Late Cenozoic Molluscan Faunas From the High Plains

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Description of mollusks from nine Pliocene and Pleistocene faunas of the High Plains region and interpretation of their stratigraphic and ecologic significance

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LATE CENOZOIC MOLLUSCAN FAUNAS FROM THE HIGH PLAINS

By D. W. Taylor

ABSTRACT

Mollusks are described from nine late Cenozoic assemblages in the High Plains region: the late middle Pliocene Buis Ranch local fauna of northwestern Oklahoma; the late Pliocene Saw Rock Canyon, Rexroad, and Bender local faunas of southwestern Kansas; the late Pliocene Red Corral local fauna of the Panhandle of Texas; the early Pleistocene Dixon, Deer Park, and Sanders local faunas of southern Kansas; and the early Pleistocene Sand Draw local fauna of north-central Nebraska. In nearly all assemblages associated mammals provide an independent age determination. The control provided by fossil mammals and stratigraphic succession permits evaluation of the mollusks for age determination and correlation. Vertebrates and mollusks are complementary, and never antagonistic, in giving age and ecologic information.

The late Pliocene and Pleistocene faunal sequence of southwestern Kansas and northwestern Oklahoma is especially significant for regional and intercontinental correlation because it is the most nearly complete sequence known from such a small area. Collecting the great number of specimens and species which represent these faunas has been possible by washing large quantities of fossiliferous matrix through screens. Ecologic interpretation of the mollusks is combined with other information from the vertebrates and inferences from the depositional sequence to summarize the late Pliocene and Pleistocene climatic and faunal sequence of southwestern Kansas.

Fossils from three horizons in the Rexroad formation indicate a relatively long interval in which the climate was warm-temperate, equable, and relatively moist. Above these assemblages the depositional and erosional sequence, and several faunas, indicate 4 periods of erosion and deposition of coarse clastic sediments in cool climates separated by 3 periods of deposition of finer materials during warmer climates. The alternate warm and cool climates are correlated with the Mississippi Valley interglacial and glacial ages. The Ballard formation, which is separated from the Rexroad formation by an erosional unconformity and contains the earliest evidence of marked climatic cooling, is correlated with the earliest Pleistocene sediments of the area in central Italy selected by the 18th International Geological Congress as definitive for the Pliocene-Pleistocene boundary.

The successive phases in the history of North American land mammals which have been called the Blancan, Irvingtonian, and Rancholabrean ages can be correlated with the Pliocene and Pleistocene sequence of southwestern Kansas, and thus indirectly with the glacial-interglacial intervals of the Mississippi Valley. The Blancan is late Pliocene and early Pleistocene. The Blancan-Irvingtonian boundary is about in the middle of the Kansan age, and the Irvingtonian-Rancholabrean boundary about in the middle of the Illinoian age.

INTRODUCTION

In the spring of 1936 M. K. Elias visited a Civilian Conservation Corps quarry in Meade County, southwestern Kansas. Questioning the workmen about the possible occurrence of fossil bones, he was given specimens which he brought to the University of Kansas. Claude W. Hibbard and a University of Kansas Museum of Vertebrate Paleontology field party, acting on this information, returned to the area in 1936 (Hibbard, 1941, p. 81). Fossils collected at this original locality and exploration of the Meade County region in general subsequently have produced almost an overabundance of paleontological riches. Intensive study by Hibbard and parties from the University of Kansas (1936–46) and University of Michigan (1947 to date) has resulted in the discovery of the most nearly complete sequence of late Pliocene and Pleistocene faunas in a small area known anywhere. The washing technique developed by Hibbard (1949c) is largely responsible for this great success in collecting; the method permits rapid recovery of 90 percent or more of the bones and shells in a fossiliferous deposit. The various animal groups so obtained—birds, mammals, salamanders, frogs, toads, lizards, snakes, turtles, fishes, and mollusks—provide a basis for reconstructing in considerable detail the changes in climate and animal life during the late Cenozoic.

This paper is concerned primarily with the description and interpretation of the late Pliocene and early Pleistocene molluscan faunas of southwestern Kansas. Several other assemblages are included for the sake of completeness: the early Pleistocene Dixon local fauna from south-central Kansas and the Sand Draw local fauna from north-central Nebraska; and the middle Pliocene Buis Ranch local fauna from northwestern Oklahoma. In ecologic and stratigraphic discussion of the faunas both vertebrate and invertebrate evidence is considered. Thus although the systematic paleontologic description is limited to the mollusks, the faunal interpretations are synthetic.

Earlier work on the various faunas is summarized under the description of each. The history of this study may be noted here, however. As a member of a University of Michigan Museum of Paleontology field party under Hibbard in the summer of 1950 I had opportunity to see at firsthand the process of mass screen-washing of fossils, to learn the advantages and disadvantages of the method, and to study the local stratigraphy of southwestern Kansas and western Oklahoma. In the summer of 1953, I collected Pleistocene and Recent mollusks and stratigraphic data in northern Nebraska for 2 weeks and spent another week in southwestern Kansas to see newly discovered faunal sites. Detailed examination of the fossils was made at the University of Michigan in 1952–53, University of California from 1953–55, and the U.S. National Museum in 1955–56.

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The line drawings of plate 1 are by Miss Joan Sischo, University of California Museum of Paleontology.

E. S. Richardson, Jr., Chicago Natural History Museum, C. W. Collinson, Illinois Geological Survey, and Henry van der Schalie, University of Michigan Museum of Zoology, loaned material for examination.

H. B. Herrington, Keene, Ontario, Canada, identified the Sphaeriidae and gave ecologic interpretations of them.

The systematic treatment of several groups of gastropods has benefited from discussions with P. F. Basch and J. B. Burch, University of Michigan Museum of Zoology, J. P. E. Morrison, U.S. National Museum, and H. E. Walter, Liberian Institute of Tropical Medicine, Harbel, Liberia.

D. E. Savage, University of California Museum of Paleontology, contributed advice and stimulating discussion of the principles of correlation, stratigraphy, and mammalian paleontology.

Most of all I am indebted to Claude W. Hibbard, University of Michigan Museum of Paleontology. He introduced me to the late Cenozoic sequence of southwestern Kansas and northwestern Oklahoma in 1950, and since that time has collaborated closely by securing funds for sorting fossils and by contributing advice and criticism.

METHODS

COLLECTING METHODS

The fossil mollusks reported here were collected almost entirely by the washing technique described by Hibbard (1949c). Poorly consolidated or unconsolidated sediments with surface exposures of fossils were collected in as large pieces as practicable. After thorough drying (especially important with clay or marl sediments) the matrix was washed through a 16-mesh screen. It was found desirable to station someone with a finer screen downstream from the washers to catch small fossils which passed through the 16-mesh screen and floated away. The small fossils which did not float were lost. Use of a smaller mesh would insure recovery of all the fossils, but this slows washing and also hinders sorting by leaving more matrix in the washers.

Adult shells of only 3 of the species considered here will pass through the 16-mesh screen: *Carychium exiguum*, *Gastrocopta holzingeri*, and *Vertigo milium*. In addition the shells of other species of *Gastrocopta*, such as *G. cristata* and *G. procera*, may pass through the screens if the shells are slightly smaller than the mean or if there are bent wires in the screens which create larger gaps than usual. Not all these smaller shells will go through the screens, however, because only the minor axis is less than the mesh size. Shells which are kept flat on the bottom or sides of the washers will tend to stay in them, while those which are agitated and turn perpendicular to the screen will pass through.

In rewashing the 16-mesh concentrate in the laboratory, it was found that only *Carychium* and *Gastrocopta holzingeri* passed through a 20-mesh screen. Probably, therefore, the relative abundances for these species are low.

The advantage of washing matrix is that an essentially complete representation of the fossil fauna is obtained. By this method Hibbard (1949c) has obtained several faunas including amphibians, reptiles, birds, mammals, mollusks (including snail eggs) and ostracodes, as well as the zygospores of *Chara*.

In collecting it was found that the larger shells were particularly fragile. This is partly because they are relatively weaker than small shells, and partly because they are more likely to have become cracked or broken in the ground or in the removal of blocks of matrix. Accordingly, surface exposures were usually examined for the larger shells before collecting matrix for washing. Large shells found in the washers were removed as soon as possible.

The amount of matrix needed to give a fair sample of the fossils is large, probably at least 20 sacks (about 2,500 lbs), as suggested by Hibbard (1949c, p. 11). The completeness of representation may be increased by sampling from several spots in the fossiliferous locality. Table 1 shows relative abundance of the species in University of Michigan collections from the Saw Rock Canyon locality, with the forms reported by Frye and Leonard (1952) added for comparison. It should be noted that all collections were made in the same way by C. W. Hibbard and that as nearly as possible the same spot was sampled. The combined 1950–52 collections naturally have more material and more species than those of the 1947 collection. The chief conclusion is that no single collection contains all species present, and that a large amount of matrix should be washed.

TABLE 1.—*Abundance or occurrence of gastropods in collections of Saw Rock Canyon local fauna*

[A, abundant (>250); C, common (41-250); S, scarce (6-40); R, rare (1-5); ×, occurrence]

Species	University of Michigan collections		Reported by Frye and Leonard (1952, p. 151, Seward County locality)
	1947	1950,1952	
Marstonia decepta (Baker)		R	
crybetes (Leonard)	S	A	×
Stagnicola bulimoides techella Haldeman		S	×
sp		R	×
Fossaria dalli Baker	S	C	×
Gyraulus parvus (Say)	C	A	
Helisoma anceps (Menke)			×
Promenetus kansasensis (Baker)	C	A	×
umbilicatellus (Cockerell)	C	A	×
Physa anatina Lea	S	A	×
Ferrissia rivularis (Say)	S	A	
Strobilops labyrinthica (Say)		S	×
Gastrocopta holzingeri (Sterki)			×
paracristata Franzen and Leonard	R	S	×
franzenae Taylor	R	S	
rexroadensis Franzen and Leonard			×
tappaniana (Adams)		S	×
Pupoides albilabris (Adams)		R	
Vertigo hibbardi Baker	R	A	×
milium (Gould)			×
Vallonia perspectiva Sterki		R	
cf. *Succinea*	R	C	×
Deroceras aenigma Leonard	R	C	×
Helicodiscus singleyanus (Pilsbry)		R	
Hawaiia minuscula (Binney)	R	S	×
Nesovitrea? sp		R	

ENVIRONMENTAL INTERPRETATIONS OF SEDIMENTS

The present study is primarily paleontologic and stratigraphic, but two probable inferences from a study of the sediments supplement the fossil evidence. These interpretations are that gravel deposits in southwestern Kansas imply a greater volume of stream flow at the times when they were laid down and that caliche indicates a semiarid climate more probably mesothermal than microthermal.

The six Pliocene and Pleistocene formations of southwestern Kansas and western Oklahoma, from the Ogallala to the Vanhem formation, each grade from gravel and coarse sand at the base to finer sediment at the top. The coarse basal gravels differ from one unit to another, however, not only in composition but in grain size (Byrne and McLaughlin, 1948, p. 80), although the finer sediments are similar. These differences suggest not only changes in stream carrying power within a depositional interval, but also differences in maximum carrying power between these intervals. The early Pleistocene coarse sand and pebble gravel units [Angell member of the Ballard formation, and the Stump Arroyo member of the Crooked Creek formation] are coarser than the sand and grit in the base of the Rexroad formation and include rocks of Rocky Mountain provenance. Such records of transport of more and coarser material than is being moved by the Cimarron River today suggest greater precipitation in the Rocky Mountains and probably also in the Plains.

The origin of caliche has been studied by Brown (1956). He concluded that in the northeastern Llano Estacado caliche recorded lime enrichment of the C-horizon of pedocal soils in an eolian aggrading profile. Such lime enrichment occurs in soils of both subhumid and semiarid environments. Caliche is left behind by evaporation, therefore a warmer climate will favor such precipitation but is not necessary. The more frequent occurrence and more conspicuous development of caliche in the southern than in the northern High Plains further strengthens such an idea. Following is part of Brown's summary concerning the origin of caliche (Brown, 1956, p. 14):

> The mechanics of formation appear to be as follows: The wind and rain bring in all the materials that form the soil and its associated caliche and deposit these materials on the soil surface. The $CaCO_3$ and silica gel are leached downward by percolating rainwater and deposited as a subsurface evaporite, largely as molds around roots and organisms that separated the clastic particles. This inception of lithification may be interrupted and the deposits destroyed by descending water following subsequent heavy rains, but eventually they will become permanent.

ENVIRONMENTAL INTERPRETATIONS OF FOSSIL MOLLUSKS

Since almost the first days of paleontology, fossil mollusks (especially those of the Cenozoic) have been used as a basis for inferring the conditions under which rocks were laid down. The early discovery that the distribution patterns of many living animals and plants changed radically in the Pleistocene contributed greatly to the theory of glaciation. The uniformitarian assumption has been made that the habitat preferences of species have been the same throughout their span of existence from then until now. Pond snails of today lived in ponds of the Pleistocene; clams of gravelly stream beds have always preferred these situations. This basis for interpreting the local habitat of fossil shells remains unquestioned and valuable.[1] The story is otherwise with the inferences of past climates, however. Workers have disagreed as to how specifically one can interpret former climates and too little attention has been given to the large number of factors which make up climate.

PREVIOUS WORK

Many earlier attempts at paleoecologic interpretations of Pleistocene fossils and deposits have been of dubious value, or so generalized as to be of little help to geologists and stratigraphers. This circumstance has been the result of uncertain stratigraphic position of fossils, inadequate data on pre-Wisconsin physical features, and the fact that so many of the known fossils represent animals of little paleoecologic value—horses, bison, camels, and wide-ranging snails. Probably for these reasons Flint (1947, p. 524) was led to the pessimistic conclusion that "* * * the ecologic interpretations placed on most of the plants and animals in the record manifestly can never be more than approximate at best. In consequence few major inferences as to Pleistocene climates rest on fossil evidence alone. The chief value of fossil data is in strengthening inferences drawn from evidence of quite other kinds".

Flint's conclusion is valid for most previous work on the Pleistocene. More detailed work on stratigraphy and fossils, particularly in nonglaciated regions of now semiarid climates, will almost surely yield significant information on climatic changes unobtainable from physical features. The study and joint use of various animal groups, and collection of adequate samples of material, is a prerequisite for these results, however. Reliance on only one group, such as mollusks or mammals, cannot help but give an incomplete and hence distorted picture.

Only four general reviews of the ecological applications of Pleistocene nonmarine mollusks are known to me—those of Shimek (1913), Geyer (1922), Baker (1937), and Eiseley (1937).

Shimek's paper is useful for information on the depositional environment of loess, and especially for comparison of fossil assemblages and drift shells from modern lakes and streams. Subsequent information has outmoded his conclusions on stratigraphic and climatic interpretations, however.

Geyer's (1922) essay "Die Quartärmollusken und die Klimafrage" (Quaternary mollusks and climate) is a searching study of the subject which unfortunately seems to have passed unnoticed by American paleontologists. The paper deals with German postglacial nonmarine mollusks, and attempts to answer the question: "Have climatic changes taken place between the Pleistocene and the present, and in what direction have they occurred?" (p. 73).

Geyer's conclusions are that the climate suggested by the fossils as a whole was moist and oceanic, for there are occurrences in central Germany of species now living only closer to ocean coasts. Furthermore, there are today associations of species with different climatic requirements, but these associations are now found in western rather than in central Europe. In general, however, a fossil assemblage can give only a picture of local conditions of environment—humidity, vegetation, soil, and microclimate—which have nothing to do directly with climate. Geyer's ideas are discussed in more detail later in this section.

Baker's (1937) summary of Pleistocene nonmarine mollusks is valuable chiefly for the section on habitat interpretation. That dealing with climatic inference sums up Baker's general conclusions, but lacks an adequate treatment of the method involved. "Mollusca as indicators of time" overrates the stratigraphic utility of the group. Baker recognized as species and subspecies shell forms which are only ecological variants, and relied too heavily on the completeness of the geological record.

Eiseley (1937), like Geyer, dealt with the application of mollusks to archeology. He discussed problems of a smaller scale than those of this report, problems which arise late in the Pleistocene.

PRINCIPLES OF PALEOECOLOGIC INTERPRETATION

It should again be emphasized that paleontologists make an assumption that species have been influenced in former periods by the same limiting factors and to the same degree as they are now. Species certainly could have changed in this respect, and one must always be aware of the possibility. In the late Cenozoic molluscan faunas studied in this paper, evidence for such changes is rare and doubtful.

The generally accepted principles used in the interpretation of late Cenozoic fossil mollusks may be summed up as follows: Interpretations based on fossil shells are governed by the present-day distribution of the various species, and their association with each other and with various kinds of habitats and climates. Fossil shells similar to those of living forms are assumed to represent the same species. Furthermore, these species are believed to have been subject to the same limiting factors of distribution then as now.

[1] For summaries see Baker (1937) and Yen (1951).

DIFFICULTIES OF PALEOECOLOGIC INTERPRETATION

Attempts to apply these principles encounter several difficulties: Some groups of mollusks are not identifiable by shell alone; recognition of limiting factors is most uncertain; habitat and distributional data are poor for many species; taxonomy of living nonmarine mollusks is unsatisfactory for many groups.

SPECIFIC IDENTIFICATION OF SHELLS

In most nonmarine mollusks the shell is the basis for specific identification, although not for classification of higher categories. In some families, such as the Pupillidae, the shell is probably a much better guide than are anatomical data. In other groups, however, such as the Zonitidae, Succineidae, and Hydrobiidae, shells are of distinctly secondary value and may not be characteristic of species or even genera. In the late Cenozoic faunas of the High Plains the Succineidae are the only common group with this disadvantage.

RECOGNITION OF LIMITING FACTORS

Unfortunately there is no experimental evidence determining limiting factors of distribution. Inferences as to what they may be must come from knowledge of the geographic distribution of the species and from collecting experience. Isolated occurrences may also be especially valuable in giving clues to such significant factors.

Virtually all previous workers concerned with factors determining distributions of nonmarine mollusks within an accessible area have seen them in part or all of the interacting complex of soil, climate, and vegetation. Other factors may be significant, but there is no good evidence for their operation as yet.

Geyer (1922) contended that the distribution of nonmarine mollusks is governed primarily by moisture. Occurrence and abundance of species are determined by the modifying effects on climate of local environment, topography and drainage. He stated[2] (p. 73–74):

> In attempts at solving climatic problems (my own not excepted), the concept of climate was regarded one sidedly. It was essentially the same as *temperature*. Climate, however, is a *multifaceted* and *complex* quantity. Warmth is certainly a necessity for all life, but only *one* aspect of climate. It affects the worldwide distribution of mollusks, but in our homeland [Germany] mollusks depend more obviously on water than on temperature. What Diels said about plants may be applied to mollusks without restriction: 'Water determines the organism's possibility of existence. It directs its growth and is the most important factor which influences and bounds its habitat on the earth. Thus the reproduction and hence the continuity, indeed the physiognomy of whole floras (and faunas) depends on water. But it also decides, in an infinite number of cases, the significance of a species within an association, its dispersal ability in a region and therefore the limits of its natural distribution.' Land snails are 'moist air animals.' Their life processes go on under the direct influence of water. Winter temperatures are unimportant as limiting factors; the snails hibernate in the soil like plants. During the summer warmth, however, there are interruptions by drought.
>
> Whatever the sun and clouds grant to the earth does not act directly on the biosphere (perhaps aside from light, which affects the color of mollusks), but only through the medium of the *soil*—the *local habitat*. It is not the amount of rain which falls from the clouds that the organisms receive. They benefit from only as much as the soil can hold and pass on. Likewise snails live not by the radiant heat of the sun, which they quickly avoid in most cases, but by the warmth which the soil has taken up and transmits to them. *Climate is the source of energy for life; soil is the transmitter, storage battery, and transformer.*
>
> In studying the climate with the help of mollusks, then, one must turn primarily to the *soil* on which they lived. *Soil*, however, is just as complex a quantity as climate. Furthermore, these two factors, climate and soil, interact, displace and supplement each other reciprocally, so that their influence on the biota is very difficult and often impossible to analyze and determine separately. *How much warmth and moisture can the soil absorb for storage and transmission?* That is the first question for all climatic research. In this way all other influences are considered: geographic position (latitude, elevation, and distance from the sea), formation, condition, and structure of the soil, angle of inclination and direction (exposure and insolation), irrigation, precipitation, humidity, wind, vegetation, cultural stage of the landscape and most recent geological history. In summary, the *ecological bases of molluscan life* must be determined as far as circumstances permit. They may be divided into *local environmental* and *climatic* factors. Only if the habitat is known can the influence of climate be sought.

The mediating influence of the soil bars us, he said, from being able to determine much about climate. What we see is the resultant of many factors working together.

> The local habitat demands adaptation. Stable species join it through selection, the variable ones by modification to given circumstances. The adaptation influences the faunal composition. Thus each locality will give its assemblage a special *aspect* according to the mixture of species and ecological forms. *From the aspect* of a fossil assemblage *the significant local conditions can be determined* which have given this characteristic. *They have nothing to do directly with the climate.* (Geyer, 1922, p. 88.)

Geyer's conclusions from the German nonmarine mollusks probably hold true for parts of North America, and for many mollusks. But there are many different patterns of distribution among the species studied in this report, some of which seem controlled by temperature extremes, others by soil and available

[2] Translated from the original German.

moisture. These patterns may be grouped most broadly into five categories, with subdivisions for some.

The first category includes widespread species found over all or nearly all of North America; they are as follows:

Sphaerium striatinum (Lamarck)
lacustre (Müller)
Pisidium compressum Prime
casertanum (Poli)
nitidum Jenyns
Fossaria obrussa Say
dalli Baker
Gyraulus parvus (Say)
Helisoma anceps (Menke)
Vertigo ovata Say
Euconulus fulvus (Müller)
Hawaiia minuscula (Binney)
Zonitoides arboreus (Say)

The second cateory includes eastern species found commonly over North America east of the Rocky Mountains. Some range barely west of the Mississippi River, others are common on the Plains.

Six species of this second category are characteristically northeastern, found in the general area of New England and the Great Lakes. They are as follows:

Sphaerium sulcatum (Lamarck)
Bulimnea megasoma (Say)
Ferrissia rivularis (Say)
parallela (Haldeman)
Stagnicola exilis (Lea)
reflexa (Say)

The other species are more generally distributed:

Sphaerium transversum (Say)
partumeium (Say)
securis (Prime)
Marstonia decepta (Baker)
Carychium exiguum (Say)
Helisoma trivolvis (Say)
Planorbula armigera (Say)
Strobilops labyrinthica (Say)
Gastrocopta armifera (Say)
holzingeri (Sterki)
tappaniana (Adams)
Pupoides albilabris (Adams)
Vertigo milium (Gould)
Vallonia parvula Sterki
Retinella wheatleyi (Bland)
rhoadsi (Pilsbry)
Stenotrema leai (Binney)

The third category is made up of northern species found over northern North America. The southern boundary of distribution is generally east-west, with an extension southward in the Rocky Mountains. Some species of this group are Holarctic. They are as follows:

Valvata tricarinata (Say)
lewisi Currier
Stagnicola palustris (Müller)
caperata (Say)
Gyraulus circumstriatus (Tryon)
deflectus (Say)
Armiger crista (Linnaeus)
Promenetus exacuous (Say)
umbilicatellus (Cockerell)
Physa skinneri Taylor
gyrina Say
Aplexa hypnorum (Linnaeus)
Vallonia pulchella (Müller)
Cionella lubrica (Müller)
Discus cronkhitei (Newcomb)
Nesovitrea electrina (Gould)

A modified northern distribution pattern may be found in *Vallonia gracilicosta* of the Rocky Mountains, northern Great Plains, and southwestern United States.

The fourth category is southern. The few species with southern distributions show considerable variation in their ranges and are as follows:

Widespread throughout the southern United States:

Gastrocopta pellucida hordeacella (Pilsbry)
Vallonia perspectiva Sterki

Southwestern, south-central, central, and southeastern United States:

Gastrocopta procera (Gould)
Helicodiscus singleyanus (Pilsbry)

Southwestern and south-central United States:

Stagnicola bulimoides techella Haldeman

South-central and central United States:

Gastrocopta cristata (Pilsbry and Vanatta)

Erratic or poorly known.

Acroloxus coloradensis (Henderson)
Ferrissia meekiana (Stimpson)
Physa anatina Lea
Pupoides inornatus Vanatta
Oxlyoma retusa (Lea)

The species with eastern distribution range onto the Plains varying distances. Some, such as *Helicodiscus parallelus*, may be found in the High Plains where there are scattered patches of trees. Others, like *Strobilops*, are narrowly restricted to areas with humus and dead wood. The distributions of these species are probably governed by available moisture, soil, and frequency of drought. This is essentially Geyer's view. The species of northern distribution, however, can hardly be so governed, for otherwise they would range south in the humid and geographically accessible Mississippi Valley or Eastern United States generally. For this reason, as well as for others mentioned below, summer extremes of temperature probably govern the southern limits of these forms. By the same token, it would seem that species of southern distribution (such as *Gastrocopta pellucida hordeacella*) are prevented from going north by winter extremes of temperature.

This thesis that the species of northern and southern distributions are limited by temperature extremes receives support from three other sources: ranges in mountains, ranges in the Coastal Plain, and relict or isolated occurrences.

