the same operation. *L. parva* lives on the borders of ponds and marshes or along sluggish streams; it is even more inclined to leave the water than is *L. dalli*, but it is restricted to wet or moist situations when out of the water. *L. parva* is distributed in North America from southern Canada through much of the United States, except for the west coastal region.

Lymnaea bulimoides Lea
pl. 1, fig. 6

Lymnaea bulimoides Lea, 1841, American Philosophical Society, Proc., 2:33.
Lymnaea bulimoides techella (Haldeman) Leonard, 1959, University of Kansas Museum of Natural History, Misc. Pub., no. 20:48, pl. 1, fig. 6.

Although Hubendick (1951, p. 129) recognized no subspecies of *L. bulimoides* because he found no geographical consistency in the occurrence of variations, he based his anatomical studies on specimens collected in Texas and labeled *L. b. techella*. The specimens from the Clayton South deposits resemble those variants that have been called *techella*. Leonard (1959, p. 48) thought that *cockerelli* was primarily found in western Kansas, while *techella* occurred in the eastern part of the state; this supposition is generally true, but both variants occur in all parts of Kansas. *Bulimoides* occurs in the lower Mississippi valley and west to California. Since form *cockerelli* seems to occur most frequently in ephemeral bodies of water, it may be that related ecological factors are responsible for the form of the shell. At any rate, *L. bulimoides* is much more nearly an aquatic snail than are *L. dalli* and *L. parva*. Since Hubendick (1951, p. 130) found *bulimoides* anatomically related to *L. cubensis*, it may well be that *bulimoides* constitutes a southern element in the Clayton South fauna.

Lymnaea claytonensis Leonard
pl. 1, fig. 5

Lymnaea claytonensis Leonard, 1977, Nautilus, v. 91, no. 4, fig. 1.

L. claytonensis has a slender, turreted form, 5-6 whorls, and an elongate elliptical aperture occupying about half the total length of the shell. Like *L. bulimoides*, it seems to belong in the *Lymnaea humilis-truncatula-cubensis* complex and may constitute another southern element in the Clayton South molluscan fauna. This new species is not known elsewhere in Ogallala or other deposits, and its ecological requirements can only be surmised from its associates. More than 20 shells representing various age groups were assignable to *L. claytonensis;* some of them, although damaged, are larger than the type specimen, which measures about 7 mm in length.

Family PLANORBIDAE

GENUS ***GYRA*** *UL US* Charpentier 1837

Gyraulus parvus (Say)
pl. 1, fig. 10

Planorbis parvus Say, 1817, Nicholson's Encyclopedia, pt. 2, v. 1 (no pagination), pl. 1, fig. *5*.
Gyraulus parvus (Say) F. C. Baker, 1928, Freshwater Mollusca Wisconsin, pt. I, p. 374, pl. 23, figs. 27-31, 39.

Gyraulus parvus has been reported from New Mexico by Leonard and Frye (1975, p. 23) and by Leonard, Frye, and Glass (1975, p. 12). It is a small planorbid snail about 4 mm in diameter, frequenting shallow, quiet bodies of water where it lives on vegetation. *G. parvus* is usually the most numerous of planorbid species where it occurs, although some records reflect confusion with other species of *Gyraulus*. This snail is characterized by rapidly increasing whorls, the last flattened above, and by the obliquely placed aperture. *G. parvus* is widely known in North America east of the Rocky Mountains.

Gyraulus circumstriatus (Tryon)
pl. 1, fig. 11

Planorbis circumstriatus Tryon, 1866, American Journal of Conchology, pt. 2, p. 113, pl. 10, figs. 6-8.
Gyraulus circumstriatus (Tryon) Leonard, University of Kansas Museum of Natural History, Misc. Pub. no. 20, p. 64, pl. 2, figs. 6-8.

G. circumstriatus is so often confused with *G. parvus* that it is difficult to determine the exact range of either. As understood, *C. circumstriatus* is basically a snail of the northeastern United States in its present distribution. Records of fossils do occur farther west, however; Leonard, Frye and Glass (1975) reported finding *G. circumstriatus* in Wisconsinan sediments in southeastern New Mexico. *G. circumstriatus* may be distinguished from *G. parvus* by the fact that its whorls increase in diameter toward the aperture much more slowly than those of *parvus*, the whorls are much more rounded above, and the aperture is less oblique. *G. circumstriatus* is found living on vegetation in quiet water, often in association with *G. parvus, Gundlachia meekiana, Helisoma,* and *Physa*.