The northern species (with the possible exception of *Valvata*) have southern extensions of range in the Rocky Mountains. The absence of such a pattern for *Valvata* could be explained by rarity of the necessary permanent quiet water habitat. The fact that other aquatic species do not have such a pattern in the Appalachian Mountains can also be readily explained by the scarcity of pond habitats.

On the Atlantic Coastal Plain several species show narrow range extensions. This Coastal Plain extension of ranges is to be expected if temperature were acting as a distributional barrier. Elsewhere hot summers or cold winters keep these species apart, but along the coast the ocean acts as a moderating influence and the ranges overlap in a narrow belt. Geyer's interpretation of such patterns might have been that greater moisture was responsible, but taking the ranges as wholes into consideration it seems that the more equable temperatures of an oceanic climate are significant rather than any possibly greater moisture. On the west side of a continent, as in Germany, humidity may change more obviously than temperature extremes. On the Atlantic Coastal Plain of the United States temperature extremes are more apparent than any other factor in limiting ranges of these northern and southern species.

Alexander (1952, p. 54) stated:

> A striking feature of the New Jersey land snail fauna is the presence of typically northern species living in association with typically southern species. This anomalous combination of species can be explained by the fact that New Jersey is located on the central part of the Atlantic coast where some northern species approach the southern limit of their distribution and some southern species reach the northern limit of their distribution. Certain species belonging to these diverse elements can be found together only in this state.

Northern species extending southward in a narrow coastal strip are *Pupilla muscorum* and *Cionella lubrica*. A southern species reaching its northern limit in New Jersey is *Gastrocopta pellucida hordeacella*. Concerning the distribution of this last form, Pilsbry (1948, p. 914) wrote:

> The northward extension along the Atlantic coast is very narrow, discontinuous so far as known, and perhaps mainly confined to the coastal islands.

There is only one known joint occurrence of *Cionella lubrica* and *Gastrocopta pellucida hordeacella*, at Cape May, N. J., and perhaps also in the Rexroad local fauna (fossil) of southwestern Kansas.

Another northern species with a Coastal Plain range extension southward is *Promenetus exacuous*.

Several isolated occurrences of species further suggest temperature extremes as range-limiting factors. These relict occurrences are of fresh-water species well south of their present northern distribution.

In Meade County, southwestern Kansas, the constant temperature and summer-cool waters of an artesian spring provide a habitat suitable for *Promenetus exacuous* (Leonard, A. E., 1943, p. 235). The nearest occurrences of the species are in the Rocky Mountains to the west and in northern Nebraska to the north.

In Cherry County, Nebr., a similar cool spring supported *Valvata tricarinata* and *Gyraulus deflectus* (this paper). Other permanent water bodies of equal depth were examined without finding these species. Probably they are able to live here because the water is warmed little if at all during summer hot spells. In the High Plains these species may not live in the United States except in unusual habitats such as this one. Their nearest occurrences are to the northeast, in eastern South Dakota.

For the various reasons given above, therefore, it seems that temperature extremes are factors limiting the ranges of species with generally northern or southern distributions. Many other species, however, are probably more influenced by a complex interaction of soil, vegetation, and climate.

At least two species have distributions which do not seem controlled by any of these factors: *Bulimnea megasoma* and *Acroloxus coloradensis*. Their ranges are not well known, but enough collecting has been done to suggest they are erratic. Why these species, formerly so widespread on the Great Plains, are now so restricted is unknown. Perhaps they are largely analogous to *Anisus pattersoni*, which was also abundant on the Plains during the Pleistocene but apparently became extinct in North America during the Wisconsin age.

Inasmuch as these two Recent species (*Bulimnea megasoma* and *Acroloxus coloradensis*) seem significantly affected by unknown influences, it is unwise to use them in paleoclimatic interpretations.

INADEQUACY OF HABITAT AND DISTRIBUTIONAL DATA

Throughout this paper only general and vague conclusions about local habitat and climate have been possible. This reflects the lack of knowledge concerning ecology and distribution of many species. Habitat data are lacking or so scanty for a number of species that they have been grouped under the "uncertain" category in charts showing faunal habitat indications. Further collecting, especially on the High Plains, will enable considerably more detailed climatic interpretations than are possible now.

Stratigraphic ranges of species also reflect the inadequate amount of collection. Further work will of course considerably advance such knowledge, particularly in the fluviatile groups such as Viviparidae, Pleuroceridae, and Unionidae. At the present time in the Great Plains, Oligocene and middle Pliocene mollusks are essentially unknown, Miocene mollusks entirely unknown, and lower Pliocene forms known only from the Laverne local fauna.

Extensions of the known geological range of Recent species have been and will be common, but it is pertinent to point out also that several species described as fossils have been subsequently found living. *Hendersonia occulta*, *Discus macclintocki*, and now *Physa skinneri* were all originally thought to be extinct Pleistocene species, but have later been collected alive.

UNSATISFACTORY TAXONOMY

Many, perhaps most of the species dealt with in this paper are well known so far as their classification and distinguishing characters are known. In many other parts of North America, however, the percentage of satisfactorily classified species is much less. In the High Plains the poorly known groups are chiefly Planorbidae, Succineidae, *Physa*, and *Fossaria*, but other areas can add more. Pleistocene and late Tertiary paleontology is nearly always dependent upon a knowledge of Recent species, and hence must lag where large parts of the living fauna are poorly known.

METHODS OF FAUNAL INTERPRETATION

The preceding summaries of the principles and difficulties of paleoecologic interpretation show the basis on which individual species can be interpreted. Two other complementary approaches are also useful: comparison of the fossil assemblage with the living fauna of the region around the fossil locality and comparison of the fossil assemblage with a similar living fauna. In these methods the fauna as a whole is considered, and the ever-present danger of overemphasizing single species can be avoided.

Comparison with Recent fauna nearby.—In comparing the fossil and Recent assemblages from the same area, one inevitably uses negative evidence to some extent. Usually some fossil species are not living nearby, and some Recent species are unknown in the fossil fauna. Reliability of conclusions depends upon the thoroughness of collecting, and one must not read too much into a poorly sampled fauna. If the Recent fauna near the fossil locality is reasonably well sampled, then the presence of fossil species living only in other areas is significant. Degree of significance will vary with the accuracy to which the distributions of the locally extinct species are known. Inasmuch as a fossil assemblage is usually known from one or a very few localities, the absence from it of certain species is much less noteworthy than absence from the better known Recent fauna.

Comparison with a similar Recent fauna.—Many fossil assemblages which differ from the fauna living locally are like a living assemblage elsewhere. The reasonable inference can then be made that the environment of the fossil site was formerly like that where the species are now living. This same principle may be applied more broadly in the case of earlier Tertiary or Mesozoic faunas, and comparison made between genera or pairs of closely related species. This approach is not strictly applicable to most of the assemblages studied in this report, however, for there are many fossil associations of species not living together today.

One such association, which occurs in several of the Blancan faunas, is that of *Stagnicola caperata* and *Promenetus umbilicatellus*, both northern species, with the southern *Stagnicola bulimoides techella*. Probably only a moderate reduction in number and duration of summer hot spells would permit the northern forms to move south. The association is not inexplicable, but does show that strict comparison with living assemblages may be inadequate.

An even more striking example is the association of *Physa skinneri* and *Stagnicola bulimoides techella* in the Sanders local fauna. The limits of distribution in the Great Plains of these two species are hundreds of miles apart. *Physa skinneri* is known only as far south as southern Manitoba; *Stagnicola bulimoides techella* barely reaches Nebraska, where it is known from a single locality in the southernmost part of the state. Elsewhere in North America, the two species have been found closer together. In Utah *Physa skinneri* is known from the Uinta Mountains, in the northeastern part of the state; *Stagnicola bulimoides techella* is known from central Utah, but at much lower elevations. Although the ranges of these species are closer in Utah than in the Great Plains, the contrast in habitats is still as great. The Sanders local fauna, containing both these now widely separated species, cannot be compared closely with modern molluscan associations.

AGE DETERMINATION

Two methods of dating faunas by fossil evidence can be used in the late Cenozoic. The more general approach is purely faunal, based on restricted or overlapping ranges. The second method is less widely applicable, but of perhaps greater value for the Pleistocene. By inference of former climatic conditions, a fauna may be placed with some precision in a known glacial-interglacial sequence.

One fundamental premise should also be stated here: all lines of available evidence bearing on the age of a fauna must be considered. This principle would seem too obvious to need pointing out, but nevertheless has sometimes been ignored.

FAUNAL DATING

In using the method of restricted or overlapping ranges, animals with short vertical but wide geographic ranges are of course most valuable. In the present state of paleontological knowledge, this fact means that mammals are the most useful group. Mollusks as a whole are less reliable in the faunas under consideration, but their great abundance means they are potentially helpful.

Associated mammals and mollusks have not yet yielded contradictory conclusions, although often one group gives evidence which the other lacks. An example of the complementary use of mollusks and mammals is as follows: The Saw Rock Canyon and Rexroad local faunas can scarcely be distinguished by mollusks, but the mammals show a considerable difference. The mollusks indicate an ecological similarity between the two faunas, while the mammals demonstrate time difference. Southwestern Kansas probably had an essentially uniform climate throughout the late Pliocene. The mollusks did not change visibly, while the mammals did.

Lyell (1833, p. 47–49) was perhaps the first to recognize the principal differences in stratigraphic utility of mollusks and vertebrates. He stated:

> Although the bones of mammalia in the tertiary strata, and those of reptiles in the secondary, afford us instruction of the most interesting kind, yet the species are too few, and confined to too small a number of localities, to be of great importance in characterizing the minor subdivisions of geological formations. * * * We shall revert in the sequel to the curious fact, that in tracing back these series of tertiary deposits, many of the existing species of testacea accompany us after the disappearance of all the recent mammalia, as well as the fossil remains of living species of several other classes. We even find the skeletons of extinct quadrupeds in deposits wherein all the land and freshwater shells are of recent species.

The following points summarize these differences between mollusks and mammals as shown by the late Pliocene and early Pleistocene faunas of the High Plains considered in this paper.

Mollusks evolve more slowly than mammals. From a stratigraphic standpoint they are therefore less valuable, but are more useful for paleoecologic inferences. In the special case of the Pleistocene epoch, when major faunal shifts took place, some mollusks may be especially valuable in refined dating within a known climatic sequence because of their sensitivity to climatic change.

Mollusks are smaller, commoner, and occur in denser populations than do mammals. For this reason they are more abundant and more easily collected as fossils.

The shells of mollusks usually provide the chief basis for specific identifications, although not for generic or familial classification. Thus the fossils in their usual state have nearly all the characters used in determination of living forms. Mammal skeletons are readily disarticulated and broken, and many individual bones may be useless for identification of species.

Mollusks are restricted in their powers of dispersal and generally show endemism in major physiographic regions. The present-day faunal regions east and west of the Rocky Mountains, for example, appear to have been in existence during the Pliocene also. Correlation between these two regions is thus impracticable on the basis of specific identity of mollusks. Most mammals, more vagile and with less temporal range, offer the most precise means of correlation.

Dating from climatic inference.—A second method of dating Pleistocene fossil assemblages is based on their ecologic interpretation. This method is potentially more precise than other paleontologic means, but depends upon an established sequence into which an assemblage may be fitted. This method may also be more versatile as well as more precise. For example, once a sequence of climatic changes has been verified for a given region, any group of fossils from which adequate environmental inferences can be drawn can be placed in this sequence. The late Pleistocene and Recent climatic history of western Europe is based on fossil pollen and inferred vegetational changes; in theory an assemblage of amphibians, snails, or beetles could be dated if their ecologic implications were precise enough to permit placing them in the sequence.

In the Great Plains region there is no such established sequence of Pleistocene climatic changes. Although a number of climatically significant faunas have been described from southwestern Kansas and northwestern Oklahoma by C. W. Hibbard and coworkers, the record is far from complete. The relative ages of the described assemblages are fairly well known, but documentation of a sequence of climatic changes is hardly continuous. Plotting the curve of Pleistocene climate in southwestern Kansas requires more points than are now available.

Furthermore, the exact correlation of the faunas of southwestern Kansas and northwestern Oklahoma in terms of glacial events is unknown. Whether a certain fauna represents a very late glacial age, when continental glaciers were in existence but waning, for example, is speculative. The known stratigraphic succession of faunas and their ecologic interpretations permits only allocation to a given glacial or interglacial age.

Although the record is incomplete, the amount of data is sufficient to suggest climatic trends, and certain similarities between parts of the Pleistocene record are striking. A working hypothesis is warranted, as a generalization about information now available and as an aid to future work. This hypothesis is that the glacial-interglacial climatic changes are cyclic.

Cyclic climatic changes.—A cyclic pattern of glacial-interglacial climatic changes cannot be confirmed fully from the record in southwestern Kansas. The confirmation is partial, however, and all of the known data are consistent with the hypothesis that these changes were cyclic from the Nebraskan to Sangamon ages. Although progressive uplift of the Rocky Mountains during the Pleistocene presumably affected the climate, evidence of this is not clear.

Consideration of the physical and climatic events of the Pleistocene in southwestern Kansas and northwestern Oklahoma as a cyclic pattern was prompted by Stokes' (1955) stimulating hypothesis of oceanic control of glacial-interglacial alterations. Consistent evidence from many parts of the world and of many different kinds is needed to confirm Stokes' hypothesis. The evidence from Kansas and Oklahoma is scarcely definitive, even though significant. Nevertheless implications of the ocean-control hypothesis fit the known faunal and stratigraphic succession in southwestern Kansas better than ideas about Pleistocene climates deduced from other theories.

The following sequence of glacial-interglacial changes fits the available information from southwestern Kansas and northwestern Oklahoma to a hypothetical cycle. The cycle is intended to apply only to this local area.

1. Late glacial age. Summers much cooler than now; winters no colder, perhaps slightly warmer; precipitation little if at all greater but much more effective. (Kansan Cudahy fauna, Illinoian Berends and Butler Spring local faunas; Wisconsin Jones local fauna).

2. Early interglacial age. Climate warm-temperate, semiarid. Summers much as today; winters much milder; precipitation about the same or slightly less. (Yarmouth Borchers local fauna; Sangamon Cragin Quarry local fauna).

3. Middle interglacial age. Climate probably warm-temperate, semiarid. A massive, indurated caliche layer about a foot thick formed during part of each of the three interglacial ages.

4. Late interglacial age. Summers much cooler than now; winters very much warmer; precipitation greater in amount and effectiveness (Aftonian Sanders local fauna; Sangamon Jinglebob local fauna).

The Sand Draw and Dixon local faunas, discussed elsewhere in this paper, do not fit this pattern well. Probably their geographic location some distance from the other local faunas is partly, but not entirely responsible. Perhaps a smaller Rocky Mountain rain shadow, or a different climatic regime during the Nebraskan age, explain their peculiarities.

Relation of the present day climate to this cycle is uncertain. The living molluscan fauna is poorer in species than any of the known fossil assemblages, and suggests that the present fauna is geologically unusual. If some phase of the hypothetical climatic cycle is similar to the present climate, this phase is probably somewhere between the late glacial and early interglacial stages.

LOCAL FAUNAS

The term "local fauna" is used by vertebrate paleontologists to designate an assemblage of fossils from one locality, or from several closely grouped localities which are demonstrably stratigraphically equivalent or nearly so. It is a group of fossils local in both time and space. Advantages of this term are as follows:

It provides a designation for fossils which can be independent of formation names. A faunal name taken from a rock unit may become either inappropriate or misleading as the fossiliferous unit is subdivided or restricted. Exceptions to the general policy of distinct faunal names are those where long usage makes the change to a distinct name undesirable (as Barstow local fauna, Barstow formation) and those where the rock unit is named later than the fauna (as Rexroad local fauna, Rexroad formation).

Such a locally restricted name does not imply a doubtful correlation. A term applied to several widely separated assemblages runs the grave risk of major restriction or dismemberment as more data become available. Only rarely can more widespread localities be shown to be contemporaneous by special methods such as the association of the Cudahy fauna with the petrographically distinct Pearlette ash bed.

The name per se implies no special age. Leonard (1950) called the mollusks associated with the Pearlette ash bed the "Yarmouthian molluscan fauna." With changed age assignment Frye and Leonard (1952) termed the same assemblage the "Kansan molluscan fauna." A Kansan age seems probable, but nevertheless the later name is still open to the objection of special age implication. Other disadvantages are that the name cannot include other groups of animals, such as mammals, and that the name does not indicate its actual geographic restriction to the central Great Plains region. Here the noncommittal term Cudahy fauna seems clearly preferable.

A widespread or thick formation may have a different time range in different areas. Assemblages grouped as a fauna from separate localities in such a formation may be far from contemporaneous. Use of a number of local faunas would obviate a "fauna" which is gradually dismembered and restricted in age as more precise information becomes available. A specific example of a unit containing faunas of markedly different ages is the Rexroad formation of southwestern Kansas. Three distinct assemblages from this unit are recorded in the present paper.

Elias, too, (1942, p. 134–136) discussed this question of independent faunal and floral names, arriving at opposite conclusions. The reasons set forth above seem to me to outweigh any possible advantages of Elias's proposed method of a unified rock-faunal terminology. Van Houten, too (1944) has discussed the question of faunal nomenclature, concluding that a geographic name independent of stratigraphic terminology is convenient and desirable.

COMPARISON OF FAUNAS

Table 2 shows the occurrence and range of the species in eight faunas. These data are summarized in table 3. Indices of taxonomic similarity are given in table 4.

First appearances of species show two marked discontinuities: Saw Rock Canyon-Rexroad and Rexroad-Sand Draw. The first of these is considered not significant because it is almost surely in large part or entirely a result of inadequate sampling. The Rexroad local fauna is known from several localities, the Saw Rock Canyon local fauna from a single locality with little diversity of habitats.

The Rexroad-Sand Draw discontinuity is at least partly climatic. Many species first known from the Sand Draw local fauna probably represent northern species driven south by glacial advance. Extinction of some Rexroad species may be due to climatic change also. (See table 5.)

Last appearances of species are most apparent in the Bender and Sanders local faunas. Cooler climates associated with formation and advance of the Nebraskan and Kansan continental glaciers seem reasonable explanations for these.

Indices of faunal similarities (table 4) reveal the following significant points: The Saw Rock Canyon, Red Corral, and Rexroad local faunas are markedly similar to one another; the Sand Draw, Dixon, and Sanders local faunas are markedly similar to one another; the Bender local fauna is most similar to the Rexroad and Sanders; the Pleistocene fauna most similar to the Rexroad is the Sanders.

Apparent ranges and occurrences of individual species may be affected by sampling error, as well as by local habitat differences and by regional causes. The differences considered significant, and possible causes, are discussed below.

Vertigo ovata is known from the Clarendonian Laverne local fauna, Hemphillian Buis Ranch local fauna, and from numerous Pleistocene faunas. In the Rexroad and Saw Rock Canyon local faunas, however, it is replaced by *V. hibbardi.* This may be an example of temporary ecological replacement, for both species are of similar size and both probably had similar habitats. A possible explanation is that *V. hibbardi* arrived in the region of southern Kansas (either by migration or evolution) at the end of the Hemphillian, largely eliminated *V. ovata* in the area, and was in turn driven out by the first glaciation. *V. ovata* is a eurythermal species as shown by its wide range; perhaps *V. hibbardi* was not.

Gastrocopta rexroadensis and *Polygyra rexroadensis* are not known from faunas later than the Rexroad and Bender but do not necessarily indicate a late Pliocene age. Neither species is common enough to be reliable as a stratigrahic indicator. *G. rexroadensis* was not found in University of Michigan collections at localities from which it is reported.

Twenty-nine late Pliocene species are not known from earlier deposits. This may be entirely the result of incomplete collecting.

Gastrocopta chauliodonta is known only from three faunas which are dated Nebraskan or Aftonian on independent grounds. Collecting in earlier and later faunas seems sufficiently adequate to establish its local restriction to the lower Pleistocene, for it is a relatively common species. It may be a species which lived to the north in the late Pliocene and was forced southward by glaciation.

TABLE 2.—*Stratigraphic occurrence of mollusks of some late Cenozoic faunas in the High Plains*

[Occurrences outside the faunas listed are not necessarily in the High Plains. Occurrence of specifically unidentified forms and uncertain occurrences are omitted]

Species	Stratigraphic occurrence										
	Pre-Buis Ranch local fauna	Buis Ranch local fauna	Saw Rock Canyon local fauna	Red Corral local fauna	Rexroad local fauna	Bender local fauna	Sand Draw local fauna	Dixon local fauna	Sanders local fauna	Late Pleistocene	Recent
Anisus pattersoni (Baker)	×	------	------	------	------	------	×	×	------	×	------
Promenetus kansasensis (Baker)	×	------	×	×	×	------	×	×	×	×	------
Gastrocopta armifera (Say)	×	------	------	------	------	------	------	×	------	×	×
Gyraulus parvus (Say)	×	------	×	×	×	------	×	×	×	×	×
Hawaiia minuscula (Binney)	×	------	×	×	×	×	×	×	×	×	×
Bulimnea megasoma (Say)	×	------	------	------	------	------	×	×	------	×	×
Pisidium casertanum (Poli)	×	×	×	×	×	------	×	×	------	×	×
compressum Prime	×	------	------	------	------	------	×	×	------	×	×
nitidum Jenyns	×	------	------	------	------	------	×	×	------	×	×
Promenetus umbilicatellus (Cockerell)	×	------	×	×	×	×	×	×	×	×	×
Pupoides albilabris (Adams)	×	------	×	------	×	×	×	×	×	×	×
inornatus Vanatta	×	------	------	×	×	------	×	------	------	×	×
Sphaerium striatinum (Lamarck)	×	------	------	------	------	------	×	------	------	×	×
Vallonia gracilicosta Reinhardt	×	------	------	------	×	------	------	------	------	×	×
Valvata tricarinata (Say)	×	------	------	------	------	------	×	×	------	×	×
Vertigo ovata Say	×	×	------	------	------	------	×	×	×	×	×
Zonitoides arboreus (Say)	×	------	------	------	------	------	------	×	------	×	×
Strobilops sparsicostata Baker	------	×	------	×	×	------	×	×	------	------	------
Ferrissia rivularis (Say)	------	×	×	×	×	------	×	×	------	×	×
Stagnicola caperata (Say)	------	×	------	------	×	×	×	×	×	×	×
Gastrocopta rexroadensis Franzen and Leonard	------	------	×	×	×	------	------	------	------	------	------
Vertigo hibbardi Baker	------	------	×	------	×	------	------	------	------	------	------
Gastrocopta franzenae Taylor	------	------	×	×	×	×	------	------	------	------	------
Marstonia crybetes (Leonard)	------	------	×	------	×	------	------	×	------	------	------
Gastrocopta paracristata Franzen and Leonard	------	------	×	×	×	×	------	------	×	------	------
Deroceras aenigma Leonard	------	------	×	×	×	×	×	×	×	×	------
Fossaria dalli (Baker)	------	------	×	------	×	×	×	×	×	×	×
Gastrocopta holzingeri (Sterki)	------	------	×	------	×	------	------	------	------	×	×
tappaniana (Adams)	------	------	×	------	×	×	×	×	×	×	×
Helicodiscus singleyanus (Pilsbry)	------	------	×	------	×	×	×	×	×	×	×
Helisoma anceps (Menke)	------	------	×	------	×	------	×	×	------	×	×
Marstonia decepta (Baker)	------	------	×	------	------	------	------	------	------	×	×
Physa anatina Lea	------	------	×	×	×	×	×	×	×	×	×
Stagnicola bulimoides techella (Haldeman)	------	------	×	×	×	×	------	------	×	×	×
Strobilops labyrinthica (Say)	------	------	×	------	------	------	------	------	------	×	×
Vallonia perspectiva Sterki	------	------	×	------	×	------	×	×	×	×	×
Vertigo milium (Gould)	------	------	×	×	×	×	×	×	×	×	×
Gastrocopta pellucida hordeacella (Pilsbry)	------	------	------	×	×	------	------	×	------	×	×
Polygyra rexroadensis Taylor	------	------	------	------	×	×	------	------	------	------	------
Carychium exiguum (Say)	------	------	------	------	×	------	------	×	------	×	×
Cionella lubrica (Müller)	------	------	------	------	×	------	------	------	------	×	×
Ferrissia parallela (Haldeman)	------	------	------	------	×	------	------	------	------	×	×
Nesovitrea electrina (Gould)	------	------	------	------	×	------	------	×	------	×	×
Retinella rhoadsi (Pilsbry)	------	------	------	------	×	------	------	------	------	------	×
wheatleyi (Bland)	------	------	------	------	×	------	------	------	------	------	×
Stagnicola exilis (Lea)	------	------	------	------	×	------	------	------	------	×	×
Gastrocopta scaevoscala Taylor	------	------	------	------	------	×	------	×	------	------	------
cristata (Pilsbry and Vanatta)	------	------	------	------	------	×	×	×	×	×	×
Vallonia parvula Sterki	------	------	------	------	------	×	------	------	------	------	×
Gastrocopta chauliodonta Taylor	------	------	------	------	------	------	×	×	×	------	------
Acroloxus coloradensis (Henderson)	------	------	------	------	------	------	×	×	------	------	×
Aplexa hypnorum (Linnaeus)	------	------	------	------	------	------	×	------	×	×	×
Ferrissia meekiana (Stimpson)	------	------	------	------	------	------	×	×	------	×	×
Fossaria obrussa (Say)	------	------	------	------	------	------	×	------	------	×	×
Physa gyrina Say	------	------	------	------	------	------	×	×	------	×	×
skinneri Taylor	------	------	------	------	------	------	×	×	×	×	×
Planorbula armigera (Say)	------	------	------	------	------	------	×	×	------	×	×
Sphaerium partumeium (Say)	------	------	------	------	------	------	×	×	------	×	×
sulcatum (Lamarck)	------	------	------	------	------	------	×	------	------	×	×
transversum (Say)	------	------	------	------	------	------	×	×	------	×	×
Vallonia pulchella (Müller)	------	------	------	------	------	------	×	------	------	×	×
Valvata lewisi Currier	------	------	------	------	------	------	×	------	------	×	×
Gastrocopta procera (Gould)	------	------	------	------	------	------	------	×	------	×	×
Helicodiscus parallelus (Say)	------	------	------	------	------	------	------	×	------	×	×
Helisoma trivolvis (Say)	------	------	------	------	------	------	------	×	------	×	×
Oxyloma retusa (Lea)	------	------	------	------	------	------	------	×	------	×	×
Sphaerium lacustre (Müller)	------	------	------	------	------	------	------	×	------	------	×
Stagnicola reflexa (Say)	------	------	------	------	------	------	------	×	------	×	×

TABLE 3.—*Summary of data from table 2*

Occurrence	Number of species	Percent restricted	Percent first appearance	Percent last appearance	Occurrence	Number of species	Percent restricted	Percent first appearance	Percent last appearance
Pre-Buis Ranch local fauna	17	--	--	--	Recent	56	--	--	--
Buis Ranch local fauna	5	0	60	0	Total species for all faunas	68	--	--	--
Saw Rock Canyon local fauna	24	0	71	0	Saw Rock Canyon, Rexroad, and Red Corral	37	5	70	5
Red Corral local fauna	16	0	6	0	Sand Draw and Dixon	52	0	37	4
Rexroad local fauna	35	0	23	6	Sand Draw, Dixon, and Sanders	54	2	35	9
Bender local fauna	17	0	18	12	Saw Rock Canyon, Red Corral, Rexroad, and Bender	40	10	73	10
Sand Draw local fauna	38	0	34	0	Sand Draw, Dixon, Sanders, and Bender	57	4	39	12
Dixon local fauna	45	0	13	7					
Sanders local fauna	20	0	0	10					
Late Pleistocene	54	--	--	--					

TABLE 4.—*Faunal similarities*

[Calculated from data of table 2 by $\frac{100C}{N_1}$, where C=number of species common to two faunas and N_1=number of species in smaller fauna]

	Local faunas: Buis Ranch	Saw Rock Canyon	Red Corral	Rexroad	Bender	Sand Draw	Dixon	Sanders
Buis Ranch (N=5)	--	40	60	80	20	100	100	40
Saw Rock Canyon (N=24)	40	--	81	92	71	58	67	70
Red Corral (N=16)	60	81	--	100	50	69	69	56
Rexroad (N=35)	80	92	100	--	83	49	60	80
Bender (N=17)	20	71	50	83	--	65	71	77
Sand Draw (N=38)	100	58	69	49	65	--	82	85
Dixon (N=45)	100	67	69	60	71	82	--	85
Sanders (N=20)	40	70	56	80	77	85	85	--

TABLE 5.—*Distribution of thermally significant species in late Pliocene and early Pleistocene faunas of the High Plains*

Climate	Species	Local fauna: Buis Ranch	Saw Rock Canyon	Red Corral	Rexroad	Bender	Sand Draw	Dixon	Sanders
Mesothermal: Winters relatively mild and short.	*Gastrocopta cristata* (Pilsbry and Vanatta).	--	--	--	--	×	×	×	×
	pellucida hordeacella (Pilsbry)	--	--	×	×	--	--	×	--
	procera (Gould)	--	--	--	--	--	--	×	--
	Helicodiscus singleyanus (Pilsbry)	--	×	--	×	×	×	×	×
	Stagnicola bulimoides techella (Haldeman).	--	×	×	×	×	--	--	×
	Vallonia perspectiva Sterki	--	×	--	×	--	--	×	×
Summers mild	*Physa skinneri* Taylor	--	--	--	--	--	×	×	×
	Vallonia pulchella (Müller)	--	--	--	--	--	×	--	--
	Valvata lewisi Currier	--	--	--	--	--	×	--	--
	tricarinata (Say)	--	--	--	--	--	×	×	--
Summers warm but not hot and dry.	*Aplexa hypnorum* (Linnaeus)	--	--	--	--	--	×	--	×
	Promenetus umbilicatellus (Cockerell)	--	×	×	×	×	×	×	×
	Stagnicola caperata (Say)	×	--	--	×	×	×	×	×
	Vallonia gracilicosta Reinhardt	--	--	--	×	--	--	--	--

Nineteen species are first known in the earliest Pleistocene. Perhaps all of these were living to the north during the late Pliocene.

Temperature differences and similarities are shown by table 5. The Saw Rock Canyon, Rexroad, Bender, and Sanders local faunas are believed to have lived in a climate with summers warm but not hot and dry; the Sand Draw and Dixon local faunas in one of mild summers. These climatic shifts probably represent continent-wide changes, for southwestern Kansas is well beyond the limits of glaciation. These changes are tentatively correlated with the glacial-interglacial sequence in the Mississippi Valley.

SUMMARY OF FAUNAL SEQUENCE

Figure 1 summarizes the sequence of some Pliocene and Pleistocene faunas in the Great Plains and their stratigraphic position and age. In addition to the middle Pliocene to early Pleistocene assemblages described in detail elsewhere in this report, middle and late Pleistocene faunas of southwestern Kansas and northwestern Oklahoma, and other faunas mentioned in the text are included. The following notes present supplementary information, including references to pertinent literature. Numbers correspond to those in figure 1.

The North American ages Hemphillian, Blancan, Irvingtonian, and Rancholabrean (Wood and others, 1941; Savage, 1951) have not been adopted for official usage by the U.S. Geological Survey.

1. Buis Ranch local fauna (Herrington and Taylor, 1958; Hibbard, 1954; Oelrich, 1957; Tihen, 1955). In the upper part of the Ogallala formation, in Beaver County, Okla. Mammals, reptiles, amphibians, and mollusks. Several of the mammals show close relations with others in the Saw Rock Canyon local fauna, in the lower part of the Rexroad formation. Occurrence in the fauna of a rhinoceros (unknown elsewhere in North America from assemblages as young as Blancan), and the stratigraphic position of the fossils in the Ogallala formation, are the suggestive but somewhat arbitrary reasons for assigning this fauna to the late Hemphillian rather than early Blancan. The few mollusks slightly differentiate the assemblage from the Saw Rock Canyon and Rexroad local faunas, but how significantly is uncertain. Climate with summers less hot and dry than those of the area today. Significant members: *Pliogeomys*, *Perognathus* cf. *P. mclaughlini* Hibbard, rhinoceros, *Stagnicola caperata* (Say), *Vertigo ovata* Say.

2. Saw Rock Canyon local fauna (Herrington and Taylor, 1958; Hibbard, 1953, 1954, 1957; Taylor, this paper; Tihen, 1955). In the XI member (of Hibbard, 1949) of the lower part of the Rexroad formation, Seward County, Kans. Fishes, amphibians, reptiles, birds, mammals, and mollusks. The mammals indicate an earliest Blancan (early late Pliocene) age. The mollusks do not differentiate this fauna from the Rexroad local fauna. Climate subhumid and mesothermal, with less extreme summer hot spells and slightly greater and more effective annual precipitation. Significant members: *Dipoides wilsoni* Hibbard, *Ogmodontomys sawrockensis* Hibbard, *Baiomys sawrockensis* Hibbard, *Osteoborus progressus* Hibbard, *Vertigo hibbardi* Baker, *Stagnicola bulimoides techella* Haldeman, *Promenetus umbilicatellus* (Cockerell).

3. Rexroad local fauna (Herrington and Taylor, 1958; Hibbard, 1950; 1954b; 1956, p. 185; Oelrich, 1957; Taylor, this paper; Tihen, 1955). In the upper part of the Rexroad formation, below the massive caliche, Meade and Seward counties, Kansas. Amphibians, reptiles, birds, mammals and mollusks. The mammals indicate a considerably younger age than that of the Saw Rock Canyon local fauna, though still Pliocene. Climate subhumid and mesothermal, with markedly milder winters than those today, summers lacking the present hot spells, and a somewhat greater annual rainfall. There is no evidence of a stratigraphic break or of a climatic change between the horizons of the Saw Rock Canyon and Rexroad local faunas. Significant members: *Dipoides rexroadensis* Hibbard and Riggs, *Ogmodontomys poaphagus* Hibbard, *Bensonomys eliasi* (Hibbard), *Procastoroides lanei* (Hibbard), *Plesippus simplicidens* (Cope), *Nannippus phlegon* (Hay), primitive *Stegomastodon*, *Testudo rexroadensis* Oelrich, *T. turgida* Cope, *Stagnicola bulimoides techella* (Haldeman), *S. exilis* (Lea), *Promenetus umbilicatellus* (Cockerell), *Gastrocopta franzenae* Taylor, *G. pellucida hordeacella* (Pilsbry), *G. rexroadensis* Franzen and Leonard.

4. Bender local fauna (Taylor, this paper). In the upper part of the Rexroad formation above the massive caliche, in Meade and Seward Counties, Kans. Mollusks only. The fauna is a little more like the Rexroad local fauna than the Sanders local fauna or other Pleistocene interglacial assemblages, and tends to favor a Pliocene age. Climate subhumid and mesothermal. Significant members: *Stagnicola bulimoides techella* (Haldeman), *S. caperata* (Say), *Promenetus umbilicatellus* (Cockerell), *Gastrocopta franzenae* Taylor, *G.* cf. *G. cristata* (Pilsbry and Vanatta), *G. scaevoscala* Taylor.

5. Unnamed assemblage (Hibbard, 1949, p. 67; 1956; Savage, 1955). A few large vertebrates have been collected from the Angell member of the Ballard formation in Meade and Clark Counties, Kans.: *Ple-*

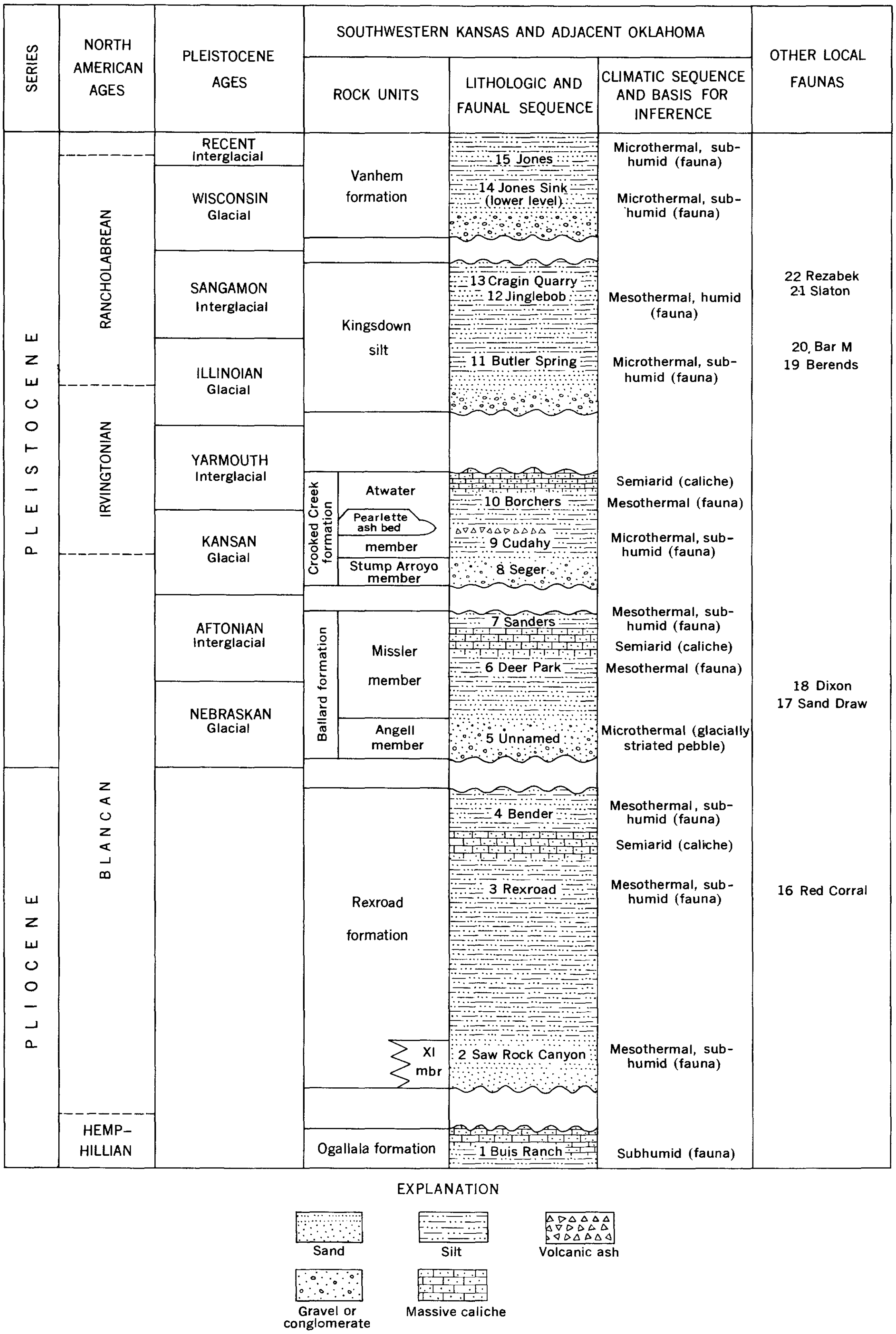

FIGURE 1.—Summary of late Cenozoic faunal, climatic, and lithologic sequences in southwestern Kansas, and correlation of other local faunas from the High Plains.

sippus simplicidens (Cope), *Equus* (*Asinus?*) sp., *Nannippus phlegon* (Hay), *Stegomastodon mirificus* (Leidy), and camel.

6. Deer Park local fauna (Hibbard, 1956). In the lower part of the Missler member of the Ballard formation, in Meade County, Kans. The mammals indicate Blancan age, narrowed to Aftonian by indications of mild climate and by their stratigraphic position. From the Angell member of the Ballard formation, below the Missler member, Hibbard (1944) reported glacially striated pebbles. Significant members: *Pliolemmus antiquus* Hibbard, *Pliopotamys meadensis* Hibbard, *Procastoroides sweeti* Barbour and Schultz, *Nannippus phlegon* (Hay), *Plesippus simplicidens* (Cope), and large species of *Testudo*.

7. Sanders local fauna (Hibbard, 1956; Taylor, this paper; Tihen, 1955). In the upper part of the Missler member of the Ballard formation, above the massive caliche, in Meade County, Kans. Mollusks, amphibians, birds, and mammals. Stratigraphic position, ecologic interpretations, and faunal evidence indicate late Aftonian age. The fauna is distinct from other Blancan assemblages in its composition as well as climatic implications. Climate subhumid and mesothermal, with more effective precipitation and sharply reduced summer temperatures. Significant members: *Sigmodon*, *Zapus*, *Plesippus simplicidens* (Cope), *Nannippus phlegon* (Hay), *Gastrocopta chauliodonta* Taylor, *G. paracristata* Franzen and Leonard, *Physa skinneri* Taylor, *Stagnicola bulimoides techella* (Haldeman).

8. Seger local fauna (Hibbard, 1951, 1953; Savage, 1955). In the Stump Arroyo member of the Crooked Creek formation, in Meade and Clark Counties, Kans. Large mammals only. The few species known do not differentiate this fauna from earlier ones, but are distinct from those of later assemblages. They have no special climatic implications. Significant members: *Plesippus* sp. cf. *P. simplicidens* (Cope), *Nannippus phlegon* (Hay), *Stegomastodon mirificus* (Leidy).

9. Cudahy fauna (Frye and Leonard, 1952, p. 158–159; Herrington and Taylor, 1958; Hibbard, 1944, 1949b; Johnston and Savage, 1955; Leonard, 1950; Tihen, 1955). Includes the Tobin and Wilson Valley faunules (Frye, Leonard, and Hibbard, 1943), the "Yarmouthian molluscan fauna" (Leonard, 1950), and the "Kansan molluscan fauna" (Frye and Leonard, 1952) in part. The Arkalon local fauna (Hibbard, 1953a) is tentatively included. Associated with the Pearlette ash bed (usually immediately below the ash) over a wide area from Iowa to Texas. In southwestern Kansas it is in the Atwater member of the Crooked Creek formation. Frye, Swineford, and Leonard (1948) recognized the petrographic distinctness of the Pearlette ash bed and listed the mollusks associated with it. This volcanic ash demonstrates the essential contemporaneity of the associated fossils. The name Cudahy fauna is used in the broad sense for the entire assemblage, for there seems no reason to use more than one name. Fishes, amphibians, reptiles, birds, mammals, and mollusks are known. Hibbard (1949b) considered the Cudahy a glacial fauna of Kansan age, pointing out the boreal relations of the vertebrates. The snails *Pupilla muscorum*, *P. blandi*, *Vertigo gouldi*, *V. modesta*, and others occur in the Great Plains today only far to the north. Their presence in the Cudahy fauna as far south as Texas indicates radically cooler and moister summers and presumably wetter, but not necessarily colder, winters. Significant members: *Equus* sp., *Sorex*, *Neosorex lacustris* Hibbard, *Microsorex pratensis* Hibbard, *Synaptomys* (*Mictomys*) *borealis* (Richardson), *Microtus paroperarius* Hibbard, *Pedomys llanensis* (Hibbard), *Pitymys meadensis* Hibbard, *Pupilla muscorum* (Linnaeus), *Vertigo modesta* (Say), *Valvata tricarinata* (Say).

10. Borchers local fauna (Hibbard, 1941b, 1949b; Tihen, 1955). In the Atwater member of the Crooked Creek formation, above the Pearlette ash bed, in Meade County, Kans. Amphibians, reptiles, birds, and mammals. The small mammals indicate a climate as warm or warmer than that of present day southwestern Kansas, and hence an interglacial age. Significant members: *Testudo*, large species, *Onychomys fossilis* Hibbard, *Sigmodon hilli* Hibbard, *Synaptomys landesi* Hibbard.

11. Butler Spring local fauna (Herrington and Taylor, 1958; Hibbard and Taylor, 1960; Smith, C. L., 1958; Tihen, 1955). In the lower part of a section included in the undifferentiated Sanborn group, in Meade County, Kans. Fishes, amphibians, reptiles, mammals, and mollusks. Stratigraphic position and ecological interpretations indicate a late Illinoian age. Climate subhumid, differing from that of Meade County today in being markedly cooler, the difference mostly in the summers. Significant members: *Ictalurus* cf. *I. punctatus* (Rafinesque), *Perca flavescens* (Mitchill), *Valvata tricarinata* (Say), *Probythinella lacustris* (Baker), *Lymnaea stagnalis jugularis* Say, *Physa skinneri* Taylor, *Pupilla muscorum* (Linnaeus), *Vallonia cyclophorella* Sterki.

12. Jinglebob local fauna (Herrington and Taylor, 1958; Hibbard, 1952, 1955, 1956a; Hibbard and Taylor, 1960; Oelrich, 1953; Rinker, 1949; Taylor and Hibbard, 1955; Tihen, 1954, 1955; van der Schalie, 1953). In the Kingsdown silt, Meade County, Kans.

Fishes, amphibians, reptiles, mammals, and mollusks. Stratigraphic position and ecologic inferences suggest a late Sangamon age. Climate humid and mesothermal; summers were cooler and winters warmer than those of the area today. Significant members: *Terrapene llanensis* Oelrich, *Arctodus simus* (Cope), *Oryzomys*, *Bison latifrons* (Harlan), *Promenetus exacuous* (Say), *Valvata tricarinata* (Say), *Laevapex kirklandi* (Walker), *Strobilops labyrinthica* (Say).

13. Cragin Quarry local fauna (Etheridge, 1958; Hibbard, 1949b; Hibbard and Taylor, 1960). In the Kingsdown silt, Meade County, Kans. Fishes, amphibians, reptiles, mammals, and mollusks. Stratigraphic position and ecologic inferences suggest an early Sangamon age. Climate semiarid and mesothermal; summers were slightly less hot, winters much warmer than those of today. Significant members: *Terrapene llanensis* Oelrich, *Testudo*, medium sized, *Phrynosoma cornutum* (Harlan), *P. modestum* Girard, *Notiosorex crawfordi* (Coues), *Peromyscus progressus* Hibbard, *Promenetus kansasensis* (Baker).

14. Jones Sink (lower level) (Goodrich, 1940; Herrington and Taylor, 1958). In the Vanhem formation, Meade County, Kans. Only mollusks have been recovered so far. Their stratigraphic position close below the Jones local fauna and climatic inferences suggest a Wisconsin age. Climate microthermal, subhumid. Significant members: *Pisidium obtusale* Pfeiffer, *P. lilljeborgi* Clessin, *P. subtruncatum* Malm.

15. Jones local fauna (Downs, 1954; Herrington and Taylor, 1958; Hibbard, 1940, 1949; Hibbard and Taylor, 1960; Taylor and Hibbard, 1955; Tihen, 1942, 1955). In the Vanhem formation, Meade County, Kans. Fishes, amphibians, birds, mammals, and mollusks. Stratigraphic position and climatic inferences suggest a Wisconsin age. No assignment to a particular subage is yet possible. Climate subhumid, microthermal; summer temperatures were much lower than those of southwestern Kansas today. Significant members: *Camelops*, *Platygonus*, *Microtus pennsylvanicus* (Ord), *Pisidium walkeri* Sterki, *P. lilljeborgi* Clessin, *P. ferrugineum* Prime, *Valvata tricarinata* (Say), *Lymnaea stagnalis jugularis* Say, *Pupilla blandi* Morse.

16. Red Corral local fauna (Herrington and Taylor, 1958; Taylor, this paper). In an unnamed formation, in Oldham County, Tex. Mammals (principally all unpublished) and mollusks. The horse *Plesippus* indicates Blancan age, narrowed to late Pliocene by the mollusks. The fauna is equivalent to or slightly older than the Rexroad, perhaps as old as the Saw Rock Canyon local fauna. Climate subhumid and mesothermal. Summers were cooler and moister than those of the area today, winters not much if any cooler. Significant members: *Plesippus*, *Nannippus*, *Gastrocopta paracristata* Franzen and Leonard, *G. rexroadensis* Franzen and Leonard, *G. pellucida hordeacella* (Pilsbry), *Ferrissia rivularis* (Say), *Promenetus umbilicatellus* (Cockerell).

17. Sand Draw local fauna (Herrington and Taylor, 1958; Hibbard, 1956, 1957; McGrew, 1944; Savage, 1955; Taylor, 1954, this paper). In an unnamed formation, in Brown County, Nebr. Fishes, reptiles, mammals, and mollusks. Faunal correlation and climatic inferences indicate a late Nebraskan age. Climate subhumid to humid and microthermal; summers were cooler and moister than those of the area today, but winters were no more severe. Significant members: *Geomys quinni* McGrew, *Pliopotamys meadensis* Hibbard, *Gastrocopta chauliodonta* Taylor, *G. cristata* (Pilsbry and Vanatta), *Helicodiscus singleyanus* (Pilsbry), *Physa skinneri* Taylor.

18. Dixon local fauna (Herrington and Taylor, 1958; Hibbard, 1956, 1958a; Tihen, 1955). In an equivalent of or in the Missler member of the Ballard formation, in Kingman County, Kans. Amphibians, birds, mammals, and mollusks. Faunal correlation and climatic inferences indicate a latest Nebraskan or earliest Aftonian age. Climate mesothermal and subhumid. Significant members: *Sorex*, *Pliophenacomys meadensis* Hibbard, *Pliopotamys meadensis* Hibbard, *Pliolemmus antiquus* Hibbard, *Gastrocopta chauliodonta* Taylor, *G. pellucida hordeacella* (Pilsbry), *Vallonia perspectiva* Sterki, *Valvata tricarinata* (Say), *Physa skinneri* Taylor.

19. Berends local fauna (Herrington and Taylor, 1958; Hibbard and Taylor, 1960; Mengel, 1952; Smith, 1954, 1958; Starrett, 1956; Taylor and Hibbard, 1955). In a basin deposit, included in the undifferentiated Sanborn group, in Beaver County, Okla. Faunal evidence and climatic interpretations indicate an Illinoian age. Climate subhumid or humid, and microthermal. Significant members: *Castoroides*, *Paradipoides stovalli* Rinker and Hibbard, *Perca flavescens* (Mitchill), *Esox masquinongy* Mitchill, *Physa skinneri* Taylor, *Valvata tricarinata* (Say).

20. Bar M local fauna (Herrington and Taylor, 1958; Hibbard and Taylor, 1960; Taylor and Hibbard, 1955). The fauna is from two sinkhole fillings in Harper County, Okla. Mammals and mollusks. Stratigraphic position and climatic inferences indicate an Illinoian or Wisconsin age. Climate subhumid or humid, and microthermal. Significant members: *Dasypus bellus* (Simpson), *Microtus pennsylvanicus* (Ord), *Lymnaea stagnalis jugularis* Say, *Physa skin-*

neri Taylor, *Pupilla muscorum* (Linnaeus), *Discus cronkhitei* (Newcomb).