Family ANCYLIDAE Menke

GENUS ***FERRISSIA*** Walker 1903

Ferrissia parallela (Haldeman)
pl. 1, fig. 8

Ancylus parallelus Haldeman, 1841, Monogr. Limnaeidae North America, pt. 2, p. 3.
Ferrissia parallela (Haldeman) Walker, 1918, Synopsis and catalogue, freshwater mollusca, p. 119.

This seems to be the first record of this species, at least as a fossil, in New Mexico. *Ferrissia parallela* is a small aquatic gastropod with a limpetlike shell, which is appressed against smooth vegetation, shells of larger mollusks-such as clam shells-or other smooth objects, including bottles and metal cans in the water. The species is primarily distributed east of the Great Plains, in the northern part of the United States and Canada; a few records occur west of the Rocky Mountains, perhaps as the result of trade in aquatic plants such as water lilies. As the name suggests, *F. parallela* is characterized by a shell having nearly parallel sides; the shell is small, rarely exceeding 5 mm in length. It is the largest of the three species of *Ferrissia* in the Clayton South molluscan fauna.

Ferrissia shimekii (Pilsbry)
pl. 1, fig. 7

Ancylus shimekii Pilsbry, 1890, Nautilus, v. 4, p. 48.
Ferrissia shimekii (Pilsbry) F. C. Baker, 1928, Freshwater Mollusca, Wisconsin pt. I, p. 402, pl. 24, figs. 14-15.

Ferrissia shimekii is a minute aquatic gastropod, having a patelliform shell about 2.5 mm long. It has not been previously reported from New Mexico, and records of it are widely scattered, indicating a wide distribution. Leonard (1959) reported a few localities of occurrence in eastern Kansas; the small size of the shell makes *F. shimekii* difficult to find. It lives in quiet water on smooth objects, such as hard, smooth leaves; reeds and sedges; and the shells of freshwater mussels. Only a few specimens were found in the collections at Clayton South section.

Ferrissia tarda (Say)
pl. 1, fig. 9

Ancylus tardus Say, 1830, New Harmony Disseminator, Jan. 15, 1930.
Ferrissia tarda (Say) F. C. Baker, 1928, Freshwater Mollusca, Wisconsin, pt. I, p. 399, pl. 24, figs. 6-9.

Ferrissia tarda is somewhat larger than *F. shimekii;* shells average slightly more than 3.0 mm in length. Like *F. parallela* and *F. shimekii,* this species has not been previously reported from New Mexico. Unlike *parallela* and *shimekii, F. tarda* seems to occur most frequently in clear, swift, cool water (Baker, 1928, p. 401); its occurrence in the Clayton South fauna seems out of character for *F. tarda,* where it is represented only by a few examples. Its general distribution is east of the Mississippi River, from southern Canada and Maine to Illinois and Ohio.

Family PHYSIDAE Dall

GENUS ***PHYSA*** Draparnaud 1801

Physa anatina Lea
pl. 1, fig. 2

Physa anatina Lea, 1864, Academy of Natural Science, Philadelphia, Proc., p. 115.
Physa anatina Lea, Leonard and Frye, 1975, New Mexico Bureau of Mines and Mineral Resources, Mem. 30, p. 24, pl. 1, fig. 5.

The identity of *Physa anatina* in the Clayton South molluscan fauna is verified by the prominent authority, Dr. William Clench; the numerous specimens recovered, however, are much smaller than the typical examples living in the Great Plains region today and in most of the Pleistocene populations in eastern New Mexico. *P. anatina* (as well as other species of the genus) is notorious for its phenotypic response to local environmental conditions. *P. anatina* and *Gyraulus parvus* are the two species represented by the most individuals in the Clayton South section, either terrestrial or aquatic.

Suborder STYLOMMATOPHORA

Family ZONITIDAE

GENUS *EUCONULUS* Reinhardt 1883

Euconulus fulvus (Muller)
pl. 2, fig. 25

Helix fulva Müller, 1774, Hist. Vermiun, 2:56.
Euconulus fulvus (Muller) Pilsbry, 1946, Land Mollusca of North America, v. 2, pt. 1, p. 235, fig. 117.

Euconulus fulvus is an holarctic species of northern distribution in the United States. This tiny terrestrial gastropod is not known to live in the southern High Plains region. It is a species that thrives in damp situations, in forested areas under moist leaves, beneath the started bark of fallen trees, and at the base of decaying stumps. Such conditions were extremely limited in the area of the Clayton South section when these sediments were being deposited, as is evident from the fact that only two examples of the species were found.