21. Slaton local fauna (Herrington and Taylor, 1958; Meade, 1942, 1952). Lubbock County, Tex. Mammals, reptiles, and mollusks. Faunal correlation and ecologic interpretation suggest a Sangamon age. Climate mesothermal and subhumid or humid. Significant members: *Neofiber leonardi* Hibbard, *Terrapene llanensis* Oelrich, *Stagnicola caperata* (Say), *Promenetus kansasensis* (Baker), *Pupoides hordaceus* (Gabb), *Pupilla blandi* Morse, *Gastrocopta pellucida hordeacella* (Pilsbry).

22. Rezabek local fauna (Franzen and Leonard, 1947; Frye, Leonard, and Hibbard, 1943; Herrington and Taylor, 1958; Hibbard, 1943). Lincoln County, Kans. Fishes, amphibians, reptiles, birds, mammals, and mollusks. Stratigraphic position and ecologic inferences indicate Sangamon age. Abundance of broken and badly worn shells suggests some may have been reworked. Significant members: *Sorex cinereus* Kerr, *Microtus* cf. *M. pennsylvanicus* (Ord), *Neofiber leonardi* (Hibbard).

CORRELATION OF NORTH AMERICAN AGES WITH LYELLIAN EPOCHS

For relating the Blancan, Irvingtonian, and Rancholabrean ages to the Lyellian epochs Pliocene and Pleistocene, southwestern Kansas and western Oklahoma is the most significant area in North America. This importance is due to a combination of several unusual factors, principally conditions of deposition peculiar to this area. Oversimplifying the picture, one may state that from the late Pliocene through the present continued solution at depth of Permian salt and gypsum beds has caused development of many sinkholes and large basins. The exceptionally thick deposits "trapped" in these depressions contain the most complete sequence of late Pliocene and Pleistocene continental faunas yet recorded. This chapter is intended to emphasize only the sequence of faunas and to show their broader implications. The foregoing summary of the faunal sequence contains a more detailed treatment, listed by individual faunas.

In the western Oklahoma and southwestern Kansas area, the unusually detailed sequence is confined to the late Pliocene and Pleistocene. Clarendonian and Hemphillian faunas not of unusual significance are mentioned below only to indicate their presence in the area. Following a summary of the depositional and biological sequence is a correlation of this sequence with the Pliocene-Pleistocene boundary and the Blancan, Irvingtonian, and Rancholabrean ages.

SUMMARY OF DEPOSITIONAL AND BIOLOGICAL SEQUENCE

Hemphillian age.—All Hemphillian fossils from the southwestern Kansas area come from the Ogallala formation. The grass seed *Biorbia fossilia* occurs in the upper part of the formation (Elias, 1942, p. 144; Hibbard, 1941b, p. 199). Three local faunas are known: Buis Ranch, Optima, and Swayze Quarry. The Buis Ranch local fauna (late Hemphillian) is closely related to the Saw Rock Canyon local fauna (earliest Blancan) in the basal part of the Rexroad formation. Deposition of the Ogallala formation was apparently followed by a period of major erosion but short duration, for the Rexroad formation (Blancan) is nowhere found overlying the Ogallala. Probably the Ogallala occurred as upland remnants when the Rexroad was being laid down at lower elevations.

Blancan age.—Six superposed local faunas from three formations are assigned to the Blancan. In order of decreasing age and successive superposition these are as follows: Saw Rock Canyon, Rexroad, Bender (in the Rexroad formation), Deer Park, Sanders (Ballard formation), and Seger (Crooked Creek formation).

The relatively fine-grained Rexroad formation is known to represent a large time range by the differences between mammals of the Saw Rock Canyon and Rexroad local faunas. The Saw Rock Canyon local fauna might almost as well be termed Hemphillian as Blancan; the Rexroad local fauna is more characteristically Blancan, containing *Plesippus* and *Nannippus.* Both mammals and mollusks indicate that the climates in which these two faunas lived were mesothermal and subhumid or humid, lacking extremely cold winters and hot summers, and with more and better distributed rainfall than southwest Kansas receives now. Furthermore, the deposits and faunas overlying the Rexroad formation show 4 cycles of erosion and deposition of coarse materials in a cool climate separated by 3 intervals of mild climate with deposition of fine-grained sediments. The most reasonable interpretation of this sequence tentatively correlates the 4 cool-climate cycles with the 4 major continental glaciations, and regards the Rexroad formation as preglacial (here, equivalent to pre-Pleistocene). The upper part of the Rexroad formation, above the level of the Rexroad local fauna, contains a massive buried caliche zone indicative of a change to semiarid climate. Above the caliche, silt containing the Bender local fauna grades into sandy silts. This succession indicates a change from semiarid to moister climate.

The Ballard formation unconformably overlies the Rexroad formation. Its lower sand and gravel member has yielded glacially striated pebbles (Hibbard, 1944), and scattered vertebrates. The higher silt member contains at its base the mild-climate Deer Park local fauna, a higher presumably interglacial buried caliche zone, and the still higher Sanders local fauna indicative of a subhumid mesothermal climate. As part of the first of four cool-climate erosional and depositional cycles, the lower part of the Ballard formation is considered probably Nebraskan, and the upper part probably Aftonian.

The Crooked Creek formation is a unit similar in lithologic succession to the unconformably underlying Ballard formation, but distinct from that formation in lithologic type. As part of the second of four cool-climate cycles of erosion and deposition, the lower part of the Crooked Creek formation is considered probably Kansan. The basal gravel of this unit contains the Seger local fauna, with such characteristically Blancan forms as *Plesippus* and *Nannippus*. For this reason the Blancan age includes the early part of the Kansan age.

Irvingtonian age.—Three faunas, all from the upper part of the Crooked Creek formation, are referred to the Irvingtonian age. These are the Cudahy fauna, associated with the Pearlette ash bed; the Arkalon local fauna, equivalent to or very slightly later than the Cudahy; and the Borchers local fauna, stratigraphically the highest of these three faunas. From its position in the sequence the Crooked Creek formation is believed to be probably Kansan and Yarmouth in age. The Arkalon and Cudahy (implying microthermal climates) are termed Kansan; but the later Borchers local fauna indicates a warm, semiarid climate of probable Yarmouth age.

Rancholabrean age.—Mammals from the younger deposits in the southwestern Kansas area are inadequate to place precisely the Irvingtonian-Rancholabrean boundary in terms of glacial ages. The late Kansan Arkalon local fauna is Irvingtonian, and the Sangamon Jinglebob local fauna is Rancholabrean. By analogy with the Blancan-Irvingtonian boundary, the middle Illinoian age may include the end of the Irvingtonian.

Later Pleistocene stratigraphy in the Meade County, Kans. area is more complex than that of the earlier Pleistocene, because of a change in type of deposition which occurred in about earliest Illinoian time. The lower Pleistocene Ballard and Crooked Creek formations are widespread sheet deposits; the fossils of these two units can be related stratigraphically to one another with relative ease. Upper Pleistocene deposits, however, are of two chief types: fillings of valleys cut into the earlier formations, and isolated sinkhole deposits. After deposition of the Crooked Creek formation (that is, in post-Yarmouth time) two intervals of valley cutting and filling took place. Deposits of the first interval are included in the Kingsdown silt, those of the second are termed the Vanhem formation. The two units are correlated tentatively with the Illinoian-Sangamon and Wisconsin ages, respectively. The isolated sinkhole deposits, regardless of age, are included in the undifferentiated Sanborn group. These later Pleistocene deposits usually lack the massive buried caliche of earlier units, and may lack a basal gravel. This more complicated upper Pleistocene stratigraphy results in less stratigraphic control for these faunas. Warm-climate faunas are called Sangamon, and cool-climate faunas are referred to the Illinoian or Wisconsin, depending upon which unit they come from.

Two Illinoian faunas are from the undifferentiated Sanborn group: the Berends and Butler Spring local faunas. Both Sangamon assemblages, the Cragin quarry and Jinglebob local faunas, are from the Kingsdown silt. The Jinglebob local fauna is of interest in containing *Bison latifrons*, marking the late Sangamon first appearance of *Bison* in the Meade County area.

The Vanhem formation has yielded the youngest assemblage of fossils in the southwest Kansas area, the Jones local fauna.

CORRELATION

Previous discussions of the Pliocene-Pleistocene boundary and of the North American ages such as Hemphillian and Blancan have been handicapped by confusion of two essentially different categories. The North American ages are successive broad phases in the development of the North American mammalian fauna. The type section of the Pliocene-Pleistocene boundary in central Italy is based upon changes in marine invertebrate faunas; the Astian-Calabrian boundary is the one evidently considered definitive by the International Geological Commission. Italian mammalian assemblages no less than those from the United States are dated relative to the Pliocene-Pleistocene boundary by indirect correlation, not definition. Chapters in the history of land mammals of North America do not necessarily correspond to those of Europe, and neither of these necessarily corresponds to chapters in the history of marine invertebrates in the Mediterranean.

Pliocene-Pleistocene boundary.—The 18th International Geological Congress recommended that the Pliocene-Pleistocene boundary have a type area in Italy, and that the marine Calabrian stage and its continental equivalent, the Villafranchian, be considered earliest Pleistocene (American Commission on Stratigraphic Nomenclature, 1949). The Pliocene-Pleistocene boundary in other parts of the world should be established with reference to this Italian type, but application of this principle is beset with difficulties of correlation as well as ambiguities in interpretation of the Congress' decision.

The most recent and most careful study of the Pliocene and Pleistocene stratigraphy of central Italy (Lüttig, 1958) has shown the need for revision of previous ideas about the Villafranchian stage. The concept of this stage has been more broadly inclusive and poorly defined than realized, and includes more than simply the continental equivalents of the marine Calabrian stage. Lüttig's conclusions are so significent in considering the Pliocene-Pleistocene boundary that it is desirable to quote some of his statements at length. After discussion of the classifications of Pliocene and Pleistocene sediments in northwestern Europe and in the Alps, Lüttig (1958, p. 655–656) stated (translation):

> Both of the classifications cited above show that there is a series of readily recognizable stratigraphic entities older than the Mindel glacial interval, or the part of the Quaternary in northwestern Europe which corresponds to it, which are included in the "Villafranchiano" of central Italy (under the assumption that they can be differentiated also in central Italy). From the results of Quaternary geology in central and northwestern Europe, the concept of the Villafranchiano would then be put in a new light, if the observations made in Italy had not already led to the demand that the "Villafranchiano" concept be applied no longer in central Italy—or at least no longer in the previous way. At the type locality, in the rest of northern Italy and in France, observations are accumulating which favor the view of Lona (1950), Venzo (1956), and Movius (1949) that the Villafranchiano in the strict sense is to be placed in the first warm interval of the Pleistocene, that is in the ?Tegelen interstadial or the Donau/Günz interstadial. The continental Villafranchiano is in striking correlation with the marine Calabriano. The differentiation of a warm from a cold Villafranchiano must be discarded, for that which has been called "warm Villafranchiano" is definitely to be placed in the Pliocene, according to Movius' useful summary and my own field work. The faunas and floras of the "cold Villafranchiano" document the selection of species caused by the first significant invasion of cold of the Pleistocene, in which the warmth-loving "Tertiary elements" were partly decimated. The faunas and floras of the Valdarno superiore, which have been called—quite inadmissibly—typical of the "Villafranchiano," range from the (middle) Pliocene to (at least) the Tegelen interstadial. The Villafranchiano in the strict sense is only a fraction of this, and it is not permissible to use this concept any longer for deposits which may have an age from middle Pliocene to Mindel.
>
> If one considers this critical view correct, the result is that none of the stratigraphic concepts previously applied in the nonmarine Quaternary (and Pliocene) of central Italy satisfy the demands which are put on stratigraphy. We may derive from this the demand, *that a new stratigraphy of the central Italian Quaternary must be provided, and this must naturally happen from the clarification of the local relationships themselves, hence from some kind of local classification.*

The descriptions of the stratigraphy in various local areas of central Italy given by Lüttig (1958) are necessary for understanding the regional relationships of the Calabrian and Villafranchian sediments, but need not be repeated here. Lüttig's discussion of the sequence in the upper Arno Valley, however, is so important as a basis for correlation with the series of faunas from the Great Plains described in this paper that part of it (Lüttig, 1958, p. 659–660) is quoted here (translation):

> *The Valdarno superiore:* The classic locality of Plio-Pleistocene faunas and floras, which have been erroneously called the typical fossil associations of the Villafranchiano, includes thick lacustrine clay and silt, which are truncated above by sands and fluviatile gravels. Within the lacustrine clay lies the boundary between Pliocene and Pleistocene. Consideration of the fossils shows that they can be divided into two types: Type a: fossils of a warm to subtropical character, Type b: fossils of temperate climate, which therefore show that a cold-invasion took place during or before their dispersal. The first "glacial interval" of the Pleistocene corresponds to this cold-invasion. The fossils of type a occur in the lower clays of the Valdarno (Stellicone series); in these clays occurs the greater part of the lignite, in particular the deposits of Santa Barbara, Gaville, Tegolaia, Monastero and San Donato in Avane. The fossils of type b are restricted to the higher parts of the lake beds (Ville beds). Both sedimentary complexes are separated by an "unconformity" according to observations by Sestini (1936). The reasoning for this unconformity of Sestini, which Movius (1949) also put to use, I cannot follow, but in effect come to the same conclusion. At Ricasoli may be seen fluviatile gravels at an horizon which corresponds to Sestini's unconformity, and which as the Ricasoli beds represent the first cold time of the Pleistocene. A division of the lake beds cannot be doubted. The hypothesis of a lower warm and an upper cold "Villafranchiano" is superfluous; the "warm Villafranchiano" is middle to upper Pliocene, the "cold Villafranchiano" corresponds to the first warm interval of the Pleistocene, the Ville series, and the decimation of the fauna and flora of a warm interval which is shown in fossil-type b, occurred during deposition of the Ricasoli series. The overlying gravels of the so-called Sansino series are to be placed in the second cold interval of the Pleistocene.
>
> If one wishes, the Ville series can be equated to the Villafranchiano in the strict sense. Since, however, this concept has been used in this area in a wider sense instead, a new usage in another sense would bring more confusion than order.

Although some confusion in the concept of the Villafranchian fauna may have been due to inadequate locality information, part may also have been due to facies changes. According to Lüttig's descriptions, the Astian (late Pliocene) deposits of central Italy are marine almost everywhere except in the upper Valdarno, where all of the Piacenzian and Astian equivalents are continental.

Correlation between the High Plains and central Italy on the basis of fossil mammals has been attempted, but is unreliable. The number of mammals known from late Pliocene deposits in the area selected by the International Geological Congress as the standard of reference for the Pliocene-Pleistocene boundary is very small indeed, and most of the mammals which have been considered as the typical Villafranchian fauna from this area are not of earliest Pleistocene age (Lüttig, 1958; Thenius, 1959). Furthermore, the latest Pliocene-earliest Pleistocene time interval involved is relatively short, and it seems that dispersal lag might affect mammalian correlations significantly even though it is unimportant in earlier parts of the Tertiary.

The most practicable, and perhaps also the most precise correlation of the Pliocene-Pleistocene boundary between the Great Plains and the type area in central Italy is adoption of the earliest horizon with evidence of marked climatic cooling in temperate latitudes as representing the earliest Pleistocene. In southwestern Kansas and northwestern Oklahoma, where the geologic record of late Pliocene and Pleistocene times is more nearly complete than elsewhere in the Great Plains, the Pliocene-Pleistocene boundary is on this criterion between the Rexroad and Ballard formations. These two units are separated by an erosional unconformity which represents an hiatus of uncertain extent.

Blancan age.—The term Blancan was proposed (Wood and others, 1941) for a group of mammalian assemblages considered roughly contemporaneous and characterized by the association of (among others) *Plesippus*, *Nannippus*, and *Borophagus*. The name, but not the entire basis for the term, was taken from the Blanco local fauna of Texas. The time characterized by this composite faunal concept was called the Blancan Provincial Age, and was thought to be late Pliocene.

Since establishment of this term, evidence has accumulated that many Blancan faunas lived during the early Pleistocene (Nebraskan to early Kansan). Other studies, principally by C. W. Hibbard and others in southwestern Kansas, have shown that Blancan assemblages lived both before and after the beginning of continental glaciation. Much of the confusion about the age of the Blancan interval comes from the tacit oversimplification by many paleontologists that all Blancan faunas lived during a relatively short interval, and that the faunas must be either Pliocene or Pleistocene.

Another reason for which the Blancan age has been correlated with the early Pleistocene is the belief that the marked faunal break between the Kimball and Broadwater formations of the Nebraska Geological Survey does not imply a considerable time interval. (See Schultz and Stout, 1948). The Kimball has been regarded as late Pliocene, the Broadwater as early Pleistocene. According to the interpretations and correlations accepted here, however, the Kimball is middle Pliocene, the Broadwater is Pleistocene, and the late Pliocene is unrepresented in the Great Plains north of southwestern Kansas.

Schultz and Stout (1948, p. 556) summarized the significant differences between the fossil mammals from the Kimball and Broadwater formations. The rhinoceroses, longirostrine mastodonts, and transitional *Pliohippus-Plesippus* from the Kimball suggest a late Hemphillian assemblage. If the Broadwater formation is Pleistocene, then the earlier Blancan interval represented by the Rexroad formation in Kansas does not have an equivalent unit in western Nebraska. The correlation of the middle Pliocene to early Pleistocene deposits of southwestern Kansas and western Nebraska with those of central Italy (as classified by Lüttig, 1958) is shown in table 6.

TABLE 6.—*Correlation of middle Pliocene to lower Pleistocene deposits in Italy and the High Plains*

North American ages	Southwestern Kansas	Western Nebraska	Central Italy stages
Blancan	Stump Arroyo member of Crooked Creek formation	Broadwater [1] formation	Arno Stage (Pleistocene)
	Ballard formation		
	Rexroad formation	(erosion)	(Pliocene) Astian Stage
Hemphillian	Ogallala formation	Ogallala [1] group	Piacenzian Stage ?

[1] Terminology of Nebraska Geological Survey.

Irvingtonian and Rancholabrean ages.—Correlation of the upper limit of the Blancan, and of the limits of the Irvingtonian and Rancholabrean ages with the glacial and interglacial stages of the midcontinent region is now possible only in southwestern Kansas. It is hardly definite, however, for the glacial and interglacial intervals recognized in southwestern Kansas are correlated in turn with the Mississippi Valley area. Accepting these correlations, however, the Blancan-Irvingtonian boundary falls within the Kansan age, and the Irvingtonian-Rancholabrean boundary falls within the Illinoian age.

DESCRIPTION OF LOCAL FAUNAS

BUIS RANCH LOCAL FAUNA

Previous work.—The Buis Ranch fossil locality was discovered in 1951 by a University of Michigan field party under the supervision of C. W. Hibbard. Subsequent collecting by Hibbard and other Michigan groups has yielded a small fauna, especially interesting because it shows relationships to both Hemphillian and Blancan assemblages. Previous references to the mollusks are by Herrington and Taylor (1958) and Hibbard (1954).

Fauna.—Following is a list of the Buis Ranch local fauna:

Class Pelecypoda
- Order Teleodesmacea
  - *Pisidium casertanum* (Poli)

Class Gastropoda
- Order Basommatophora
  - *Stagnicola caperata* (Say)
  - *Ferrissia rivularis?* (Say)
- Order Stylommatophora
  - *Strobilops sparsicostata* Baker
  - *Vertigo ovata* Say

Class Amphibia
- Order Caudata
  - Ambystomatidae, indet.
- Order Salientia
  - Frogs or toads, or both

Class Reptilia
- Order Chelonia
  - *Testudo turgida* Cope
- Order Squamata
  - Snake and lizard bones

Class Mammalia
- Order Insectivora
  - *Hesperoscalops* sp.
- Order Carnivora
  - *Buisnictis schoffi* Hibbard
- Order Rodentia
  - *Citellus dotti* Hibbard
  - *Perognathus* cf. *P. mclaughlini* Hibbard
  - *Prodipodomys* sp.
  - *Pliogeomys buisi* Hibbard
  - Cricetidae, indet.
- Order Lagomorpha
  - Leporidae, indet.
- Order Artiodactyla
  - Giant camel
- Order Perissodactyla
  - *Nannippus* sp.
  - Rhinoceros, indet.

Occurrence.—The Buis Ranch local fauna is known only from Beaver County, Okla.

Stratigraphy.—Hibbard (1954) reported the fauna to occur in the lower part of the Rexroad formation. Later fieldwork, however, has shown that it occurs in the Ogallala formation of that area (Tihen, 1955, p. 238). Apparently both Permian rocks and Ogallala formation sagged, perhaps because of ground water solution of salt and gypsum at depth. The Ogallala was thus kept largely below the water table, so that weathering could not form the mortar beds so characteristic of the formation in northwestern Oklahoma and southwestern Kansas.

Localities.—Only one locality is known, on the west side of Buckshot Arroyo, Buis Ranch, NE¼SW¼ sec. 5, T. 5 N., R. 26 E., Beaver County, Okla.

Age.—*Perognathus* cf. *P. mclaughlini*, and *Pliogeomys* suggest that the Buis Ranch local fauna is of approximately the same age as the Saw Rock Canyon local fauna (earliest Blancan). The presence of a rhinoceros tends to indicate a Hemphillian, rather than Blancan, age. A latest Hemphillian age thus seems reasonable.

Mollusks are so rare that they cannot give an accurate picture of the fauna which lived in the area. The occurrence of *Vertigo ovata*, unknown from the thoroughly collected Saw Rock Canyon fauna, suggests a greater age for the Buis Ranch local fauna, however, for the mutually exclusive occurrence of *Vertigo hibbardi* and *V. ovata* suggests ecologic replacement. *V. ovata* is known from the Clarendonian Laverne local fauna and from Pleistocene faunas, but is absent from the Saw Rock Canyon and Rexroad local faunas. *V. hibbardi* is known only from these last two faunas.

Paleoecology.—Climate: *Stagnicola caperata* occurs in the High Plains as far South as Nebraska. It suggests cooler summers at the time the Buis Ranch fauna lived. *Ferrissia* requires permanent water, and implies greater rainfall than northwest Oklahoma receives today. Habitat: The few species and their rarity suggest the possibility that the mollusks may not have lived where their shells were found. *Ferrissia rivularis* is a stream snail, *Stagnicola caperata* a temporary pond species.

SAW ROCK CANYON LOCAL FAUNA

Previous work.—The Saw Rock Canyon local fauna was discovered in 1943 by Thad G. McLaughlin and Claude W. Hibbard. Subsequent fieldwork has been by Hibbard and parties from the Universities of Kansas (1944) and Michigan (since 1950). Hibbard (1944a, b) named the fauna and described vertebrates from the deposit. Later stratigraphic studies and more vertebrate material (principal reference Hibbard,

1953) have emphasized the transitional Hemphillan-Blancan aspect of the fauna. Previous references to the mollusks are by Franzen and Leonard (1947), Frye and Leonard (1952, p. 151, Seward County locality), Herrington and Taylor (1958), and Leonard (1952a). Mollusks collected by University of Michigan parties form the chief basis for the present report.

Fauna.—Following is a list of the Saw Rock Canyon local fauna:

Class Pelecypoda
  Order Teleodesmacea
    Sphaerium striatinum (Lamarck)
      sp.
    Pisidium casertanum (Poli)
Class Gastropoda
  Order Mesogastropoda
    Marstonia decepta (Baker)
      crybetes (Leonard)
  Order Basommatophora
    Stagnicola bulimoides techella (Haldeman)
      sp.
    Fossaria dalli (Baker)
    Gyraulus parvus (Say)
    Helisoma anceps (Menke)
    Promenetus kansasensis (Baker)
      umbilicatellus (Cockerell)
    Ferrissia rivularis (Say)
    Physa anatina Lea
  Order Stylommatophora
    Strobilops labyrinthica (Say)
    Gastrocopta holzingeri (Sterki)
      franzenae Taylor
      paracristata Franzen and Leonard
      rexroadensis Franzen and Leonard
      tappaniana (Adams)
    Pupoides albilabris (Adams)
    Vertigo hibbardi Baker
      milium (Gould)
    Vallonia perspectiva Sterki
    cf. *Succinea*
    Deroceras aenigma Leonard
    Helicodiscus singleyanus (Pilsbry)
    Nesovitrea? sp.
    Hawaiia minuscula (Binney)
Class Osteichthyes
    Small catfish
Class Amphibia
  Order Caudata
    Ambystomatidae, indet.
  Order Salientia
    Frog and toad bones
Class Reptilia
  Order Chelonia
    Turtle, indet.
  Order Squamata
    Eumeces striatulatus Taylor
    Snake, indet.
Class Aves
    Unstudied bird remains
Class Mammalia
  Order Insectivora
    Soricidae, indet.
  Order Rodentia
    Marmota? sp.
    Pliogeomys sp.
    Perognathus mclaughlini Hibbard
    Prodipodomys sp.
    Dipoides wilsoni Hibbard
    Onychomys larrabeei Hibbard
    Baiomys sawrockensis Hibbard
    Cimarronomys stirtoni Hibbard
    Ogmodontomys sawrockensis Hibbard
  Order Carnivora
    Osteoborus progressus Hibbard
    Buisnictis cf. *B. schoffi* Hibbard
  Order Artiodactyla
    Gigantocamelus cf. *G. spatulus* (Cope)

Occurrence.—The Saw Rock Canyon local fauna is known only from Seward County, southwest Kansas.

Stratigraphy.—See Hibbard, 1949a, p. 92–97. The fauna occurs near the base of the Rexroad formation in the XI member.

Localities.—Only one locality is known, near the center of the west line of sec. 36, T. 34 S., R. 31 W., Seward County, Kans.

Age.—Essentially all mollusks of the Saw Rock Canyon local fauna occur also in the Rexroad local fauna, but considerable age difference between the two is indicated by the associated mammals. Hibbard (1949a) considered the Saw Rock Canyon local fauna as either late middle Pliocene or early late Pliocene, and later (Hibbard, 1953) as early late Pliocene. The Rexroad local fauna (which see) is of later late Pliocene age.

Leonard (quoted by R. C. Moore, *in* McLaughlin, 1946, p. 33) stated that "fossil mollusk assemblages associated with the Saw Rock Canyon vertebrates are clearly differentiated from those of the type Rexroad." This distinction was maintained by Leonard (1948). Frye and Leonard (1952) indicated that all Saw Rock Canyon mollusks occurred in the Rexroad local fauna also, but did not discuss the previously held difference. They further believed the faunas to be of the same age, but did not consider the conflicting vertebrate evidence.

Paleoecology.—Climate: *Promenetus umbilicatellus* has a northern distribution in the High Plains, ranging as far south as Nebraska. It indicates summers without the present extremes of heat. *Stagnicola bulimoides techella* is found in the High Plains only as far north as Kansas. It shows that winters were very slightly, if at all, cooler than now, and may even have been milder.

Table 7 compares the Blancan and Recent molluscan faunas of southwestern Kansas. There are two probably significant differences between the Recent and Saw Rock Canyon faunas: The fossil fauna has four snails requiring permanent water, the Recent none. There are two fossil forms needing humus in wooded spots, but the better known Recent fauna has but one rare species of such a habitat. In comparing the two faunas it should be noted that the Recent list is slightly increased by permanent water species found only in cool artesian springs, and not characteristic of the area as a whole.

TABLE 7.—*Comparison of Blancan and Recent molluscan faunas of southwestern Kansas, by habitats*

[Recent list based on Lee (1951), Leonard (1943), Miles (1958), and personal collections in Meade County]

Habitat	Species	Fauna				
		Saw Rock Canyon local fauna	Rexroad local fauna	Bender local fauna	Sanders local fauna	Recent
Permanent water:						
Stream	*Ferrissia rivularis* (Say)	×	×			
Pond or stream	*Anodonta grandis* Say					×
	Helisoma anceps (Menke)	×	×			
	Marstonia crybetes (Leonard).	×	×			
	decepta (Baker)	×				
	Sphaerium striatinum (Lamarck).	×				
	transversum (Say)					×
	?*Ligumia subrostrata* (Say)		×			
Pond	*Ferrissia parallela* (Haldeman).		×			
Permanent to temporary:						
Permanent or subpermanent.	*Helisoma trivolvis* (Say)					×
	Physa anatina Lea	×	×	×	×	×
	Promenetus exacuous (Say)					×
	kansasensis (Baker)	×	×		×	
	Uniomerus tetralasmus (Say).					×
Permanent or temporary.	*Gyraulus parvus* (Say)	×	×		×	×
	Stagnicola exilis (Lea)		×			
	sp	×		×	×	
Temporary water:						
Temporary pond or marginal pool.	*Aplexa hypnorum* (Linnaeus).				×	
	Pisidium casertanum (Poli)	×	×			×
	Promenetus umbilicatellus (Cockerell).	×	×	×	×	
	Stagnicola caperata (Say)		×	×	×	
Temporary pond or stream.	*bulimoides techella* (Haldeman).	×	×	×	×	×
	cockerelli (Pilsbry and Ferriss).					×
Marginal pools and wet mud.	*Fossaria dalli* (Baker)	×	×	×	×	×
	obrussa (Say)					×
Semiaquatic, riparian habitat.	*Oxyloma retusa* (Lea)					×
Moister humus	*Carychium exiguum* (Say)		×			
	Deroceras laeve (Müller)					×
	Gastrocopta tappaniana (Adams).	×	×	×	×	×
	Vertigo milium (Gould)	×	×	×	×	
	ovata Say				×	×
Damp humus or grass	*Gastrocopta holzingeri* (Sterki).	×	×			
	Quickella vagans (Pilsbry)					×
	Vallonia gracilicosta Reinhardt.		×			
	parvula Sterki			×		×
Damp humus of wooded area.	*Cionella lubrica* (Müller)		×			
	Helicodiscus parallelus (Say).					×
	Nesovitrea electrina (Gould).	?	×			
	Retinella rhoadsi (Pilsbry)		×			
	wheatleyi (Bland)		×			
	Strobilops labyrinthica (Say).	×				
	sparsicostata Baker		×			
	Zonitoides arboreus (Say)		?			

TABLE 7.—*Comparison of Blancan and Recent molluscan faunas of southwestern Kansas, by habitats*—Continued

[Recent list based on Lee (1951), Leonard (1943), Miles (1958), and personal collections in Meade County]

Habitat	Species	Fauna				
		Saw Rock Canyon local fauna	Rexroad local fauna	Bender local fauna	Sanders local fauna	Recent
Damp to dry ground	*Gastrocopta armifera* (Say)					×
	cristata (Pilsbry and Vanatta).			×	×	×
	pellucida hordeacella (Pilsbry).		×			×
	procera (Gould)					×
	Hawaiia minuscula (Binney).	×	×	×	×	×
	Helicodiscus singleyanus (Pilsbry).	×	×	×	×	×
	Pupoides albilabris (Adams).	×	×	×	×	×
	Succinea concordialis Gould.					×
	vaginacontorta Lee					×
Uncertain	*Deroceras aenigma* Leonard.	×	×	×	×	
	Gastrocopta franzenae Taylor.	×	×	×		
	paracristata Franzen and Leonard.	×	×	×	×	
	rexroadensis Franzen and Leonard.	×	×			
	scaevoscala Taylor			×		
	chauliodonta Taylor				×	
	Physa skinneri Taylor				×	
	Polygyra rexroadensis Taylor.		×	×		
	Pupillidae, new genus?				×	
	Pupoides inornatus Vanatta.		×			
	Sphaerium sp	×	×			
	cf. *Succinea*	×	×	×	×	
	Vallonia perspectiva Sterki	×	×		×	
	Vertigo hibbardi Baker	×	×			

A former climate explaining all these data would differ from that of the present by less extreme summer hot spells and rainfall not necessarily much greater but more effective, probably within the 20–30 inches per year range. The minimum changes one needs to postulate to explain the former molluscan fauna are summer rains occurring more often and more gently, rather than as occasional intense thundershowers; summer hot spells less extreme; and annual precipitation perhaps increased to 25 inches per year.

Habitat: Table 8 summarizes the habitat indications of the mollusks of the Saw Rock Canyon local fauna. The site of deposition apparently was close to three sorts of aquatic habitats: a permanent, slow moving stream, shallower water near shore, with dense vegetation, and fluctuating lagoons and backwaters with shallow, muddy borders.

Two terrestrial habitats may be distinguished also, moist to quite damp humus associated with dead wood and decaying leaves, the floor of a wooded area, and a slightly dryer but still protected habitat, perhaps more open grassy areas. *Deroceras* and cf. *Succinea* may have been associated in a transitional, nearly semiaquatic situation, but their habitat preferences are unknown for sure.

TABLE 8.—*Habitat indications of mollusks of Saw Rock Canyon local fauna*

[A, abundant (>1,000); C, common (101-1,000); S, scarce (21-100); R, rare (1-20)]

Habitat	Species	Abundance
Permanent water:		
Pond or stream	*Helisoma anceps* (Menke)	R
	Marstonia crybetes (Leonard)	C
	decepta (Baker)	R
	Sphaerium striatinum (Lamarck)	R
Stream	*Ferrissia rivularis* (Say)	C
Permanent to temporary water:		
Permanent or subpermanent	*Physa anatina* Lea	A
	Promenetus kansasensis (Baker)	A
Permanent or temporary	*Gyraulus parvus* (Say)	A
	Stagnicola sp	R
Temporary pond or marginal pool	*Pisidium casertanum* (Poli)	C
	Promenetus umbilicatellus (Cockerell).	C
Temporary pond or stream	*Stagnicola bulimoides techella* (Haldeman).	R
Marginal pools or wet mud	*Fossaria dalli* (Baker)	C
Moister humus	*Vertigo milium* (Gould)	R
Damp humus or grass	*Gastrocopta holzingeri* (Sterki)	R
	tappaniana (Adams)	S
Damp humus of wooded area	*Nesovitrea?* sp	R
	Strobilops labyrinthica (Say)	S
Damp to dry ground	*Hawaiia minuscula* (Binney)	S
	Helicodiscus singleyanus (Pilsbry)	R
	Pupoides albilabris (Adams)	R
Uncertain	*Deroceras aenigma* Leonard	C
	Gastrocopta franzenae Taylor	R
	paracristata Franzen and Leonard.	S
	rexroadensis Franzen and Leonard.	R
	Sphaerium sp	R
	cf. *Succinea*	C
	Vallonia perspectiva Sterki	R
	Vertigo hibbardi Baker	C

Before combining these data to reconstruct the area, we may note that the sediments containing the fauna are all fine grained—fine sand, silt, and clay. There are no coarse clastics above the rubble incorporated in the base of the Rexroad formation.

These data suggest that the Saw Rock Canyon local fauna lived in and close to a perennial, slow-moving stream, such as a large creek or river. There were wooded areas along the stream, and perhaps also patches of open grassland. The timbered area was strictly riparian, not covering the uplands.

RED CORRAL LOCAL FAUNA

Previous work.—In the summer of 1954 D. E. Savage and a University of California Museum of Paleontology field party visited a group of Frick Laboratory vertebrate quarries southwest of Channing, Tex. In its brief visit the party observed mollusks and collected scraps of mammalian fossils. Later in the same year C. W. Hibbard went to the site to collect the mollusks. The name Red Corral local fauna is applied to the mammals and mollusks known from the quarries 10 miles southwest of Channing, on the west side of the valley of Rita Blanca Creek. The only fossils previously described from the assemblage are the sphaeriid clams (Herrington and Taylor, 1958).

Fauna.—Following is a list of the Red Corral fauna:

Class Pelecypoda
- Order Teleodesmacea
  - *Pisidium casertanum* (Poli)

Class Gastropoda
- Order Basommatophora
  - *Stagnicola bulimoides techella* (Haldeman)
  - *Gyraulus parvus* (Say)
  - *Promenetus kansasensis* (Baker)
    - *umbilicatellus* (Cockerell)
  - *Ferrissia rivularis* (Say)
  - *Physa anatina* Lea
- Order Stylommatophora
  - *Strobilops sparsicostata* Baker
  - *Gastrocopta franzenae* Taylor
    - *pellucida hordeacella* (Pilsbry)
    - *paracristata* Franzen and Leonard
    - *rexroadensis* Franzen and Leonard
  - *Pupoides inornatus* Vanatta
  - *Vertigo milium* (Gould)
  - Pupillidae?, indet.
  - cf. *Succinea*
  - *Deroceras aenigma* Leonard
  - *Hawaiia minuscula* (Binney)

Class Mammalia
- Order Perissodactyla
  - *Plesippus* sp.
  - *Nannippus* sp.

Occurrence.—The Red Corral local fauna is known only from northern Oldham County, Tex.

Stratigraphy.—Essentially no data are available. The fossiliferous unit in the immediate vicinity of the fossil locality is a west-dipping series of sand and clay.

Localities.—(USGS Cenozoic loc. 21040). Only one mollusk locality is known, included in aerial photograph DAY—10M—63. A west-dipping unit of sand and clay is exposed in the upper part of draws running into the west side of Rita Blanca Creek. In the basin of a north-northeast-trending draw about half a mile south of the county line and about three-quarters of a mile north of a red corral are several Frick Laboratory vertebrate quarries. All or most of these quarries are about 20 feet stratigraphically below 2- to 3-foot-thick bed of massive caliche. Shells were collected from a fine to very fine compact sand immediately below a 2-foot bed of carbonaceous papery clay shale with abundant crushed shells at the north end of one of the quarries. This quarry is on the east side of the main draw, just south of a minor tributary gully.

Age.—Among the vertebrate material in University of California collections from a Frick Laboratory quarry close to and at the same stratigraphic horizon as the mollusk locality are *Plesippus* and *Nannippus*, indicative of Blancan age.

The mollusks suggest correlation of the Red Corral and Rexroad local faunas. Virtually all species of the Red Corral local fauna occur also in the Rexroad local fauna. (See tables 2 and 4.)

Paleoecology.—Climate: Two species (*Gastrocopta pellucida hordeacella* and *Stagnicola bulimoides techella*) have southern distributions in the United States. In the High Plains they range as far north as Kansas. These two suggest that winters were not much if at all more severe than those of the Texas Panhandle today. *Promenetus umbilicatellus*, of northern distribution, occurs in the High Plains as far south as Nebraska. It suggests that the Red Corral fauna lived in a climate with summers lacking the present extremes of heat and temperature.

Recent mollusks of the Texas Panhandle are practically unknown. Several local lists have been published, but nearly all are drift collections which may be contaminated by Pleistocene shells. The list given by Clarke (1938) is based partially on drift also, but at least there are no obvious anomalies of distribution. Palo Duro Creek (spelled Paladora by Clarke) has cut deeply into the eastern edge of the Llano Estacado. Permanent water and the protected situation in a deep canyon probably give an assemblage unusually varied for the Texas Panhandle. Clarke did not record the exact site of his collection, but distance and direction given ("* * * Paladora Creek which lies 4 miles east and 3 miles north of Canyon, Tex.") indicate Palo Duro Creek near 6-mile crossing, 10 miles upstream from Palo Duro State Park, Randall County, Tex. The locality is about 40 miles southeast of the Red Corral site.

TABLE 9.—*Habitat indications of mollusks of Red Corral local fauna*

[A, abundant (>100); C, common (21–100); S, scarce (6–20); R, rare (1–5)]

Habitat	Species	Abundance
Permanent stream	*Ferrissia rivularis* (Say)	R
Permanent to temporary water:		
Permanent or subpermanent	*Physa anatina* Lea	A
	Promenetus kansasensis (Baker)	S
Permanent or temporary	*Gyraulus parvus* (Say)	A
Temporary water:		
Temporary pond or marginal pool.	*Pisidium casertanum* (Poli)	C
	Promenetus umbilicatellus (Cockerell).	A
Temporary pond or stream	*Stagnicola bulimoides techella* (Haldeman).	A
Moister humus	*Vertigo milium* (Gould)	C
Damp humus of wooded area	*Strobilops sparsicostata* Baker	R
Damp to dry ground	*Hawaiia minuscula* (Binney)	R
Uncertain	*Deroceras aenigma* Leonard	C
	Gastrocopta paracristata Franzen and Leonard.	R
	pellucida hordeacella (Pilsbry)	R
	rexroadensis Franzen and Leonard.	R
	franzenae Taylor	C
	Pupoides inornatus Vanatta	R
	cf *Succinea*	R
	Pupillid?	R

Table 10 compares the mollusks of the Red Corral local fauna with the Recent collection from Palo Duro Canyon. This list is modified from Clarke (1938) as

TABLE 10.—*Comparison of mollusks of Red Corral local fauna with Recent mollusks from Palo Duro Canyon, Texas, by habitats*

[Recent list from Clarke (1938), modified as explained in text]

Habitat	Species	Red Corral	Recent
Permanent water:			
Pond or stream	*Pisidium compressum* Prime	-	×
	Sphaerium sulcatum (Lamarck)	-	×
	transversum (Say)	-	×
	Uniomerus tetralasmus (Say)	-	×
Stream	*Ferrissia rivularis* (Say)	×	-
Permanent to temporary water:			
Permanent or subpermanent.	*Helisoma trivolvis* (Say)	-	×
	Physa anatina Lea	×	-
	Promenetus kansasensis (Baker)	×	-
Permanent or temporary	*Gyraulus parvus* (Say)	×	×
	Physa gyrina Say	-	×
Temporary water:			
Temporary pond or marginal pool.	*Pisidium casertanum* (Poli)	×	-
	Promenetus umbilicatellus (Cockerell).	×	-
Temporary pond or stream	*Stagnicola bulimoides techella* (Haldeman).	×	-
Marginal pools and wet mud	*Fossaria obrussa* (Say)	-	×
Moister humus	*Carychium exiguum* (Say)	-	×
	Vertigo ovata Say	-	×
	V. milium (Gould)	×	-
Damp humus or grass	*Vallonia parvula* Sterki	-	×
Damp humus of wooded area	*Helicodiscus parallelus* (Say)	-	×
	Strobilops sparsicostata Baker	×	-
Damp to dry ground	*Gastrocopta armifera* (Say)	-	×
	cristata (Pilsbry and Vanatta)	-	×
	procera (Gould)	-	×
	Hawaiia minuscula (Binney)	×	×
	Pupoides albilabris (Adams)	-	×
Uncertain	*Deroceras aenigma* Leonard	×	-
	Gastrocopta paracristata Franzen and Leonard.	×	-
	pellucida hordeacella (Pilsbry)	×	×
	rexroadensis Franzen and Leonard.	×	-
	franzenae Taylor	×	-
	Pupoides inornatus Vanatta	×	-
	cf. *Succinea*	×	×

follows: *Vallonia costata* and *V. perspectiva* are considered *V. parvula* following Pilsbry (1948, p. 1028). *Succinea avara* is changed to cf. *Succinea*. Other changes are nomenclatural.

Two differences appear significant at first: The Red Corral local fauna has one permanent stream snail, the Recent assemblage none. The Red Corral fauna includes several temporary water species, the Recent assemblage none. In comparing these two faunas it must be remembered that the Recent collection is from a deep canyon with a permanent stream supplied by springs and seepage, but that the Red Corral local fauna lived in a shallow, exposed valley.

Habitat indications of the Red Corral local fauna (see table 9) suggest the presence of some woodland and moist humus, as well as seasonal ponds and a permanent stream. The occurrence of *Strobilops*, not now found in the Great Plains except in woodland at the eastern edges, is especially significant.

These data and inferences suggest that the Red Corral local fauna lived in a climate with winters not much if at all more severe than those of the area today, summers lacking present extremes of heat and drought, and a greater rainfall of about 30 inches per year.

Habitat: Table 9 summarizes the habitat indications of the mollusks of the Red Corral local fauna. The four species classed as abundant suggest a shallow pond fluctuating annually, with thick, submerged vegetation. The other aquatic species fit such a picture, except for *Ferrissia rivularis*, which requires permanent water. Probably the pond was a lagoon or oxbow lake near a permanent stream. The occurrence of *Strobilops* indicates the presence of woodland and moist humus, but there are so few land snails, and most of these are so scarce, that this habitat was probably not close to the site of deposition.

REXROAD LOCAL FAUNA

Previous work.—Hibbard (1938) named the Rexroad local fauna and described vertebrates from it. Subsequent field work has been by Hibbard and parties from the University of Kansas (1936–46) and University of Michigan (1947 to date). The rich vertebrate fauna has been described in numerous papers summarized by Hibbard (1950, 1954a). Later contributions are by Hibbard (1956, p. 185), Oelrich (1957), Savage (1955, p. 67–68), and Tihen (1955). The mollusks of the Rexroad local fauna have been studied primarily by Baker, Franzen, and Leonard (Baker, 1938; Franzen and Leonard, 1947; Frye and Hibbard, 1941, p. 408; Frye and Leonard, 1952, p. 151, Meade County localities; Herrington and Taylor, 1958; Hibbard, 1941, p. 95; 1941a, p. 265; Leonard, 1950, p. 38; 1952a; 1957; Smith, 1940, p. 98). The most nearly complete lists are those of Baker (in Hibbard, 1941, p. 95) and Leonard (Frye and Leonard, 1952, p. 151).

According to Hibbard (written communication, November 29, 1954) most of the University of Kansas material reported from the SW¼ sec. 22, T. 33 S., R. 29 W., Meade County, Kans. (collected by Hibbard and Leonard), is from localitites 1a, 1b, and 1c of the Bender local fauna; some is from Rexroad locality 3. Several species reported from University of Kansas collections were not found by University of Michigan parties, and hence their stratigraphic horizon is in doubt. *Sphaerium* sp., *Marstonia crybetes* (Leonard), and *Helisoma anceps* (Menke) have habitat requirements which suggest they came from Rexroad locality 3. *Gastrocopta rexroadensis* Franzen and Leonard and *Cionella lubrica* (Muller) have been found at other Rexroad localities, but not in the Bender local fauna, and so probably came from Rexroad locality 3. *Zonitoides arboreus* (Say) is listed with a query under both faunas.

Fauna.—Following is a list of the Rexroad local fauna:

Class Pelecypoda
- Order Prionodesmacea
  - ?*Ligumia subrostrata* (Say)
- Order Teleodesmacea
  - *Sphaerium* sp.
  - *Pisidium casertanum* (Poli)

Class Gastropoda
- Order Mesogastropoda
  - *Marstonia crybetes* (Leonard)
- Order Basommatophora
  - *Carychium exiguum* (Say)
  - *Stagnicola bulimoides techella* (Haldeman)
    - *caperata* (Say)
    - *exilis* (Lea)
  - *Fossaria dalli* (Baker)
  - *Gyraulus parvus* (Say)
  - *Helisoma anceps* (Menke)
  - *Promenetus kansasensis* (Baker)
    - *umbilicatellus* (Cockerell)
  - *Ferrissia parallela* (Haldeman)
    - *rivularis* (Say)
  - *Physa anatina* Lea
- Order Stylommatophora
  - *Strobilops sparsicostata* Baker
  - *Gastrocopta franzenae* Taylor
    - *holzingeri* (Sterki)
    - *paracristata* Franzen and Leonard
    - *pellucida hordeacella* (Pilsbry)
    - *rexroadensis* Franzen and Leonard
    - *tappaniana* (Adams)
  - *Pupoides albilabris* (Adams)
    - *inornatus* Vanatta
  - *Vertigo hibbardi* Baker
    - *milium* (Gould)
  - *Vallonia gracilicosta* Reinhardt
    - *perspectiva* Sterki
  - *Cionella lubrica* (Müller)
  - cf. *Succinea*
  - *Helicodiscus singleyanus* (Pilsbry)
  - *Deroceras aenigma* Leonard
  - *Retinella rhoadsi* (Pilsbry)
    - *wheatleyi* (Bland)
  - *Nesovitrea electrina* (Gould)
  - *Hawaiia minuscula* (Binney)
  - ?*Zonitoides arboreus* (Say)
  - *Polygyra rexroadensis* Taylor

Class Amphibia
- Order Caudata
  - *Ambystoma hibbardi* Tihen
- Order Salientia
  - *Scaphiopus diversus* Taylor
  - *Neoscaphiopus noblei* Taylor
  - *Bufo* sp.
  - *Anchylorana moorei* Taylor
    - *dubita* Taylor
    - *robustocondyla* Taylor
  - *Rana fayeae* Taylor
    - *meadensis* Taylor
    - *ephippium* Taylor
    - *rexroadensis* Taylor
    - *valida* Taylor
    - *parvissima* Taylor

Class Reptilia
- Order Chelonia
  - *Testudo rexroadensis* Oelrich
    - *turgida* Cope
- Order Squamata
  - *Phrynosoma cornutum* Harlan
  - *Sceloporus robustus* Twente
  - *Cnemidophorus bilobatus* Taylor
  - *Eumeces striatulatus* Taylor
  - *Eumecoides hibbardi* Taylor
    - *mylocoelus* Taylor
  - *Heterodon plionasicus* Peters

Class Aves
- Order Podicipediformes
  - *Podiceps* sp.
- Order Ciconiiformes
  - Threskiornithidae, indet.
- Order Anseriformes
  - *Anas bunkeri* (Wetmore)
  - *Bucephala albeola* (Linnaeus)
- Order Falconiformes
  - *Buteo* sp.
- Order Galliformes
  - *Colinus hibbardi* Wetmore
  - *Meleagris gallopavo* Linnaeus
  - Meleagrididae, indet.
- Order Gruiformes
  - *Rallus prenticei* Wetmore
  - *Fulica americana* Gmelin
- Order Charadriiformes
  - Scolopacidae, indet.
  - *Sterna* sp.
- Order Columbiformes
  - *Zenaidura macroura* (Linnaeus)
- Order Psittaciformes
  - Psittacidae, indet.
- Order Passeriformes
  - Indeterminate remains

Class Mammalia
- Order Insectivora
  - *Sorex rexroadensis* Hibbard
    - *taylori* Hibbard
  - *Paracryptotis rex* Hibbard
  - *Cryptotis? meadensis* Hibbard
  - *Blarina adamsi* Hibbard
  - *Notiosorex jacksoni* Hibbard
  - *Hesperoscalops rexroadi* Hibbard
- Order Chiroptera
  - *Lasiurus fossilis* Hibbard
- Order Edentata
  - *Megalonyx* cf. *M. leptostomus* Cope
- Order Rodentia
  - *Paenemarmota barbouri* Hibbard and Schultz
  - *Citellus howelli* Hibbard
    - *rexroadensis* Hibbard
  - *Nerterogeomys minor* (Gidley)
  - *Geomys quinni* McGrew
  - *Perognathus rexroadensis* Hibbard
    - *gidleyi* Hibbard
    - *pearlettensis* Hibbard
  - *Prodipodomys rexroadensis* Hibbard
  - *Liomys centralis* Hibbard
  - *Dipoides rexroadensis* Hibbard and Riggs

Class Mammalia—Continued
- Order Rodentia—Continued
  - *Procastoroides lanei* (Hibbard)
  - *Sigmodon intermedius* Hibbard
  - *Reithrodontomys rexroadensis* Hibbard
    - *wetmorei* Hibbard
  - *Peromyscus baumgartneri* Hibbard
    - *kansasensis* Hibbard
  - *Parahodomys quadriplicatus* Hibbard
  - *Bensonomys eliasi* (Hibbard)
  - *Baiomys kolbi* Hibbard
    - *rexroadi* Hibbard
  - *Onychomys gidleyi* Hibbard
  - *Symmetrodontomys simplicidens* Hibbard
  - *Ogmodontomys poaphagus* Hibbard
  - *Pliophenacomys primaevus* Hibbard
  - *Zapus rinkeri* Hibbard
- Order Carnivora
  - *Canis lepophagus* Johnston
    - sp. (large)
  - *Borophagus diversidens* Cope
  - *Bassariscus casei* Hibbard
    - *rexroadensis* Hibbard
  - *Procyon rexroadensis* Hibbard
  - *Buisnictis breviramus* (Hibbard)
  - *Trigonictis kansasensis* Hibbard
  - *Mustela rexroadensis* Hibbard
    - sp.
  - *Martes foxi* Hibbard and Riggs
  - *Taxidea taxus* (Schreber)
  - *Spilogale rexroadi* Hibbard
  - *Mephitis? rexroadensis* Hibbard
  - *Brachyopsigale dubius* Hibbard
  - *Lutra* cf. *L. piscinaria* Leidy
  - *Felis lacustris* Gazin
    - sp. (large)
  - *Machairodus?* sp.
- Order Proboscidea
  - *Stegomastodon* sp.
  - *Mammut adamsi* (Hibbard)
- Order Lagomorpha
  - *Pratilepus kansasensis* Hibbard
  - *Notolagus lepusculus* (Hibbard)
  - *Hypolagus regalis* Hibbard
  - *Nekrolagus progressus* (Hibbard)
- Order Artiodactyla
  - *Platygonus bicalcaratus* Cope
  - *Pliauchenia cochrani* Hibbard and Riggs
  - *Gigantocamelus spatulus* (Cope)
  - *Tanupolama blancoensis* Meade
  - *Odocoileus brachyodontus* Oelrich
  - Antilocapridae, indet.
- Order Perissodactyla
  - *Nannippus phlegon* (Hay)
  - *Plesippus simplicidens* (Cope)

Occurrence.—Vertebrates of the Rexroad local fauna are known from both Meade and Seward Counties, Kans., but all mollusks come from Meade County. In this area alluvial deposition had been going on continuously since the early late Pliocene. The stream shifted back and forth across its flood plain, laying down sands and fine gravels (derived from the Rocky Mountains), sandy silt, and clay (Hibbard, 1950, p. 119).