GENUS ***HAWAHA*** Gude 1911

Hawaiia minuscula (Binney)
pl. 2, fig. 28

Helix minuscula A. Binney, 1840, Boston Journal of Natural History, 3:435, pl. 22, fig. 4.
Hawaiia minuscula (Binney) Pilsbry, 1946, Land Mollusca of North America, v. 2, pt. 1, p. 420.

One of the most ubiquitous of North American terrestrial gastropods is *Hawaiia minuscula,* although it is less populous in the extreme western part of the country. It has a minute, discoid shell, which is transparent to white. The animal is found living under stones and logs in both upland and lowland situations, and it has a remarkable adaptability to local environmental conditions, especially as regards the amount and distribution of rainfall, but also as regards the mineral composition of local soils. *H. minuscula* often is found in nurseries and greenhouses and seems to have been scattered over the world as a stowaway on nursery stock. Strangely, only five examples of *H. minuscula* were in the Clayton South collections.

Family SUCCINEIDAE

GENUS *SUCCINEA* Draparnaud 1801

Succinea grosvenori Lea
pl. 2, fig. 26

Succinea grosvenori Lea, 1864, Proc., Academy of Natural Science, Philadelphia, p. 109.
Succinea grosvenori Lea, Pilsbry, 1948, Land Mollusca of North America, v. 2, pt. 2, p. 819, figs. 442H, 444, 452.

As now understood, *S. grosvenori* tolerates an extremely wide variation in local environmental conditions; it ranges from the warm and humid Gulf Coast region to arid High Plains environments. The species frequently emerges from cover in semi-desert sagebrush habitats and crawls on vegetation in great numbers when a rare rainy period occurs. On the other hand, because adaptation in succineids has involved the soft anatomy more than it has involved the shells, it is by no means certain that all the shells called *grosvenori* by us and by other authors are actually that species. Unfortunately, the material on which Pilsbry (1948, fig. 442H) based his illustrations of the soft anatomy of *S. grosvenori* has not been found. Specimens of *grosvenori* are not numerous in the Clayton South fauna.

Succinea gelida F. C. Baker
pl. 2, fig. 27

Succinea grosvenori gelida F. C. Baker, 1927, Nautilus, 40:118.

There seems to be no reason to refer this small succineid to *grosvenori* even if some specimens do resemble specimens of *grosvenori;* for one argument, *gelida* occurs in the absence of *grosvenori* as well as with it. There seems to be more reason to refer *gelida* to the genus *Catinella*, but the absence of the soft anatomy *(gelida* is known only as a fossil) does not permit either confirmation or denial of this possibility. *S. gelida* is smaller than *grosvenori*, the aperture is more nearly round, and the spire-for the size of the shell-is higher. Like *grosvenori*, *gelida* is not numerous in the Clayton South deposits.

Family PUPILLIDAE
GENUS *GASTROCOPTA* Wollaston 1878

Gastrocopta pilsbryana (Sterki)
pl. 2, fig. 21

Pupa pilsbryana Sterki, 1890, Nautilus, 3:123.
Gastrocopta pilsbryana (Sterki) Pilsbry, Land Mollusca of North America, v. 2, pt. 2, p. 890, figs. 477-478.

This minute terrestrial gastropod is known in the Clayton South deposits from a single typical example. It resembles some examples of *G. debilis*, except the crest behind the aperture is weak, there is an impression over the lower palatal fold, and the basal fold is prominent. The example is also larger than usual, measuring 2.8 mm in length. *G. pilsbryana* occurs in Arizona and New Mexico, usually in the mountains; the significance of a single example in the Clayton South fauna is difficult to assess.

Gastrocopta cristata (Pilsbry and Vanatta)
pl. 2, fig. 18

Bifidaria procera cristata Pilsbry and Vanatta, 1900, Proc., Academy of Natural Science, Philadelphia, p. 595, pl. 22, figs. 4-5.
Gastrocopta cristata (Pilsbry and Vanatta) Pilsbry, Land Mollusca of North America, v. 2, pt. 2, p. 911, fig. 493:6, 8-12, Philadelphia.

Only three examples of *Gastrocopta cristata* were recovered from the deposits at the Clayton South section, but these are entirely typical of the species. *G. cristata* is distributed from eastern Oklahoma to Arizona. This small pupillid gastropod is about 3 mm in length; it lives today in woodland and border situations. This species was reported by Leonard, Frye, and Glass (1975) from southeastern New Mexico and, by Leonard and Frye (1975) from eastern New Mexico.