Stratigraphy.—See Hibbard 1949a, 1950, and McLaughlin, 1946. The Rexroad local fauna occurs in the upper part of the Rexroad formation below the massive caliche.

Localities.—All the following localities are in Meade County, Kans.:

Locality 1. (Big Springs Ranch; University of Kansas Meade County loc. 25). Center of south edge NW¼NE¼ sec. 18, T. 32 S., R. 28 W. Exposure in the south bank of a tributary of Spring Creek, where the Rexroad formation is unconformably overlain by the Meade formation. Sanders local fauna locality 1 is in this exposure also. This locality was listed by Hibbard (1950, p. 174) as near the center of the line between secs. 17 and 18, T. 32 S., R. 28 W.

Locality 2. (Big Springs Ranch). Center of NE¼NW¼ sec. 24, T. 32 S., R. 29 W. Exposure on the south side of the main branch of Spring Creek. Nearly a mile up the Sand Draw are Sanders local fauna localities 2 and 3 in the overlying Meade formation. This locality is given as the NW¼NW¼ sec. 19, T. 32 S., R. 28 W. by Franzen and Leonard (1947) and by Hibbard (1950, p. 174); and as the NW¼ sec. 19, T. 32 S., R. 28 W. by Frye and Leonard (1952, p. 151).

Locality 3. (Rexroad Ranch; University of Kansas Meade County loc. 3, USGS Cenozoic loc. 21171). W½SW¼ sec. 22, T. 33 S., R. 29 W. Mollusks come from a pond or bog deposit now covered by the sandy bed of a tributary of Stump Arroyo. This zone is downstream around the bend from the chief vertebrate locality, figured by Hibbard (1950, pl. 3). The mollusks occur stratigraphically at or slightly above the upper limit of vertebrate occurrence at this locality. Mollusks were reported by Baker (1938), Hibbard (1941, p. 95), Franzen and Leonard (1947), Leonard (1950, p. 38; 1952a), and Frye and Leonard (1952, p. 151).

Locality 4. (Fox Canyon; University of Michigan loc. UM-K1-47). Sec. 35, T. 34 S., R. 30 W. Exposures along Fox Canyon (Hibbard, 1950, pl. 5, fig. 1). Locality 4a is a pocket of fluviatile sandy silts, 17 feet below the massive caliche, from which the vertebrates and a few mollusks were collected. Locality 4b is a lenticular bed of blue-gray clay, 10 feet below the caliche, from which most of the mollusks were collected. Franzen and Leonard (1947), Leonard (1952a) and Frye and Leonard (1952, p. 151) reported mollusks from this locality.

Age.—Mammalian evidence for the late Pliocene age of the Rexroad local fauna has been summarized by Hibbard (1950). Additional evidence for this age is as follows.

The Rexroad local fauna indicates a climate more humid than the present and lacking such hot summers. This fauna occurs below 4 formations representing 4 cycles of erosion and deposition. These cycles are represented also by four cool-climate faunas separated by three warmer-climate faunas. A correlation of these faunas with the standard glacial-interglacial sequence in the Mississippi Valley indicates a preglacial (Pliocene) age for the Rexroad local fauna.

TABLE 11.—*Locality occurrence of mollusks of Rexroad local fauna*

[Unverified records from following sources: (1) Hibbard, 1941 (2) Franzen and Leonard, 1947 (3) Leonard, 1952a (4) Frye and Leonard, 1952. ×, verified occurrence]

Species	Localities				
	1	2	3	4a	4b
?*Ligumia subrostrata* (Say)			×		
Sphaerium sp		4	4		
Pisidium casertanum (Poli)		×	×		
Marstonia crybetes (Leonard)	×		4		×
Carychium exiguum (Say)		4	×		4
Stagnicola exilis (Lea)	×		×		×
bulimoides techella (Haldeman)	×	×			4
Fossaria dalli (Baker)	×	×	×		×
Gyraulus parvus (Say)		4			
Helisoma anceps (Menke)			4		4
Promenetus kansasensis (Baker)	×		×		
umbilicatellus (Cockerell)	×				3
Physa anatina Lea	×	×	×		×
Ferrissia parallela (Haldeman)			1		4
rivularis (Say)			×		4
Strobilops sparsicostata Baker	×		×		×
Gastrocopta franzenae Taylor		×	×		×
holzingeri (Sterki)	×	×	×		
paracristata Franzen and Leonard	×	×	×		×
pellucida hordeacella (Pilsbry)			×		
rexroadensis Franzen and Leonard		2	2		2
tappaniana (Adams)		×	×		×
Pupoides albilabris (Adams)	×	×	×	×	×
inornatus Vanatta		×	×		
Vertigo hibbardi Baker		×	×		4
milium (Gould)		×	×		×
Vallonia gracilicosta Reinhardt			×		
perspectiva Sterki		×	×		
Cionella lubrica (Müller)		4	4		
cf. *Succinea*	×	×	×		×
Helicodiscus singleyanus (Pilsbry)		×	×		×
Deroceras aenigma Leonard	×	×	×	×	×
Nesovitrea electrina (Gould)			×		4
Retinella rhoadsi (Pillsbry)			1		
wheatleyi (Bland)			1		
Hawaiia minuscula (Binney)	×	×	×		×
Zonitoides arboreus (Say)			?4		
Polygyra rexroadensis Taylor		×	×		×

The Saw Rock Canyon local fauna, in the lower part of the Rexroad formation, might be assigned to the middle Pliocene almost as well as to the upper Pliocene. The Rexroad local fauna, in the upper part of the Rexroad formation, is of late Pliocene age. A large time gap between these two faunas is thus indicated. Both faunas indicate a similar temperate climate, lacking present hot, dry summers. There is no evidence of climatic change between these two faunas. This period of probably uniform climate endured longer than the glacial-interglacial ages, as indicated by mammalian evolution. Such an interval of mild climate is more reasonably Pliocene than Pleistocene.

Paleoecology.—Climate: *Stagnicola caperata*, *Promenetus umbilicatellus*, and *Vallonia gracilicosta* occur in the High Plains as far south as Nebraska. They indicate that the Rexroad local fauna lived in a climate lacking the hot summers of southwestern Kansas today. *Gastrocopta pellucida hordeacella* and *Stagnicola bulimoides techella* have southern distributions in the United States, and range north in the High Plains into Kansas. They suggest the Rexroad local fauna lived in a climate with winters slightly if at all colder than those of the region now.

Table 7 compares the Blancan and Recent molluscan faunas of southwestern Kansas. There are two probably significant differences between the Recent and Rexroad local faunas: The fossil assemblage has several snails requiring permanent water, the Recent none. The Recent fauna has only one rare species characteristic of damp humus in wooded areas, whereas there are several common species of such requirements in the Rexroad local fauna. The contrast between the two assemblages is further shown by the much greater number of species in the Rexroad local fauna. In comparing the two assemblages it should be noted that the Recent list is slightly increased by permanent water species found only in cool artesian springs, and not characteristic of the area as a whole.

The association of *Cionella lubrica* and *Gastrocopta pellucida hordeacella* in the Rexroad local fauna is especially significant, for the only known joint occurrence of these two today is in southern New Jersey. Presumably here the ocean reduces seasonal extremes of temperature, permitting usually remote species to live in the same locality.

Hibbard (1950, p. 175–177) summarized the ecological evidence of various groups represented in the Rexroad local fauna. He concluded (p. 177): "There is evidence that the climate in the Upper Pliocene was more equable than at present, without extremely cold winters or severely hot summers, and that there was a greater degree of humidity in the region than there is now."

Habitat interpretations (see below) of the Rexroad local fauna suggest the presence of timbered areas and of grassland. Such vegetation implies greater rainfall than southwestern Kansas receives now.

The former climate suggested by all these lines of evidence differed from that of the present in having summers with less extreme hot spells, and a greater annual rainfall of about 30–35 inches. If precipitation distribution were better, and gentle rains rather than thundershowers were more frequent, one can guess that perhaps rainfall was only about 30 inches per year. Winters were markedly milder than at present.

Habitat: Table 12 summarizes habitat indications of the Rexroad local fauna. Only material represented in University of Michigan collections is considered.

Locality 1 was apparently a temporary pond habitat. Rarely occurring species characteristic of permanent water indicate it was perhaps a small oxbow pond close to a permanent stream. The scarcity and small variety of land snails suggest that riparian vegetation nearby was scanty. Possibly the pond was located on a floodplain without nearby woodland, and on which only cf. *Succinea* thrived.

TABLE 12.—*Habitat indications of mollusks of Rexroad local fauna*

[A, abundant (>225); C, common (41-225); S, scarce (8-40); R, rare (1-7). Based on material examined only]

Habitat	Species	Locality 1	Locality 2	Locality 3	Locality 4a	Locality 4b
Permanent water:						
Stream	*Ferrissia rivularis* (Say)	----	----	S	----	----
Pond or stream	*Marstonia crybetes* (Leonard)	R	----	----	----	R
	?*Ligumia subrostrata* (Say)	----	----	R	----	----
Permanent to temporary water:						
Permanent or subpermanent.	*Physa anatina* Lea	S	R	C	----	A
	Promenetus kansasensis (Baker).	R	----	S	----	----
Permanent or temporary	*Stagnicola exilis* (Lea)	C	----	R	----	A
Temporary water:						
Temporary pond or marginal pool.	*Pisidium casertanum* (Poli)	----	R	R	----	----
	Promenetus umbilicatellus (Cockerell).	A	----	----	----	----
Temporary pond or stream.	*Stagnicola bulimoides techella* Haldeman.	A	R	----	----	----
Marginal pools and wet mud.	*Fossaria dalli* Baker	R	R	R	----	A
Moister humus	*Carychium exiguum* (Say)	----	----	C	----	----
	Vertigo milium (Gould)	----	S	C	----	R
Damp humus or grass	*Gastrocopta holzingeri* (Sterki)	R	S	C	----	----
	tappaniana (Adams)	----	S	S	----	R
	Vallonia gracilicosta Reinhardt.	----	----	A	----	----
Damp humus of wooded area.	*Nesovitrea electrina* (Gould)	----	----	C	----	----
	Strobilops sparsicostata Baker	R	----	A	----	R
Damp to dry ground	*Hawaiia minuscula* (Binney)	S	C	A	----	A
	Helicodiscus singleyanus (Pilsbry).	----	C	A	----	S
	Pupoides albilabris (Adams)	S	C	C	S	C
Uncertain	*Deroceras aenigma* Leonard	S	R	A	A	R
	Gastrocopta franzenae Taylor	----	A	A	----	A
	paracristata Franzen and Leonard.	R	S	S	----	C
	pellucida hordeacella (Pilsbry).	----	----	R	----	----
	Polygra rexroadensis Taylor	----	S	C	----	R
	Pupoides inornatus Vanatta	----	S	C	----	----
	cf. *Succinea*	C	S	A	----	R
	Vallonia perspectiva Sterki	----	S	C	----	----
	Vertigo hibbardi Baker	----	R	S	----	----

Locality 2 apparently had only rare surface water. Scarcity of temporary-pond species shows that probably habitats were unsuitable for most aquatic snails. Significantly greater abundance of dry-tolerant snails further suggests little ground moisture and perhaps no vegetation but grass. The site of deposition may have been the bare floor of a small intermittent stream valley bordered by small shrubs and grass, but no trees.

Locality 3 is the richest and shows the greatest ecologic diversity of all Rexroad localitites. Aquatic species are few in number, and only *Physa anatina* is common. There is a rich land-snail fauna, however, which suggests a wooded area providing damp humus and dead wood as favorable habitats for many species. This somewhat peculiar situation—a rich land assemblage but poor freshwater fauna—suggests that deposition may have been on land. The local area could well have been a well-wooded flood plain, with only minor amounts of open water. These could have been provided by small, shaded pools, seepages, or beaver canals (Hibbard, 1941, p. 97). Probably the *Physa* lived near the area of deposition, but other freshwater shells were brought in by the stream when it overflowed its banks. Absence of larger land snails such as *Triodopsis* or *Mesodon* probably indicates that woodland was not widespread, but restricted largely to the stream valleys.

Locality 4a has yielded abundant small vertebrates but only two species of mollusks. From a study of the sediments and contained bones Hibbard (1950, p. 167–168) concluded:

> The deposit from which the fossils were taken in Fox Canyon was laid down by a stream that was carrying fine sediments which consisted chiefly of silts and fine sands. The remains of fishes in the deposit indicate that the stream was probably permanent. The size of the fossils recovered shows the effect of stream sorting. The material does not show signs of abrasion and appears to have been transported but a short distance, either from slope wash along the valley or carried by a short tributary that headed in the upland area. Because of the dominance of rodents, the concentration of small vertebrates is best accounted for as an accumulation of remains from the pellets or castings of owls or hawks that nested nearby.

The mollusks from locality 4a agree well with this picture. The only two species found, *Pupoides albilabris* and *Deroceras aenigma*, are both of medium size and have shells of relatively high density and strength, compared to other mollusks in the Rexroad local fauna. Probably other shells were broken and carried away, while those of only two species were concentrated at the edge of the stream.

Locality 4b represents a slough or stagnant oxbow lake. The land snails suggest some vegetation, such as shrubs and grass, but again no extensive forest. The *Physa* and *Stagnicola* indicate a semipermanent aquatic habitat with probably abundant vegetation. The rare *Marstonia* was perhaps washed in from a nearby stream during high water.

BENDER LOCAL FAUNA

Previous work.—Mollusks from above the massive caliche in the type section of the Rexroad formation have previously been considered part of the Rexroad local fauna. They are segregated here as the Bender local fauna (new name). The fauna is named after Mr. H. C. Bender, Plains, Kans., who now owns the Rexroad ranch, on which the type locality is located. Only mollusks are known in the fauna.

Some species not in University of Michigan collections, but reported in University of Kansas material from SW¼ sec. 22, T. 33 S., R. 29 W., Meade County, may be from either Rexroad locality 3 or from Bender localities 1a, 1b, or 1c. See under Rexroad local fauna for discussion.

Fauna.—Following is a list of the Bender local fauna:

Class Gastropoda
- Order Basommatophora
  - *Stagnicola bulimoides techella* (Haldeman)
    - *caperata* (Say)
    - sp.
  - *Fossaria dalli* (Baker)
  - *Promenetus umbilicatellus* (Cockerell)
  - *Physa anatina* Lea
- Order Stylommatophora
  - *Gastrocopta* cf. *G. cristata* (Pilsbry and Vanatta)
    - *franzenae* Taylor
    - *paracristata* Franzen and Leonard
    - *scaevoscala* Taylor
    - *tappaniana* (Adams)
  - *Pupoides albilabris* (Adams)
  - *Vertigo milium* (Gould)
  - *Vallonia parvula* Sterki
  - cf. *Succinea*
  - *Helicodiscus singleyanus* (Pilsbry)
  - *Deroceras aenigma* Leonard
  - *Hawaiia minuscula* (Binney)
  - ?*Zonitoides arboreus* (Say)
  - *Polygyra rexroadensis* Taylor

Occurrence.—The Bender local fauna is known only from Meade and Seward Counties, southwestern Kansas.

Stratigraphy.—This assemblage occurs in the uppermost Rexroad formation above the massive caliche. Locality 2 is at the same stratigraphic position as the mollusks recorded by Hibbard (1949a, p. 94) in a section measured close by that locality.

Localities.—Following are from the Bender local fauna:

Locality 1. Three sites at the same stratigraphic level, in exposures within about an eighth of a mile along the banks of a tributary of Stump Arroyo, SE¼SW¼ and SW¼SE¼ sec. 22, T. 33 S., R. 29 W., Meade County, Kans. Uppermost part of the Rexroad formation, above massive caliche bed. About 300 yards downstream from Rexroad locality 3. Locality 1a. NE¼SE¼SW¼ sec. 22. Dark bed (soil?). South side of stream, upstream from locality 1b. Locality 1b. NW¼SW¼SE¼ sec. 22. East side of stream, about halfway between localities 1a and 1c. Just below Meade gravels. Locality 1c. SW¼SW¼SE¼ sec. 22. Southwest side of stream, downstream from locality 1b; near section road along south side of section 22.

Locality 2. Seward County, Kans. Wolf Canyon, in approximately the center of W½ sec. 12, T. 35 S., R. 31 W. Uppermost part of the Rexroad formation, above massive caliche bed.

Age.—Since associated vertebrates are lacking, age assignments must be based on the molluscan fauna and on climatic inferences from the sediments and fauna.

The molluscan fauna has similarities to both the Rexroad and Sanders local faunas, but is slightly closer to the Rexroad. In addition, *G.* cf. *cristata* is intermediate between the Rexroad *G. franzenae* and the Sanders, Dixon, and Sand Draw *G. cristata*. Negative evidence, interesting but of slight or no significance, is the absence in the Bender local fauna of *Vertigo hibbardi* of the Rexroad local fauna, and the absence of *Vertigo ovata*, *Gastrocopta chauliodonta*, *Physa skinneri*, and *Aplexa hypnorum* of the Sanders local fauna. Comparison of the Bender local fauna with early Pleistocene faunas besides the Sanders would be of little value. The Sanders and Bender local faunas probably lived under similar conditions, while the Sand Draw and Dixon mollusks suggest markedly different climates.

Hibbard (1954a, p. 235–236) discussed the significance of the massive caliche bed in the uppermost part of the Rexroad formation. In summary, it may be stated that the caliche suggests a semiarid climate, whereas the faunas above and below indicate moister climates. There is no evidence that the Bender local fauna lived in a climate cooler than that of the Rexroad local fauna. The uppermost part of the Rexroad formation, above the massive caliche and including the Bender local fauna, might be considered Pleistocene if the climatic change from semiarid to moister were considered contemporaneous with the beginning of continental glaciation, and if the Pleistocene epoch were defined as beginning with the first activity of major continental glaciers (see Frye and Leonard, 1953).

The differences between the Bender and first Pleistocene faunas (Sand Draw, Dixon) are much greater than those between the Rexroad and Bender, however. The weight of evidence favors a Pliocene age for the Bender local fauna.

Paleoecology.—Climate: *Stagnicola caperata* and *Promenetus umbilicatellus* occur in the High Plains as far south as Nebraska. They indicate that the Bender local fauna lived in a climate lacking the present summer extremes of heat. *Stagnicola bulimoides techella* has a southern distribution, and ranges north in the High Plains only as far as Kansas. Its occurrence suggests winters only slightly if at all colder than those of southwestern Kansas today.

Table 7 compares the Blancan and Recent molluscan faunas of southwestern Kansas. Only 9 of the 19 species of the Bender local fauna still live in the area. *Vertigo milium* lives not too far to the east however, and several extinct species have ecological equivalents in southwestern Kansas.

The few aquatic species suggest only subpermanent to temporary bodies of water. Several of the land snails can withstand dry upland conditions in the High Plains today (*Gastrocopta cristata*, *Pupoides albilabris*, *Hawaiia minuscula*), and none of the others requires much shelter or permanent moisture. There is no indication of vegetation heavier than grass and a little scrub, or (in conjunction with summers slightly cooler than present) of rainfall greater than about 20 inches per year.

Habitat: Table 13 summarizes the habitat indications of the Bender local fauna. Locality 1 probably represents deposition on land, for terrestrial species are abundant and aquatic forms rare. The land snails are all species which do not require woodland, though the *Polygyra* may have inhabited patches of scrub. The few fresh water species are all able to endure drying of their water body. The general environment suggested is a slow-moving temporary stream with bordering vegetation of grass and clumps of bushes or scattered trees.

Locality 2 suggests similar conditions, except that conditions were more favorable for freshwater snails and less favorable for land snails.

TABLE 13.—*Habitat indications of Bender local fauna*
[A, abundant (>250); C, common (41–250); S, scarce (8–40); R, rare (1–7)]

Habitat	Species	Locality			
		1a	1b	1c	2
Permanent to subpermanent water.	*Physa anatina* Lea	R	R	------	C
Permanent or temporary water.	*Stagnicola* sp.	R	------	------	S
Temporary pond or marginal pool.	*caperata* (Say)	S	------	R	C
	Promenetus umbilicatellus (Cockerell).	S	------	S	C
Temporary pond or stream.	*Stagnicola bulimoides techella* (Haldeman).	S	------	S	C
Marginal pools and wet mud.	*Fossaria dalli* (Baker)	------	S	R	R
Moister humus	*Vertigo milium* (Gould)	C	R	C	------
Damp humus or grass	*Gastrocopta tappaniana* (Adams).	R	S	------	------
	Vallonia parvula Sterki	S	------	R	------
Damp to dry ground	*Gastrocopta cristata* (Pilsbry and Vanatta).	A	------	A	------
	Hawaiia minuscula (Binney)	A	C	A	C
	Helicodiscus singleyanus (Pilsbry).	S	A	C	R
	Pupoides albilabris (Adams)	C	C	C	S
Uncertain	*Deroceras aenigma* Leonard	C	------	C	------
	Gastrocopta franzenae Taylor	------	S	------	C
	paracristata Franzen and Leonard.	A	A	C	C
	scaevoscala Taylor	S	------	S	------
	Polygyra rexroadensis Taylor	------	S	------	------
	cf. *Succinea*	S	------	S	C

SAND DRAW LOCAL FAUNA

Previous work.—Fossils representing the Sand Draw local fauna were first collected by M. F. Skinner for the Frick Laboratories in 1934. From these and later collections by Skinner only two species have been published (Frick, 1937, p. 529; Osborn, 1936, p. 726). Later collections by Bryan Patterson and J. H. Quinn of the Chicago Natural History Museum yielded many additional vertebrates and mollusks (Baker, 1938; McGrew, 1944). In 1950 C. W. Hibbard and a party from the University of Michigan Museum of Paleontology visited the area and collected at other localities not sampled by Patterson and Quinn. Additional species found include mollusks (Taylor, 1954a) and a few mammals (Hibbard, 1956, 1957). Taylor visited the region in 1953, studied the stratigraphy of the localities where mollusks had been found, and collected more material. This stratigraphic study and an examination of the shells collected by these persons form the basis of the present discussion.