Gastrocopta debilis Leonard
pl. 2, fig. 23

Gastrocopta debilis Leonard, 1977, Nautilus, v. 91, no. 4, October.

Gastrocopta debilis is a small gastrocoptid, about 2.5 mm in length, having five whorls and four denticles, the two palatals being very weakly developed. Among a hundred shells, four have adequately developed palatal folds, and in four of them the palatal folds are essentially absent. *G. debilis* superficially resembles *G. pellucida parvidens* of Sterki but differs from that species in having a simple angulo-parietal fold and in having a prominent crest behind the peristome. *G. debilis* differs from *G. corticaria* in several ways: *G. corticaria* lacks the crest behind the peristome, the angulo-parietal fold is not simple, and the two palatals in *corticaria* are strongly developed. Judging from the relative abundance of this gastropod in the Clayton South deposits, *G. debilis* was a locally successful terrestrial snail. At present, it is not known elsewhere.

Gastrocopta arena Leonard
pl. 2, fig. 22

Gastrocopta arena Leonard, 1977, Nautilus, v. 91, no. 4, p. 143-45, figs. 1-3, October.

Gastrocopta arena is a minute terrestrial gastropod, little more than 2 mm in length. It bears a striking resemblance to a diminutive *G. armifera* but differs from that species in characteristics other than size. *G. arena* is known only from the holotype and three paratypes, the latter all variously damaged. The small number of specimens recovered does not permit speculation on the significance of this gastropod.

GENUS *PUPOIDES* Pfeiffer 1854

Pupoides albilabris (C. B. Adams)
pl. 2, fig. 16

Pupa albilabris "Ward's Letter," C. B. Adams, 1841, American Journal of Science 40:271. (New name for *Cyclostoma marginata*, Say)
Pupoides albilabris (C. B. Adams) Pilsbry, 1948, Land Mollusca of North America, v. 2, pt. 2, p. 921, fig. 499.

This species was first noted by Thomas Say, who gave it a previously used name, *Cyclostoma marginata*. The correct name of the species, still not entirely clear, is a matter of technical history not appropriate here. The shell is conical, and the aperture is reflected, white, and very strong. Shells are about 5 mm in length. *P. albilabris* is distributed in North America from southeastern Canada and the northeastern United States to northern Mexico. It does not occur in extreme western parts of the United States.

Pupoides modicus (Gould)
pl. 2, fig. 14

Pupa modica Gould, 1848, Proc., Boston Society of Natural History, 3:40.
Pupoides modicus (Gould) Pilsbry, 1948, Land Mollusca of North America, p. 923, fig. 499:13-15, Philadelphia.

In spite of the fact that the distribution of the living species of *P. modicus* is limited to the extreme southeastern United States, eight specimens from the Clayton South deposits are referred to *P. modicus* on the basis of size and shell characteristics. The shell is more broadly conical but smaller than that of *P. albilabris,* and the lip is white and reflected but not thickened. There is no indication of the small angular lamella sometimes present in *P. albilabris.* Although the evidence is not strong (since shells of *Pupoides* vary so widely within accepted limits of species), it may be that *P. modicus,* like *Lymnaea bulimoides,* represents a southern element in the Clayton South fauna.

Pupoides hordaceous (Gabb)
pl. 2, fig. 17

Pupa hordacea Gabb, 1866, American Journal of Conchology, 2:331, pl. 21, fig. *7.*
Pupoides hordaceous (Gabb) Pilsbry, Land Mollusca of North America, v. 2, pt. 2, p. 924, fig. 499:11, 12.

This species has been known by various names; its nomenclatural history has been discussed at length by Pilsbry and Vanatta (1900). *P. hordaceous* is a species of the arid Southwest but was previously much more widespread; it occurs in Pleistocene faunas over a much wider region. Its frequent occurrence in drift may reflect this Pleistocene distribution. Pilsbry (1948, p. 925) mentions that "in deposits" at Las Vegas, New Mexico, *P. hordaceous* occurs with *P. inornatus. P. hordaceous* is an easily recognized snail; the shell has the general form of the genus, but the whorls are provided with obliquely directed riblets. *P. hordaceous* is also somewhat less conical and more cylindrical than the other species of *Pupoides,* except for *P. inornatus.* Only two shells of *P. hordaceous* were recovered from the Clayton South deposits.

Pupoides inornatus Vanatta
pl. 2, fig. 15

Pupoides inornata Vanatta, 1915, Nautilus, 29:95.
Pupoides inornatus Vanatta, Pilsbry, 1948, Land Mollusca of North America, v. 2, pt. 2, p. 926, fig. 499:10.

P. inornatus resembles *P. hordaceous* but lacks the oblique riblets of the latter. It is a montane species, ranging from the Rocky Mountains eastward, while *P. hordaceous* ranges toward the west; the two species overlap in their distribution in eastern New Mexico. Shells from living animals are rare but are known from several localities, such as the Pike's Peak area. Only a single specimen assignable to *P. inornatus* was taken from the Clayton South deposits.

P. albilabris, P. hordaceous, and *P. inornatus* have been reported in New Mexico by us, *P. albilabris* from southeastern New Mexico at 6 Pleistocene stations (Leonard, Frye, and Glass, 1975) and from east-central New Mexico at 16 Pleistocene stations (Leonard and Frye, 1975). We reported a single specimen of *P. inornatus,* and *P. hordaceous* from 4 localities. *P. modicus* has not been previously reported from New Mexico.

GENUS *PUPILLA* Leach 1831

Pupilla blandi Morse
p1. 2, fig. 20

Pupilla blandi Morse, 1865, Ann. Lyc. Natural History, New York, 8:5, fig. 8.
Pupilla blandi Morse, Pilsbry, 1948, Land Mollusca of North America, v. 2, pt. 2, p. 929, fig. 502:1-5.

Pupilla blandi has a short cylindrical shell, with 6 whorls that bear delicate, diagonal striae. Typically, the shell has three denticles in the aperture: one on the parietal margin, one on the columellar margin, and one deep within the aperture in the palatal position. *P. blandi* is a species distributed from South Dakota to New Mexico and southwestward. Its even wider Pleistocene distribution results in fossil shells occurring as drift shells, leading to false reports of its actual occurrence. *P. blandi* can be confused with *P. muscorum,* but *P. blandi* differs by its relatively shorter shell and the three denticles mentioned; *P. muscorum* usually bears no denticles, although the parietal denticle may be present, and shells of *P. blandi* may lack one or more denticles occasionally. *P. muscorum* is a circumboreal species that spread southward during the various Pleistocene climatic oscillations, while *P. blandi* seems to be a western montane species that spread out onto the Great Plains at favorable climatic periods. Shells of *P. blandi* are rare in the Clayton South deposits, and *P. muscorum* is entirely absent there.

GENUS *VERTIGO* Milner 1774

Vertigo milium (Gould)
pl. 2, fig. 19

Pupa milium Gould, 1840, Boston Journal of Natural History 3:402, 4:359.
Vertigo milium (Gould) Pilsbry, 1948, Land Mollusca of North America, v. 2, pt. 2, p. 944, fig. 509.

Vertigo milium is an extraordinarily small terrestrial gastropod—the length is about 1.5 mm—having the typical shell form of species of *Vertigo.* The aperture is almost filled with a complex series of denticles—so crowded is the aperture that one wonders how the animal can emerge. *V. milium* ranges from Maine and Quebec to the Florida Keys and westward to Arizona; it occurs also in Jamaica, the Dominican Republic, and Mexico. This snail is a rather common fossil in Pleistocene deposits in the southern and central Great Plains region. *V. milium* apparently requires calcium-rich soils and considerable moisture and is most often found in damp leaves and wet grass near water. Leonard and Frye (1975, p. 18) report *V. milium* from 5 localities in east-central New Mexico, but it was not reported from southeastern parts of the state. *V. milium* is represented in the South Clayton fauna by about 20 shells.

Family VALLONIDAE
GENUS *VALLONIA* Risso 1826

***Vallonia perspectiva* Sterki**
p1. 2, fig. 24

Vallonia perspectiva Sterki, 1893, Manual of Conchology, 8:257, pl. 33, figs. 39-45.
Vallonia perspectiva Sterki, Pilsbry, 1948, Land Mollusca of North America, v. 2, pt. 2, p. 1033, fig. 553.

V. perspectiva is one of the smaller members of the genus; it is about 2 mm in diameter, approximately the same size as *V. parvula*, which differs by having a thickened lip on the peristome. *V. perspectiva*, of thin texture and delicate ribs, is often numerous locally; its general distribution is erratic, which may in part reflect confusion with other species. Reported localities range from the eastern United States to Minnesota, with scattered occurrences in the Great Basin. Pilsbry (1948) reports several localities in New Mexico, some of them in drift that may represent fossil shells. In the Clayton South fauna, the species is known from a single but characteristic specimen. *V. perspectiva* has not been previously reported as a fossil in New Mexico.