Fauna.—Following is a list of the Sand Draw local fauna:

Class Pelecypoda
- Order Prionodesmacea
  - *?Anodonta grandis* Say
- Order Teleodesmacea
  - *Sphaerium partumeium* (Say)
    - *striatinum* (Lamarck)
    - *sulcatum* (Lamarck)
    - *transversum* (Say)
  - *Pisidium casertanum* (Poli)
    - *compressum Prime*
    - *nitidum* Jenyns

Class Gastropoda
- Order Mesogastropoda
  - *Valvata lewisi* Currier
    - *tricarinata* (Say)
- Order Basommatophora
  - *Carychium* sp.
  - *Stagnicola* cf. *S. reflexa* (Say)
    - *caperata* (Say)
  - *Fossaria dalli* (Baker)
    - *obrussa* (Say)
  - *Bulimnea megasoma* (Say)
  - *Anisus pattersoni* (Baker)
  - *Gyraulus parvus* (Say)
  - *Helisoma anceps* (Menke)
  - *Planorbula armigera* (Say)
  - *Promenetus kansasensis* (Baker)
    - *umbilicatellus* (Cockerell)
  - *Acroloxus coloradensis* (Henderson)
  - *Ferrissia meekiana* (Stimpson)
    - *rivularis* (Say)
  - *Physa anatina* Lea
    - *gyrina* Say
    - *skinneri* Taylor
  - *Aplexa hypnorum* (Linnaeus)
- Order Stylommatophora
  - *Strobilops sparsicostata* Baker
  - *Gastrocopta chauliodonta* Taylor
    - *cristata* (Pilsbry and Vanatta)
    - *tappaniana* (Adams)
  - *Vertigo milium* (Gould)
    - *ovata* Say
  - *Pupoides albilabris* (Adams)
    - *inornatus* Vanatta
  - *Vallonia pulchella* (Müller)
  - cf. *Succinea*

Class Gastropoda—Continued
- Order Stylommatophora—Continued
  - *Helicodiscus singleyanus* (Pilsbry)
  - *Deroceras aenigma* Leonard
  - *Hawaiia minuscula* (Binney)

Class Osteichthyes
- *Ictalurus* sp.

Class Reptilia
- Order Chelonia
  - *Pseudemys* sp.
  - *Testudo*, 2 species

Class Mammalia
- Order Rodentia
  - *Geomys quinni* McGrew
  - *Procastoroides sweeti* Barbour and Schultz
  - *Nebraskomys mcgrewi* Hibbard
  - *Pliopotamys meadensis* Hibbard
- Order Carnivora
  - *Canis* cf. *C. latrans* Say
  - *Trigonictis kansasensis* Hibbard
  - *Taxidea* cf. *T. taxus* (Schreber)
  - *Smilodon* sp.
- Order Proboscidea
  - *Stegomastodon primitivus* Osborn
- Order Artiodactyla
  - *Platygonus* sp.
  - *Gigantocamelus* sp.
  - *Camelops* sp.
  - *Capromeryx* sp.
- Order Perissodactyla
  - *Plesippus simplicidens* (Cope)

Occurrence.—All known outcrops of the beds containing the Sand Draw local fauna are in northern Brown County, Nebr., within a northwest trending area about 10 by 4 miles. It appears that the beds are the fill in a late Pliocene valley, possibly related to an ancestor of the Elkhorn River.

Stratigraphy.—The deposits yielding the Sand Draw local fauna are unnamed. They rest unconformably, upon the underlying Pliocene rocks, and are overlain unconformably by a widespread sand and gravel sheet which forms much of the High Plains surface in the area. The approximate maximum thickness of the beds is 125 feet.

Lithology varies from fine-bedded alternating black clays and buff sands to crossbedded coarse sand and gravel. The fine-bedded sediments are extensively exposed along Deep Creek, and probably represent quiet-water deposition. The top of a thick sand and gravel unit is indicated at the base of the section on page 34. Crossbedding and lenticular clay and gravel beds represent fluviatile deposition.

There are three principal mollusk-bearing horizons: A, 75 feet below the unconformity (loc. 1); B, 35 feet–40 feet (loc. 2–3); and C, 15–22 (loc. 4–7). The following section contains only the highest horizon.

Section at center north side SW¼ sec. 25, T. 31 N., R. 22 W., Brown County, Nebr. Section and photograph by McGrew (1944, p. 34–35) are from this same exposure.

	Feet
9. Topsoil	4. 0
8. Fine sand and gravel, dark tan	1. 75
7. Sand, medium-grained, crossbedded, light rust-colored with many thin manganese-stained layers, occasional fine silt lenses	5. 25
6. Coarse sand and fine gravel, dark rust color	2. 0
5. Sand, fine white, with coarse rusty layer 1–4 inches thick at base	6. 25
Erosional unconformity	
Formation containing Sand Draw local fauna	
4. Sand, fine, light tan, grading upward into silt	7. 5
3. Silt, tan (weathering light gray) with rodent burrows filled by sand from unit 4; some shells (loc. 6)	2. 0
2. Sand, fine, slightly marly, gray-buff with abundant shells (loc. 6)	9. 0
1. Channel sands, fine, gray-tan, with lenses of clay and gravel	9. 0
Bed of wash (base of formation not exposed)	

Localities.—All the following localities are in Brown County, Nebr.:

Locality 1. Center west side SE¼SW¼ sec. 24, T. 31 N., R. 22 W; exposure on north side of Sand Draw at mouth of second wash downstream from bridge on former State Highway 7; locally reddish marly spot, 75 feet below unconformity.

Locality 2. NW¼ sec. 14, T. 31 N., R. 23 W. (USGS Cenozoic loc. 19090), exposures at head of West Fork of Deep Creek; sandy layer in thin-bedded sand and clay layers about 38 feet below unconformity.

Locality 3. NE¼SW¼ sec. 12, T. 31 N., R. 23 W; exposure on east side of Middle Fork of Deep Creek; thin-bedded sand and dark-gray clay, 35 feet–40 feet below unconformity.

Locality 4. NW¼ sec. 33, T. 31 N., R. 22 W; exposure on north side of Sand Draw; marly silt, 21–22 feet below unconformity.

Locality 5. Center of north side sec. 34 and southeast corner SW¼ sec. 27, T. 31 N., R. 22 W; exposures on small draw near earth dam; marly silt, 18–20 feet below unconformity; mollusks from this locality were listed by McGrew (1944, p. 36) as "from an exposure 2 miles west of Sand Draw." Baker (1938, p. 130) reported the snails by error as from the exposure on Sand Draw. (See below.)

Locality 6. North side of SW¼ and south side of NW¼, sec. 25, T. 31 N., R. 22 W. (USGS Cenozoic loc. 19091). Exposures along first wash south of Sand Draw on former State Highway 7. Marly sand and tan silt (units 2 and 3 of section), 8–15 feet below unconformity. This wash is not the Sand Draw proper, as considered by McGrew (1944, p. 35, explanation of figure), but a small tributary to it. The photograph and section given by McGrew (1944, p. 34–35) were taken in the center of the north side of the SW¼ of sec. 25. Mollusks from this locality were listed by McGrew (1944, p. 36) as from the "Sand Draw exposure," and by Baker (1938, p. 131) by error (see below) as from 2 miles west of the Sand Draw exposure.

Locality 7. Near center of SW¼SE¼ sec. 4, T. 30 N., R. 21 W. Exposure on Bone Creek near *Stegomastodon* quarry. Baker (1938, p. 130–131) listed mollusks from two localities, one "6 miles north of Ainsworth" and the other "about 2 miles west" of the former. Bryan Patterson, who collected the material, in a letter (dated December 22, 1949) to C. W. Hibbard, stated that Baker transposed the two localities. A letter from Baker to Patterson clearly shows that this transposition took place. McGrew (1944, p. 36) corrected the error, but without so indicating.

Age.—Faunal correlation and climatic inferences indicate the Sand Draw local fauna is of Nebraskan or Aftonian age. *Pliopotamys meadensis* is otherwise known only from the late Nebraskan or early Aftonian Dixon local fauna and the Aftonian Deer Park local fauna. This rodent is especially significant for correlation of the Sand Draw local fauna. The snail *Gastrocopta chauliodonta* is known only from the Sand Draw, Dixon, and Sanders local faunas and thus tends to support the mammalian evidence.

Although the mollusks of the Dixon, Sanders, and Sand Draw local faunas are generally similar (table 4), the Dixon and Sand Draw local faunas are related by sharing *Bulimnea megasoma* and *Acroloxus coloradensis*. These two species are rare or unknown in other Pleistocene assemblages, and suggest a similar environment for both faunas.

Climatic interpretation of the fauna is somewhat restricted because land snails are relatively underrepresented, and because the known vertebrates are mostly large mammals of little ecologic value. The large turtle *Testudo* indicates much warmer winters than those of north-central Nebraska today, with minimum temperatures rarely if ever at freezing. With the limited stratigraphic and paleontologic evidence available no precise climatic or age interpretations are possible. The mollusks alone, but especially the large *Testudo*, indicate that the assemblage did not live during a time of major glacial advance. It is not a late glacial age assemblage if the contrast with the late Kansan Cudahy fauna and the late Illinoian Butler Spring and Berends local faunas is reliable. The Sand Draw local fauna may be a transitional Nebraskan and Aftonian assemblage, as the Dixon local fauna is thought to be, or it may date from an interstadial in the Nebraskan age analogous to the Donau/Günz interstadial of the Alps.

Paleoecology.—Climate: Comparison of the mollusks of the Sand Draw local fauna with those living today in north-central Nebraska (table 15) shows 2 main contrasts which are most simply explained in 2 different ways. *Valvata lewisi*, *V. tricarinata*, *Physa skinneri*, and *Vallonia pulchella* have a generally

TABLE 14.—*Habitat indications of mollusks of Sand Draw local fauna*

[A, abundant (>200); C, common (41-200); S, scarce (16-40); R, rare (1-15)]

Habitat	Species	Locality and abundance						
		Level A	Level B		Level C			
		1	2	3	4	5	6	7
Permanent water: Pond	*Acroloxus coloradensis* (Henderson).	----	----	S	----	----	----	----
	Bulimnea megasoma (Say).	S	R	C	R	----	R	----
	Valvata lewisi Currier	----	----	----	----	C	A	----
Pond or stream	*Helisoma anceps* (Menke).	C	R	A	----	----	R	----
	Pisidium compressum Prime.	A	----	A	----	----	R	----
	nitidum Jenyns	----	----	C	----	----	----	R
	Sphaerium partumeium (Say).	C	----	----	----	----	----	----
	striatinum (Lamarck)	R	----	R	----	----	----	----
	sulcatum (Larmarck)	R	----	----	----	----	----	----
	transversum (Say)	----	S	----	----	----	----	----
	Valvata tricarinata (Say)	----	C	A	----	----	----	----
	?*Anodonta grandis* Say	----	R	----	----	----	----	----
Stream	*Ferrissia rivularis* (Say)	C	R	A	----	----	----	----
Permanent to temporary water: Permanent or subpermanent.	*Planorbula armigera* (Say).	C	----	----	R	----	----	----
	Physa anatina Lea	----	R	C	R	S	R	----
	Promenetus kansasensis (Baker).	C	C	A	C	A	A	C
Permanent or temporary.	*Gyraulus parvus* (Say)	A	C	A	A	A	A	C
	Physa gyrina Say	R	R	----	----	----	----	----
	Stagnicola cf. *S. reflexa* (Say).	C	S	A	C	A	A	C
Temporary pond or marginal pool.	*Aplexa hypnorum* (Linnaeus).	----	----	R	R	A	R	----
	Pisidium casertanum (Poli).	----	----	R	S	S	R	R
	Promenetus umbilicatellus (Cockerell).	R	S	A	C	A	A	A
	Stagnicola caperata (Say)	----	S	S	R	A	A	S
Marginal pools and wet mud.	*Fossaria dalli* (Baker)	----	R	----	----	----	R	----
	obrussa (Say)	----	----	C	----	----	----	----
Moister humus	*Carychium* sp	----	----	R	----	----	----	----
	Vertigo milium (Gould)	----	R	R	R	S	S	----
	ovata Say	----	R	S	S	C	S	R
Damp humus or grass	*Gastrocopta tappaniana* (Adams).	----	----	R	----	R	S	----
	Vallonia pulchella (Müller).	----	----	R	----	----	R	----
Damp to dry ground	*Gastrocopta cristata* (Pilsbry and Vanatta).	----	----	----	----	R	R	----
	Hawaiia minuscula (Binney).	R	R	R	----	----	R	R
	Helicodiscus singleyanus (Pilsbry).	----	R	----	----	----	----	----
	Pupoides albilabris (Adams).	----	R	----	----	----	S	----
Uncertain	*Anisus pattersoni* (Baker).	----	R	C	R	R	A	C
	Deroceras aenigma Leonard.	R	----	R	C	----	R	R
	Ferrissia meekiana (Stimpson).	R	----	R	----	----	----	----
	Gastrocopta chauliodonta Taylor.	----	S	R	----	----	R	R
	Physa skinneri Taylor	----	R	C	R	C	C	S
	Pupoides inornatus Vanatta.	----	R	----	----	----	----	----
	Strobilops sparsicostata Baker.	----	R	R	----	----	----	----
	cf. *Succinea*	R	R	S	R	C	S	S

northern distribution in North America. *Physa skinneri* does not range south in the Great Plains as far as the United States; the others are found a little farther south, but are ordinarily found only north of the Sand Draw fossil localities. These species suggest that the fauna lived under cooler summer conditions than those of northern Nebraska today.

The other contrast between the fossil and Recent faunas is in the habitats represented. Table 15 shows that there are 13 species which live in perennial water bodies in the Sand Draw local fauna, but only 3 in the local living fauna. This is considered a real and significant difference. The three Recent species in this habitat type are all known from a single locality where a group of springs forms a summer-cool, permanent pond. North-central Nebraska now is probably considerably drier and warmer in the summers than formerly. A number of land snails, particularly those of damp humus and sheltered habitats, are present in the Recent fauna but not in the Sand Draw local fauna. This may be explained by sampling error.

Only two mollusks (*Gastrocopta cristata, Helicodiscus singleyanus*) in the fossil assemblage have a relatively southern distribution in North America. The former reaches its northern known limit of range in northern Nebraska; the latter, in South Dakota. They suggest that winters were formerly no colder than those of the area today. The most significant temperature indicator in the fauna is the large land turtle, *Testudo.* The occurrence of this species in northern Nebraska indicates that winters were formerly much milder than now, with the lowest temperatures rarely if ever at freezing.

The mild winter climate inferred from the Sand Draw local fauna contrasts with the climates inferred from other late glacial faunas from the High Plains, such as the Cudahy fauna and the Berends, Butler Spring, and Jones local faunas. The occurrence of several markedly northern species suggests a climate more likely to be glacial than interglacial, but several land snails usually found in glacial faunas, such as *Pupilla muscorum* (Linnaeus), *P. blandi* Morse, *Vertigo modesta* Say, and *V. gouldi* (Binney), are absent. Until pollen analyses or better samples of the terrestrial fauna are available, the former climate and precise age of the Sand Draw local fauna will remain uncertain.

Habitat: Table 14 shows the habitat indications of the Sand Draw mollusks. Distribution and relative abundance of the species suggest that horizon *C* represents deposition in shallower water with a smaller variety of aquatic habitats than the other levels. Such an interpretation is supported by the fine-grained noncrossbedded sediments, and by the presence of rodent burrows at locality 6 (see section). Presence of *Ferrissia rivularis*, *Valvata tricarinata*, and *Helisoma anceps* at horizons *A* and *B* suggests a nearby stream. The fine-bedded, alternating black carbonaceous clays and light-colored sands along Deep Creek in which these species occur probably indicate lacustrine deposition, however.

TABLE 15.—*Comparison of Sand Draw local fauna and Recent mollusks from northern Nebraska*

Habitat	Species	Occurrence: Sand Draw horizon A	Occurrence: Sand Draw horizon B	Occurrence: Sand Draw horizon C	Recent
Permanent water:					
Stream	*Ferrissia rivularis* (Say)	×	×		
Pond or stream	*Helisoma anceps* (Menke)	×	×	×	×
	Pisidium nitidum Jenyns		×	×	
	compressum Prime	×	×	×	
	Sphaerium sulcatum (Lamarck)	×			
	striatinum (Lamarck)	×	×		
	partumeium (Say)	×			
	transversum (Say)		×		
	Valvata tricarinata (Say)		×		×
	?*Anodonta grandis* Say		×		
Pond	*Acroloxus coloradensis* (Henderson).		×		
	Bulimnea megasoma (Say)	×	×	×	
	Gyraulus deflectus (Say)				×
	Valvata lewisi Currier			×	
Permanent to temporary water:					
Permanent or subpermanent.	*Helisoma trivolvis* (Say)				×
	Planorbula armigera (Say)	×		×	×
	Physa anatina Lea		×	×	×
	Promenetus exacuous (Say)				×
	kansasensis (Baker)	×	×	×	
	Sphaerium securis Prime				×
Permanent or temporary	*Gyraulus parvus* (Say)	×	×	×	×
	circumstriatus (Tryon)				×
	Physa gyrina Say	×	×		×
	Stagnicola palustris (Müller)				×
	sp. cf. *S. reflexa* (Say)	×	×	×	
Temporary pond or marginal pool.	*Aplexa hypnorum* (Linnaeus)		×	×	×
	Armiger crista (Linnaeus)				×
	Pisidium casertanum (Poli)		×	×	×
	Promenetus umbilicatellus (Cockerell).	×	×	×	×
	Sphaerium lacustre (Müller)				×
	Stagnicola caperata (Say)		×	×	×
Marginal pools and wet mud.	*Fossaria dalli* (Baker)		×	×	×
	obrussa (Say)		×		×
Moister humus	*Carychium exiguum* (Say)				×
	sp		×		
	Deroceras laeve (Müller)				×
	Punctum minutissimum (Lea)				×
Semiaquatic, riparian habitat.	*Vertigo milium* (Gould)		×	×	
	ovata Say		×	×	×
	Oxyloma retusa (Lea)				×
Damp humus or grass	*Gastrocopta holzingeri* (Sterki)				×
	tappaniana (Adams)		×	×	×
	Vallonia gracilicosta Reinhardt				×
	parvula Sterki				×
	pulchella (Müller)		×	×	
Damp humus of wooded area.	*Cionella lubrica* (Müller)				×
	Discus cronkhitei (Newcomb)				×
	Euconulus fulvus (Müller)				×
	Nesovitrea electrina (Gould)				×
	Stenotrema leai (Binney)				×
	Succinea ovalis Say				×
	Zonitoides arboreus (Say)				×
Damp to dry ground	*Gastrocopta armifera* (Say)				×
	cristata (Pilsbry and Vanatta).			×	×
	Hawaiia minuscula (Binney)	×	×	×	×
	Helicodiscus singleyanus (Pilsbry)		×		
	Pupoides albilabris (Adams)		×	×	
Uncertain	*Anisus pattersoni* (Baker)		×	×	
	Deroceras aenigma Leonard	×	×	×	
	Ferrissia meekiana (Stimpson)	×	×		
	Gastrocopta chauliodonta Taylor		×	×	
	Physa skinneri Taylor		×	×	
	Pupoides inornatus Vanatta		×		
	Strobilops sparsicostata Baker		×		
	cf. *Succinea*	×	×	×	×

Horizon *A* contains a relatively low proportion of land species and a high proportion of aquatic species, especially those characteristic of permanent water. The local habitat may have been a permanent pond fed by or draining into a stream. Rarity of temporary pond and land snails may indicate that the locality is well out from the former shore.

Horizon *B* is the richest of the three. The sediments and mollusks of varied habitats suggest a large, quiet lake bordered by shallow marginal pools with grass and bushes along the shore. Absence of genera such as *Discus*, *Retinella*, and *Zonitoides* may indicate there were no woods along the shore. Shells from the shore and shallow water were apparently washed out to the deeper areas of the lake. A connecting river probably contributed some shells, especially *Ferrissia*.

Horizon *C* species indicate some permanent water, but apparently many shallow temporary pools were present. The increased percentage of temporary water and land species suggests a series of small pools and shoreline lagoons around a basin which did not dry up, but in which water level fell annually. Grass and a few trees and bushes lined the shore, but as in horizon *B*, evidence of extensive woodlands is absent.

DIXON LOCAL FAUNA

Previous work.—Frye and Leonard (1952, p. 151, Kingman County locality) reported mollusks from what is here called Dixon locality 1. Acting on their discovery, C. W. Hibbard and University of Michigan field parties have made additional large collections which yielded amphibians, birds, and mammals, besides many more mollusks (Herrington and Taylor, 1958; Hibbard, 1956; Taylor, this paper; Tihen, 1955). Mollusks and a few vertebrates (Hibbard, 1958a) from a second locality in Kingman County are included in the Dixon local fauna in this paper. University of Michigan collections are the basis of the present study.

Fauna.—Following is a list of the Dixon fauna:

Class Pelecypoda
- Order Teleodesmacea
  - *Sphaerium lacustre* (Müller)
    - *partumeium* (Say)
    - *transversum* (Say)
  - *Pisidium casertanum* (Poli)
    - *compressum* Prime
    - *nitidum* Jenyns

Class Gastropoda
- Order Mesogastropoda
  - *Valvata tricarinata* (Say)
  - Viviparidae, indet.
  - *Marstonia crybetes* (Leonard)
  - Hydrobiidae, indet.
- Order Basommatophora
  - *Carychium exiguum* (Say)
  - *Stagnicola caperata* (Say)
    - *reflexa* (Say)
  - *Fossaria dalli* (Baker)
  - *Bulimnea megasoma* (Say)
  - *Anisus pattersoni* (Baker)
  - *Gyraulus parvus* (Say)
  - *Helisoma anceps* (Menke)
    - *trivolvis* (Say)

Class Gastropoda—Continued
- Order Basommatophora—Continued
  - *Planorbula armigera* (Say)
  - *Promenetus kansasensis* (Baker)
  - *umbilicatellus* (Cockerell)
  - *Acroloxus coloradensis* (Henderson)
  - *Ferrissia meekiana* (Stimpson)
  - *rivularis* (Say)
  - *Physa anatina* Lea
  - *gyrina* Say
  - *skinneri* Taylor
- Order Stylommatophora
  - *Strobilops sparsicostata* Baker
  - *Gastrocopta armifera* (Say)
  - *chauliodonta* Taylor
  - *cristata* (Pilsbry and Vanatta)
  - *pellucida hordeacella* (Pilsbry)
  - *procera* (Gould)
  - *scaevoscala* Taylor
  - *tappaniana* (Adams)
  - *Pupoides albilabris* (Adams)
  - *Vertigo milium* (Gould)
  - *ovata* Say
  - *Vallonia perspectiva* Sterki
  - *Oxyloma retusa* (Lea)
  - cf. *Succinea*
  - *Helicodiscus parallelus* (Say)
  - *singleyanus* (Pilsbry)
  - *Deroceras aenigma* Leonard
  - *Nesovitrea electrina* (Gould)
  - *Hawaiia minuscula* (Binney)
  - *Zonitoides arboreus* (Say)

Class Amphibia
- Order Caudata
  - *Ambystoma tigrinum* (Green)

Class Aves
- Undescribed bird remains

Class Mammalia
- Order Insectivora
  - *Sorex dixonensis* Hibbard
  - *leahyi* Hibbard
  - sp.
  - *Blarina* sp.
  - *Cryptotis kansasensis* Hibbard
- Order Rodentia
  - *Citellus* sp.
  - *Geomys* sp.
  - Castoridae, indet.
  - *Sigmodon* sp.
  - *Peromyscus* sp.
  - *Pliophenacomys meadensis* Hibbard
  - *Pliopotamys meadensis* Hibbard
  - *Pliolemmus antiquus* Hibbard
  - *Synaptomys rinkeri* Hibbard
- Order Carnivora
  - Mustelidae, indet.

Occurrence.—The Dixon local fauna is known only from Kingman County, south-central Kansas.

Stratigraphy.—Neither the top nor the base of the fine silt unit containing the Dixon local fauna is exposed at the localities examined. On the basis of the age indicated by the fauna, the deposit is equivalent to or may be part of the Missler member of the Ballard formation.

Localities.—Both in Kingman County, Kans.: Locality 1: S½ sec. 12, T. 29 S., R. 8 W. Most of the material collected by Hibbard and party came from the southeast corner of the SW¼ (see Frye and Leonard, 1952, p. 62, pl. 3, fig. B). The exposure continues into the southwest corner of the SE¼. Additional material was collected from the center of the SW¼, on a slope above the northeast side of Red Creek. Locality 2: SE¼NE¼ sec. 23, T. 30 S., R. 5 W.

These two localities are believed to represent one fauna on the basis of the mollusks alone. All other faunas known from more than one locality which are reported in this paper are defined by independent stratigraphic or mammalian evidence.

Table 17 shows the close similarity of the molluscan assemblages from localities 1 and 2. Species considered especially significant are *Acroloxus coloradensis*, *Bulimnea megasoma*, and the viviparid. In the Pleistocene of the Great Plains the first two are known only from the Sand Draw and Dixon local faunas, the last from the Dixon local fauna only. It should be emphasized that the collection from each locality gives independently a similar and unusual ecological picture. Barring extinct species, the fossil land snail fauna is closely similar to that living in southern Kansas; the fossil and Recent freshwater assemblages are markedly distinct, however.