Environmental implications of the fauna

The relatively large number of taxa (26) from the Clayton South section indicates favorable local habitats for a variety of mollusks. The largest number of mollusks from a single Pleistocene locality in the northeastern sector of New Mexico is 14, but two Pleistocene localities west of Fort Sumner (Leonard and Frye, 1975, fig. 6) yielded 21 and 25 taxa respectively, and another Pleistocene deposit north of Milnesand, Roosevelt County, produced 20 species of mollusks. In general, however, in all of eastern New Mexico local Pleistocene molluscan assemblages tend to number less than ten.

All 11 species of aquatic mollusks (one sphaeriid clam and 10 pulmonate gastropods) are able to survive in ephemeral bodies of water for varying lengths of time. The only true branchiate is *Pisidium casertanum*, but it is known to survive for months in damp mud or in holes excavated by insects or crayfishes. There is, therefore, nothing in the assemblage of aquatic mollusks to indicate perennial water as a local habitat. The majority of the aquatic mollusks—we can only assume the habitat requirements of *Lymnaea claytonensis—live* today in ponds, small streams, or the quiet reaches of larger streams, where such organisms as the ancylids and gyraulids live on aquatic vegetation. Today, the lymnaeids in the assemblage tend to frequent the damp shores of streams and ponds rather than to live in open water, but *L. bulimoides* is often found in water, where it lives on vegetation such as reeds and sedges, sometimes emerging from the water on these plants. At present the area around the Clayton South section supports an extremely meager aquatic molluscan fauna, and there is nothing to indicate more favorable conditions in the recent past.

The gastropods of terrestrial habitat preference are mainly forest border types that can maintain themselves in gallery woodland along streams; they live in damp leaves and other organic litter near streams and ponds. Many of them, such as *Euconulus fulvus*, the pupillas, and some species of *Pupoides*, are here montane species that tend to extend their ranges into the foothills and plains. There is nothing in the terrestrial assemblage to indicate significantly cooler climatic conditions when the Clayton South deposits were being formed; the most that can be inferred is a more stable climate, with perhaps slightly greater average annual rainfall and lacking the extreme hot, dry summers now characteristic of the area.

References

Baker, F. C., 1911, The Lymnaeidae of North and Middle America: Chicago Academy of Science, Spec. Pub. No. 3, p. i-xvi, 1-539, 58 pls., 51 figs.

, 1928, The freshwater mollusca of Wisconsin: Wisconsin Geological and Natural History Survey, Bull. 70, pt. 1, Gastropoda, p. 1-507, 28 pls.

Berry, E. W., 1928, Fossil nutlets of the genus Lithospermum: U.S. National Museum, Proc., v. 73, art. 13, p. 1-3, 1 pl.

Brooks, B. W., 1928, A new species of fossil hackberry *(Celtis)* from the "Loup Fork" Miocene: Carnegie Museum Annals, v. 18, p. 299, pl. 17, fig. 1

Chaney, R. W., 1925, Description of a fruit species from the White River Formation of South Dakota: Carnegie Institution of Washington, Contributions to Paleontology, p. 54-56, pl. 1, fig. 8

Darton, N. H., 1899, Preliminary report on the geology and water resources of Nebraska west of the one hundred and third meridian: U.S. Geological Survey, 19th annual report, pt. 4, Hydrology, p. 719-785

Elias, M. K., 1942, Tertiary prairie grasses and other herbs from the High Plains: Geological Society of America, Spec. Paper No. 41, 176 p., 17 pls., 6 tables, 1 fig.

Frye, J. C., Glass, H. D., Leonard, A. B., and Coleman, D. D., 1974, Caliche and clay mineral zonation of Ogallala Formation, central eastern New Mexico: New Mexico Bureau of Mines and Mineral Resources, Circ. 144, 16 p.

Frye, J. C., and Leonard, A. B., 1957, Studies of Cenozoic geology along eastern margin of Texas High Plains: University of Texas Bureau of Economic Geology, Rept. of Inv. No. 32, 63 p.

, 1959, Correlations of the Ogallala Formation (Neogene) in western Texas with type localities in Nebraska: University of Texas Bureau of Economic Geology, Rept. of Inv. No. 39, 46 p.

Frye, J. C., Leonard, A. B., and Glass, H. D., 1978, Late Cenozoic sediments, molluscan faunas, and clay minerals in northeastern New Mexico: New Mexico Bureau of Mines and Mineral Resources, Circ. 160

Frye, J. C., Leonard, A. B., and Swineford, Ada, 1956, Stratigraphy of the Ogallala Formation (Neogene) of northern Kansas: Kansas Geological Survey, Bull. 118, 92 p., 9 pls.

Frye, J. C., Swineford, Ada, and Leonard, A. B., 1948, Correlation of Pleistocene deposits of the central Great Plains with the glacial section: Journal of Geology, v. 56, no. 6, p. 501-525.

Herrington, H. B., 1962, Revision of Sphaeriidae North America (Mollusca: Pelecypoda): University of Michigan, Museum of Zoology, Misc. Pub., no. 188, 75 p., 7 pls., 2 figs.

Hubendick, Bengt, 1951, Recent Lymnaeidae, their variation, morphology, taxonomy, nomenclature and distribution: Kungl. Svenska Vetenskapakademiens Handlingar, Fjarde serien, Band 3, no. 1, 223 p., 5 pls., 369 figs.

Leonard, A. B., 1958, Two new fossil plants from the Pliocene of Northwestern Texas: University of Kansas, Science Bull., v. 38, p. 1393-1403, 1 pl.

, 1959, Handbook of gastropods in Kansas: University of Kansas Museum of Natural History, Misc. Publ. No. 20, 224 p., 11 pls., 87 figs.

, 1977a, History of the name combination *Biorbia micro-endocarpica* (Brooks) Leonard: Southwestern Naturalist, v. 22, no. 3, June 15, p. 391-393

, 1977b, Three new pulmonate gastropods from the Tertiary of New Mexico: Nautilus, v. 91, no. 4, October

Leonard, A. B., and Frye, *J.* C., 1975, Pliocene and Pleistocene deposits and molluscan faunas, east-central New Mexico: New Mexico Bureau of Mines and Mineral Resources, Mem. 30, 44 p., 3 pls., 3 tables, 6 figs.

Leonard, A. B., Frye, J. C., and Glass, H. D., 1975, Late Cenozoic mollusks and sediments, southeastern New Mexico: New Mexico Bureau of Mines and Mineral Resources, Circ. 145, 19 p., 2 tables, 2 figs.

Pilsbry, H. A., 1948, Land Mollusca, North America: v. 2, pt. 2, Academy of National Sciences of Philadelphia, Mon. 3, p. 5211113, figs. 282-585

Pilsbry, H. A., and Vanatta, E., 1900, A partial revision of the Pupae of the United States: Academy of Natural Sciences of Philadelphia, Proc., p. 588-89, pl. 22, fig. 11

Segal, R. H., 1966, A review of some Tertiary endocarps of *Celtis* (Ulmaceae): Southwestern Naturalist, v. 11, p. 211-216, 1 fig.

Taylor, D. W., 1960, Late Cenozoic molluscan faunas from the High Plains: U.S. Geological Survey, Prof. Paper 337, 94 p., 4 pls., 2 figs.

Plates

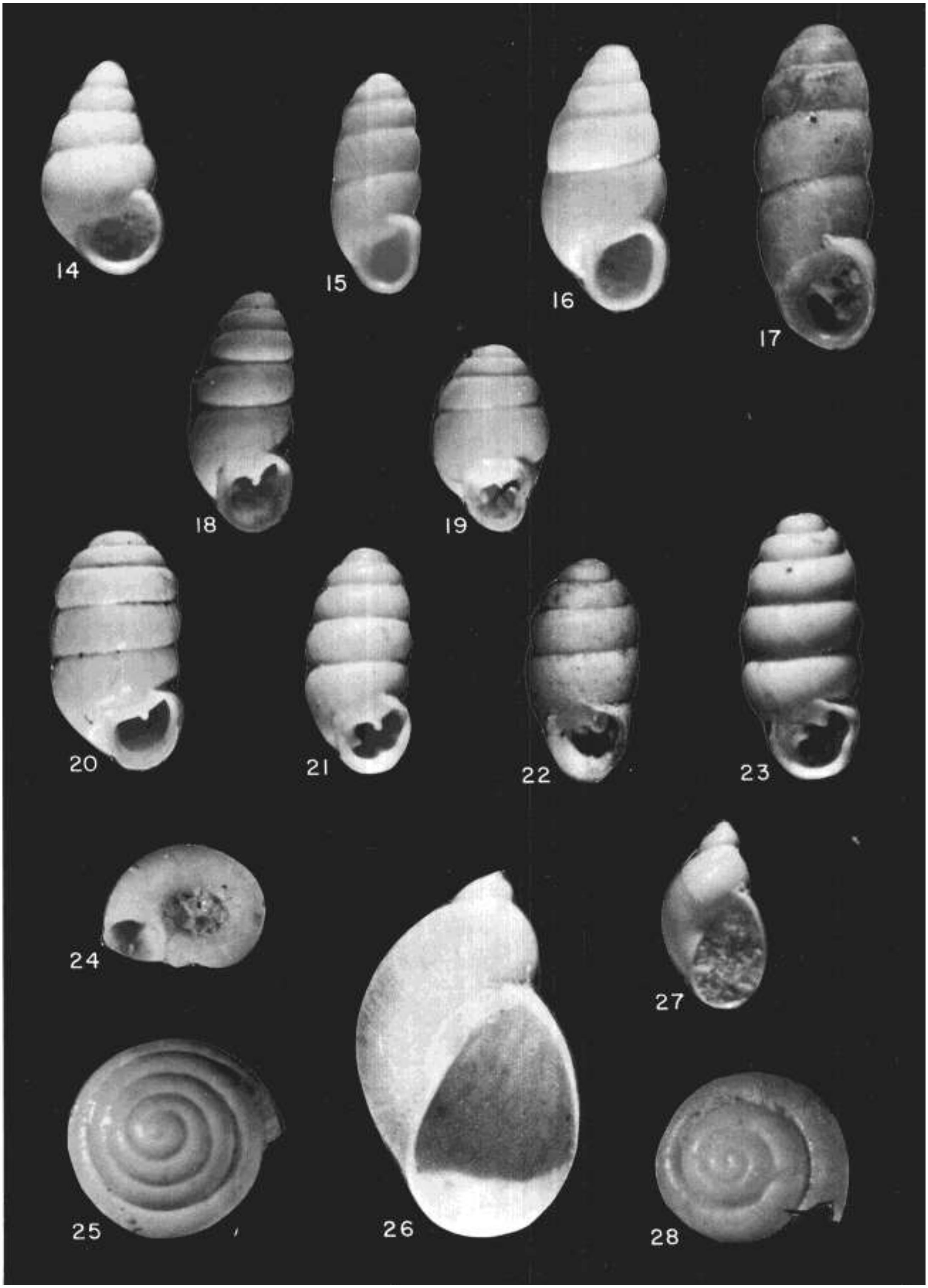
PLATE 1—Aquatic mollusca

Figures		*Page*
1	External view (left) and internal view (right) of *Pisidium casertanum* (Poli), x 8.	10
2	Apertural view of *Physa anatina* Lea, x 5.	12
3	Apertural view of *Lymnaea parva* F. C. Baker, x 10.	11
4	Apertural view of *Lymnaea dalli* F. C. Baker, x 10.	10
5	Apertural view of *Lymnaea claytonensis* Leonard, x 3.2	11
6	Apertural view of *Lymnaea bulimoides* Lea, x 5	11
7	Left lateral view of *Ferrissia shimekii* (Pilsbry), x 15	12
8	Left lateral view of *Ferrissia parallela* (Haldeman), x 15.	11
9	Left lateral view of *Ferrissia tarda* (Say), x 15	12
10	Apical view of *Gyraulus parvus* (Say), x 5	11
11	Apical view of *Gyraulus circumstriatus* (Tryon), x 5.	11
12	Seed of *Celtis hatcheri* Chaney, a hackberry; view at right angles to plane of suture, x 8.	9
13	Seed of *Celtis willistoni* (Cockerell) Berry, x 8	9

The two figured seeds of *Celtis* are from the Seneca Northeast section, SE 'A NE 'A sec. 15, T. 28 N., R. 36 E., Union County, Flora No. 88, Ash Hollow member of the Ogallala Formation.


1
2
3
4
5
6
7
8
9
10
11
12
13

PLATE 2—Terrestrial mollusca


14
15
16
17
18
19
20
21
22
23
24
25
26
27
28

Composition:	Text in 8 and 10 pt. English Times, leaded one point; subheads 12 and 14 pt. English Times Display heads in 24 pt. English Times bold, letterspaced
Presswork:	Miehle Single Color Offset Harris Single Color Offset
Binding.	Saddlestitched
Paper:	Cover on 65 lb. White Carnival Hopsack Text on 70 lb. Mountie Matte