Mammals from locality 2 are few in number. If this locality is correlative with locality 1, as the mollusks suggest strongly, then the association of *Sigmodon* with so many shrews is remarkable. Furthermore, the occurrence of another species of shrew at locality 2, in addition to the four known from locality 1, suggests peculiarities of sampling error or only an approximate correlation between the two localities.

Age.—Faunal correlation and ecologic inferences indicate a latest Nebraskan or earliest Aftonian age (Hibbard, 1956). *Pliophenacomys meadensis* Hibbard, *Pliopotamys meadensis* Hibbard, *Pliolemmus antiquus* Hibbard, and *Gastrocopta chauliodonta* Taylor are all species known only from the Deer Park, Dixon, Sand Draw, and Sanders local faunas, of Nebraskan and Aftonian age. Ecologic interpretation of the mollusks and mammals tends to favor a late Nebraskan age, but the salamanders suggest Aftonian age. The fauna is therefore considered latest Nebraskan or earliest Aftonian.

Paleoecological indications (see below) are that the fauna lived in a climate with summers similar to or slightly cooler than those of today, and with runoff considerably greater from winter precipitation. The climate was not as markedly glacial as that of the Cudahy, Berends, and Bar M local faunas, nor as mild as that of the Sanders or Jinglebob local faunas. Summers were probably not quite so cool as those under which the Sand Draw local fauna lived, but this difference can be explained by latitude. The Dixon local fauna seems to represent the latest Nebraskan glacial age, when the climate had already begun to aproach that of today.

Frye and Leonard (1952, p. 148–151) distinguished the Dixon local fauna from the Kansan Cudahy fauna. They confused the late Pliocene Saw Rock Canyon and Rexroad local faunas with it, however, and gave all three a Nebraskan age. This procedure was based upon 12 supposed index fossils, 5 of which were found associated with Nebraskan till. Occurrence of these species is shown in Table 16.

TABLE 16.—*Occurrence of supposed Nebraskan index fossils*

[After Frye and Leonard, 1952, p. 151]

Species	Fauna and locality			
	Saw Rock Canyon local fauna	Rexroad local fauna	Dixon local fauna	Nebraskan till and David City gravel
1. *Gyraulus enaulus*	------	×	×	------
2. *Lymnaea diminuta*	×	×	×	×
3. *macella*	×	×	×	------
4. *parexilis*	×	×	×	×
5. *turritella*	×	×	×	------
6. *Promenetus blancoensis*	×	×	×	×
7. *Polygyra mooreana*	------	×	------	------
8. *Gastrocopta paracristata*	×	×	------	------
9. *Menetus kansasensis*	×	×	×	×
10. *Gastrocopta rexroadensis*	×	×	------	------
11. *Vertigo hibbardi*	×	×	×	------
12. *Amnicola crybetes*	×	×	×	×

Numbers 1–6 are considered synonyms of living species. Number 7 is believed to be not the living *Polygyra mooreana* but an extinct species known only from the Rexroad and Bender local faunas. Numbers 8 and 9 range from the late Pliocene Saw Rock Canyon local fauna to the Aftonian Sanders local fauna. Numbers 10 and 11 are believed restricted to the upper Pliocene; the record of 11 in the Dixon local fauna is considered erroneous. Number 12 occurs in the upper Pliocene and Nebraskan. The extensions in range of these species are due to two chief reasons: difference in taxonomic evaluation (whether the fossils are different from other species or not), and use of vertebrate fossils for age determination.

Paleoecology.—Climate: Mollusks of the Dixon local fauna are compared with those living in Kingman County today in table 18. The most significant and obvious difference is the much greater number of freshwater species, especially those requiring permanent water, in the Dixon local fauna. The terrestrial components of the two assemblages, however, are not significantly different. In this case sampling error is probably not important, for the Dixon local fauna is known from two fairly well sampled localities representing several habitats. The absence of such characteristically northern land snails as *Pupilla*, *Vallonia gracilicosta*, *Discus*, and some species of *Vertigo* is probably real.

The occurrence in the Dixon local fauna of some freshwater snails of generally northern distribution in North America may be explained by their habitat in summer-cool, perennial water bodies. Other freshwater species which do not range as far west as Kingman County also indicate a greater variety of aquatic habitats in the early Pleistocene. The evidence of the land snails suggests that the markedly northern snails *Valvata tricarinata* and *Physa skinneri* indicate the persistence of cool water habitats during the summer, rather than markedly cooler summer climate. The close similarity of the land snails to those living locally tends to suggest a climate not unlike that of Kingman County today.

The sources of water for the perennial streams which contained the relatively diverse fresh-water molluscan assemblage of the Dixon local fauna are speculative. Presumably the mean annual precipitation did not differ greatly in amount from that today, for then a larger, more diverse land snail fauna would be expected. Perhaps greater annual snowfall in the Rocky Mountains or the melting of glaciers were contributing factors.

The Dixon local fauna evidently represents a later stage of deglaciation than do the Cudahy, Berends, Butler Spring, or Bar M local faunas, for these assemblages suggest much cooler, moister summers. It is most similar to the Sand Draw local fauna, and differences between the two can be explained by latitude and sampling error.

Habitat: Table 17 summarizes the habitat indications of the mollusks of the Dixon local fauna. At locality 1 the area of deposition was probably close to two freshwater habitats: a permanent slow-moving stream or slack-water stretch, probably of at least moderate size, and shallower, quiet water near shore, with dense vegetation. The more abundant land snails taken as a group suggest a streamside situation of damp grass and humus with some dead wood, but no wooded area. The species characteristic of woodland are so much rarer that this habitat was either not important at the time, or else some distance upstream. This inference is erroneous to an uncertain degree, however, because of the larger size of the species in question, whose shells

TABLE 17.—*Habitat indications of mollusks of Dixon local fauna*

[A, abundant (>250); C, common (41–250); S, scarce (8–40); R, rare (1–7)]

Habitat	Species	Abundance	
		Loc. 1	Loc. 2
Permanent water:			
Pond	*Acroloxus coloradensis* (Henderson).	R	R
	Bulimnea megasoma (Say)	C	S
	Sphaerium lacustre (Müller)	S	----
Pond or stream	*Helisoma anceps* (Menke)	C	R
	Marstonia crybetes (Leonard)	R	----
	Pisidium compressum Prime	C	----
	nitidum Jenyns	R	----
	Sphaerium partumeium (Say)	----	C
	transversum (Say)	R	----
	Valvata tricarinata (Say)	----	S
	Viviparidae, indet	R	R
	Hydrobiidae, indet	R	----
Stream	*Ferrissia rivularis* (Say)	C	----
Permanent to temporary water:			
Permanent or subpermanent.	*Helisoma trivolvis* (Say)	R	C
	Physa anatina Lea	C	----
	Planorbula armigera (Say)	R	C
	Promenetus kansasensis (Baker)	A	C
Permanent or temporary	*Gyraulus parvus* (Say)	A	A
	Physa gyrina (Say)	C	C
Temporary pond or marginal pool.	*Pisidium casertanum* (Poli)	R	----
	Promenetus umbilicatellus (Cockerell).	S	R
	Stagnicola caperata (Say)	S	C
	reflexa (Say)	A	A
Marginal pools and wet mud	*Fossaria dalli* (Baker)	S	R
Semiaquatic, riparian habitat	*Oxyloma retusa* (Lea)	S	S
Moister humus	*Carychium exiguum* (Say)	R	----
	Vertigo ovata Say	C	R
	milium (Gould)	C	S
Damp humus or grass	*Gastrocopta tappaniana* (Adams)	C	S
Damp humus of wooded area	*Helicodiscus parallelus* (Say)	----	S
	Nesovitrea electrina (Gould)	R	----
	Strobilops sparsicostata Baker	R	----
	Zonitoides arboreus (Say)	R	----
Damp to dry ground	*Gastrocopta armifera* (Say)	S	----
	cristata (Pilsbry and Vanatta)	S	R
	procera (Gould)	R	S
	Hawaiia minuscula (Binney)	C	C
	Helicodiscus singleyanus (Pilsbry)	R	A
	Pupoides albilabris (Adams)	S	S
Uncertain	*Anisus pattersoni* (Baker)	S	----
	Deroceras aenigma Leonard)	C	R
	Ferrissia meekiana (Stimpson)	R	C
	Gastrocopta chauliodonta Taylor	S	----
	pellucida hordeacella (Pilsbry)	----	R
	scaevoscala Taylor	----	R
	Physa skinneri Taylor	S	S
	cf. *Succinea*	R	S
	Vallonia perspectiva Sterki	R	----

would not be transported as readily as those of smaller forms.

The mammals from Dixon local fauna locality 1 were studied by Hibbard (1956, p. 18). He stated "The 3 species of *Sorex*, *Blarina*, and the 4 species of microtines indicate a marshy habitat along the water edge, and *Blarina* indicates the presence of trees and shrubs."

Thus the local habitat at locality 1 may have been as follows: A small to medium-sized river meandered slowly across the plain, depositing fine sand and silt. The quiet but more open water 2–4 feet deep had a molluscan assemblage dominated by *Bulimnea megasoma* and *Helisoma anceps*. Driftwood, reeds, and mussel shells in slow to moderate current furnished a suitable habitat for *Ferrissia*. The dense growth of vegetation such as *Potamogeton* and *Myriophyllum* in thick patches here and there supported abundant *Physa*, *Promenetus*, *Gyraulus*, and *Stagnicola reflexa*. Shallow embayments and marginal pools near shore had *Physa*, *Fossaria*, *Gyraulus*, *Promenetus unbilicatellus*, and *Pisidium casertanum*. On shore was some woodland, and damp grassy areas with dead wood and leaf mold supporting many small land snails.

Locality 2 was generally similar to locality 1, except that the fresh water and land faunas were not quite so diversified. The more common fresh water snails are those which live in subpermanent or temporary water bodies. The land snail assemblage at locality 2 is like that of locality 1 in composition and in relative abundance of species, but suggests a little more grass and less woodland.

The local habitat was probably a side-channel, backwater, or oxbow pond which dried up partly in the summer. The reeds and submerged vegetation supported many *Gyraulus*, *Helisoma*, *Planorbula*, *Promenetus*, *Stagnicola*, *Physa*, and *Ferrissia*. In the

TABLE 18. *Comparison of mollusks of Dixon local fauna with those living in Kingman County, Kans., by habitats*

[Recent list based on Franzen and Leonard (1942) and personal collections]

Habitat	Species	Dixon	Recent
Permanent water:			
Pond	*Acroloxus coloradensis* (Henderson)	×	----
	Bulimnea megasoma (Say)	×	----
	Sphaerium lacustre (Müller)	×	----
Pond or stream	*Helisoma anceps* (Menke)	×	×
	Marstonia crybetes (Leonard)	×	----
	Pisidium compressum Prime	×	----
	nitidum Jenyns	×	----
	Sphaerium partumeium (Say)	×	----
	transversum (Say)	×	----
	Valvata tricarinata (Say)	×	----
	Viviparidae, indet	×	----
	Hydrobiidae, indet	×	----
Stream	*Ferrissia rivularis* (Say)	×	----
Permanent to temporary water:			
Permanent or subpermanent.	*Helisoma trivolvis* (Say)	×	×
	Physa anatina Lea	×	×
	Planorbula armigera (Say)	×	----
	Promenetus kansasensis (Baker)	×	----
Permanent or temporary	*Gyraulus parvus* (Say)	×	×
	Physa gyrina Say	×	----
	Stagnicola palustris (Müller)	----	×
Temporary pond or marginal pool.	*Pisidium casertanum* (Poli)	×	----
	Promenetus umbilicatellus (Cockerell).	×	----
	Stagnicola caperata (Say)	×	----
	reflexa (Say)	×	----
Temporary pond or stream	*Stagnicola bulimoides techella* (Haldeman)	----	×
Marginal pools and wet mud	*Fossaria dalli* (Baker)	×	----
	obrussa (Say)	----	×
Semiaquatic, riparian habitat.	*Oxyloma retusa* (Lea)	×	----
	Succinea concordialis Gould	----	×
Moister humus	*Carychium exiguum* (Say)	×	×
	Vertigo ovata (Say)	×	×
	milium (Gould)	×	----
Damp humus or grass	*Gastrocopta contracta* (Say)	----	×
	tappaniana (Adams)	×	×
	Vallonia parvula Sterki	----	×
Damp humus of wooded area	*Helicodiscus parallelus* (Say)	×	×
	Nesovitrea electrina (Gould)	×	----
	Retinella indentata (Say)	----	×
	Stenotrema fraternum (Say)	----	×
	Strobilops sparsicostata Baker	×	----
	Zonitoides arboreus (Say)	×	×
Damp to dry ground	*Gastrocopta armifera* (Say)	×	×
	cristata (Pilsbry and Vanatta)	×	----
	procera (Gould)	×	×
	Hawaiia minuscula (Binney)	×	×
	Helicodiscus singleyanus (Pilsbry)	×	×
	Pupoides albilabris (Adams)	×	×
Uncertain terrestrial	*Deroceras aenigma* Leonard	×	----
	Gastrocopta chauliodonta Taylor	×	----
	pellucida hordeacella (Pilsbry)	×	----
	scaevoscala Taylor	×	----
	cf. *Succinea*	×	×
	Vallonia perspectiva Sterki	×	----
Uncertain aquatic	*Anisus pattersoni* (Baker)	×	----
	Ferrissia meekiana (Stimpson)	×	----
	Physa skinneri Taylor	×	----

deeper parts of this quiet water, and especially toward the nearby stream, lived *Bulimnea megasoma*, *Helisoma anceps*, and *Valvata*. Soft mud furnished a suitable habitat for the common *Sphaerium partumeium*. The vegetation on shore was grass and shrubs with some trees, among which many small land snails lived.

SANDERS LOCAL FAUNA

Previous work.—This fauna was discovered in 1953 by C. W. Hibbard and a University of Michigan field party. Collecting in 1953 and 1954 yielded mollusks, amphibians, birds, and mammals (Hibbard, 1956; Tihen, 1955).

Fauna.—Following is a list of the Sanders local fauna:

Class Gastropoda
- Order Basommatophora
  - *Stagnicola bulimoides techella* (Haldeman)
    - *caperata* (Say)
    - sp.
  - *Fossaria dalli* (Baker)
  - *Gyraulus parvus* (Say)
  - *Promenetus kansasensis* (Baker)
    - *umbilicatellus* (Cockerell)
  - *Physa anatina* Lea
    - *skinneri* Taylor
  - *Aplexa hypnorum* (Linnaeus)
- Order Stylommatophora
  - *Gastrocopta chauliodonta* Taylor
    - *cristata* (Pilsbry and Vanatta)
    - *paracristata* Franzen and Leonard
    - *tappaniana* (Adams)
  - *Vertigo milium* (Gould)
    - *ovata* Say
  - *Pupoides albilabris* (Adams)
  - Pupillidae, new genus and species?
  - *Vallonia perspectiva* Sterki
  - cf. *Succinea*
  - *Helicodiscus singleyanus* (Pilsbry)
  - *Deroceras aenigma* Leonard
  - *Hawaiia minuscula* (Binney)

Class Amphibia
- Order Caudata
  - *Ambystoma tigrinum* (Green)?

Class Aves
- Undescribed bird remains

Class Mammalia
- Order Insectivora
  - *Sorex sandersi* Hibbard
- Order Rodentia
  - *Geomys tobinensis* Hibbard
  - *Perognathus* cf. *P. pearlettensis* Hibbard
  - *Prodipodomys* sp.
  - *Sigmodon* cf. *S. intermedius* Hibbard
  - *Bensonomys meadensis* Hibbard
  - *Pliophenacomys meadensis* Hibbard
  - *Pliolemmus antiquus* Hibbard
  - *Zapus sandersi* Hibbard

Class Mammalia—Continued
- Order Carnivora
  - *Mustela* sp.
- Order Proboscidea
  - Mastodont, indet.
- Order Artiodactyla
  - Camelidae, indet.
- Order Perissodactyla
  - *Nannippus phlegon* (Hay)
  - *Plesippus simplicidens* (Cope)

Occurrence.—The Sanders local fauna is known only from Meade County, southwest Kansas.

Stratigraphy.—The fauna occurs in the Missler member of the Ballard formation, above the caliche. Hibbard (1956, p. 150–151; 1958, p. 56) has published measured sections including localities of the Sanders local fauna.

Localities.—All the following localities are in Meade County, Kans.

Locality 1 (University of Michigan UM–K1–53): Center of south edge NW¼NE¼ sec. 18, T. 32 S., R. 28 W. Exposure on tributary of Spring Creek, where Ballard formation unconformably overlies Rexroad formation. Rexroad local fauna locality 1 (Kansas University locality 25) is in this exposure also.

Localities 2 and 3 (University of Michigan UM–K2–53): Near center of sec. 23, T. 32 S., R. 29 W. Exposures of gray silt above a tributary of Spring Creek. The two fossiliferous localities are only a few tens of feet apart and at the same stratigraphic horizon. All the vertebrates have been grouped as coming from one locality. The more numerous shells were kept separate to determine the extent of local environmental differences—evidently minor. (See table 19.)

Age.—The Sanders local fauna is believed to be of late Aftonian age from faunal evidence, ecologic inferences, and stratigraphic position. The faunal evidence from the restricted ranges of extinct groups comes primarily from the mammals. They indicate a Nebraskan or Aftonian age. *Gastrocopta chauliodonta*, otherwise known only from the Sand Draw and Dixon local faunas, also suggests an earliest Pleisticene age.

Ecologic inferences from the fauna suggest a mesothermal, subhumid climate with seasonal extremes much less marked than those of today. The fauna as a whole contrasts with the glacial assemblages which have a marked element of northern species. The inferred climate is intermediate between that of the glacial intervals and the warm-temperate, semiarid climate suggested by the caliche horizon. For these reasons the Sanders local fauna is called Aftonian.

The stratigraphic position of the fauna in the upper part of the Ballard formation, above a buried, massive caliche layer, is interpreted to indicate an age less than that of some part of the Aftonian. The caliche is believed to be Aftonian, but what part of this interval it represents is uncertain.

Paleoecology. — Climate: Both characteristically northern and characteristically southern faunal elements occur in the Sanders local fauna. The most extreme contrast in distributions is between those of *Physa skinneri* and *Stagnicola bulimoides techella.* These species now live hundreds of miles apart, but were associated in southwestern Kansas. The joint occurrence of these and other species is taken to indicate a former reduction of climatic extremes.

The southern element among the mollusks is composed of species which in the Great Plains are restricted to or characteristic of the southern part. These are *Stagnicola bulimoides techella*, *Gastrocopta cristata*, *Vallonia perspectiva*, and *Helicodiscus singleyanus*. A moderately northern element is composed of *Stagnicola caperata*, *Promenetus umbilicatellus*, and *Aplexa hypnorum*, which range south in the Great Plains as far as Nebraska. The most striking element is *Physa skinneri*, which is widespread in the plains of southern Canada but unknown in the United States.

This association of species is different from that known in any other Blancan fauna. Southern and mid-northern species are known in the late Pliocene faunas, but with no markedly northern forms. Glacial faunas have a much reduced southern element, or none at all, and many northern species. Such a peculiar combination of elements is shown also by the mammals of the Sanders local fauna. Hibbard (1956, p. 156) noted that there are some southern types of mammals: the cotton rat (*Sigmodon*), *Bensonomys*, and a kangaroo rat (*Prodipodomys*). These, and the relative scarcity of shrews, suggest a warm, interglacial climate, but the cricetine rodents would then be expected to be common. "The paucity of cricetine rodents may be due in part to the habitat, but it is in contrast to their abundance in the warm-temperate Rexroad fauna" (Hibbard, 1956, p. 156).

The local lenses of grayish organic muds in which the Sanders local fauna occurs suggest small, shallow ponds or a slow-moving, unentrenched stream. The aquatic snails and land snails of moist habitats indicate permanent moisture and subpermanent standing water. Hence, the Sanders local fauna probably lived in and near shallow annual ponds or else a small, slow-moving stream of local origin. The absence of genera usually associated with bushes or trees bordering such a habitat further suggests seasonal grassland ponds or streams. Neither of these situations necessarily implies greater rainfall than that of southwestern Kansas at the present time, but only greater effectiveness of precipitation. Milder summers might well account for this. Occurrence of the jumping mouse, *Zapus*, and the abundance of microtine rodents also indicates a moister climate (Hibbard, 1956, p. 156).

The former climate in which the Sanders local fauna lived thus differed from the present by more effective rainfall, and summers with much less intense hot spells. Neither distribution nor amount of annual rainfall was necessarily different.

An earlier interpretation of the fauna, based on my misidentification of *Stagnicola bulimoides techella*, suggested that winters were considerably warmer than now (Hibbard, 1956, p. 156). The winters may indeed have been warmer than now, but the mollusks give no evidence for this.

Habitat. Table 19 summarizes habitat indications of the mollusks of the Sanders local fauna. All three localities seem to represent the same situation: shallow sub-permanent ponds or stream backwaters with surrounding grassy areas. *Discus*, *Euconulus*, *Helicodiscus parallelus*, *Retinella*, *Zonitoides*, and other forms usually associated with damp humus around dead wood are absent. This fact suggests that woodland, if present, was not all well developed, and recalls the hay meadow regions of north-central Nebraska. Here large areas of grassland have streams and ponds each spring, and trees are infrequent.

TABLE 19.—*Habitat indications of mollusks of Sanders local fauna*

[A, abundant (>250); C, common (41-250); S, scarce (8-40); R, rare (1-7)]

Habitat	Species	Locality 1	Locality 2	Locality 3
Permanent to temporary water:				
Permanent or subpermanent.	*Physa anatina* Lea	S	R	R
	Promenetus kansasensis (Baker)	-----	R	R
Permanent or temporary	*Gyraulus parvus* (Say)	R	-----	R
	Stagnicola sp.	R	R	R
Temporary water:				
Temporary pond or marginal pool.	*Aplexa hypnorum* (Linnaeus)	S		
	Stagnicola caperata (Say)	C	S	C
	Promenetus umbilicatellus (Cockerell).	A	R	S
Temporary pond or stream.	*Stagnicola bulimoides techella* (Haldeman).	S	R	C
Marginal pools and wet mud	*Fossaria dalli* (Baker)	-----	-----	R
Moister humus	*Vertigo milium* (Gould)	A	R	A
	ovata (Say)	R		
Damp humus or grass	*Gastrocopta tappaniana* (Adams)	C	R	S
Damp to dry ground	*Gastrocopta cristata* (Pilsbry and Vanatta).	A	C	A
	Hawaiia minuscula (Binney)	A	S	A
	Helicodiscus singleyanus (Pilsbry).	-----	S	R
	Pupoides albilabris (Adams)	A	S	S
Uncertain	*Deroceras aenigma* Leonard	C	R	S
	Gastrocopta chauliodonta Taylor	S	-----	-----
	paracristata Franzen and Leonard.	S	R	-----
	Physa skinneri Taylor	R	-----	R
	Pupillid, n. gen.?	-----	-----	R
	cf. *Succinea*	C	S	C
	Vallonia perspectiva (Sterki)	C	R	R

DEER PARK LOCAL FAUNA

Previous work.—Collections at the Deer Park locality have been made by C. W. Hibbard and parties from the University of Kansas (1936, 1944) and University of Michigan (1954). The mammals now included in the Deer Park local fauna were originally referred to the Rexroad local fauna (Hibbard, 1938, 1941a), but later recognized as coming from a higher stratigraphic horizon (Hibbard, 1949). A number of vertebrates but only one mollusk have been discovered (Hibbard, 1956).

Fauna.—Following is a list of the Deer Park local fauna:

Class Gastropoda
- Order Stylommatophora
  - *Deroceras aenigma* Leonard

Class Reptilia
- Order Chelonia
  - *Testudo*, large species
- Order Squamata
  - Snake, indeterminate

Class Aves
- Birds, indet.

Class Mammalia
- Order Rodentia
  - *Cynomys meadensis* Hibbard
  - *Citellus* sp.
  - *Geomys quinni* McGrew
  - *Procastoroides sweeti* Barbour and Schultz
  - *Ogmodontomys* sp. or *Mimomys* (*Cosomys*) sp.
  - *Pliopotamys meadensis* Hibbard
  - *Pliolemmus antiquus* Hibbard
- Order Carnivora
  - *Canis* sp.
  - Mustelidae, indet.
  - *Taxidea* cf. *T. taxus* (Schreber)
- Order Proboscidea
  - *Stegomastodon* sp.
  - *Rhynchotherium* sp.
- Order Lagomorpha
  - *Hypolagus* sp.
- Order Artiodactyla
  - *Platygonus* sp.
  - Camelidae, 2 indeterminate species
- Order Perissodactyla
  - *Nannippus phlegon* (Hay)
  - *Plesippus simplicidens* Cope

Occurrence.—The Deer Park local fauna is known only from Meade County, southwest Kansas.

Stratigraphy.—The fauna occurs in the Missler member of the Ballard formation (Hibbard, 1949, 1956).

Localities.—Only one locality is known, in Meade County State Park, near the west edge SE¼ sec. 15, T. 33 S., R. 29 W., Meade County, Kans. (University of Kansas Meade County loc. 1).

Age.—Ecologic interpretation and the stratigraphic position of the Deer Park local fauna indicate an Aftonian age.

Paleoecology.—The occurrence of pockets and tubes of flour sand within the surrounding unconsolidated silt and silty clay of the Missler member, badly worn and polished bone fragments, the greater abundance of harder enamel teeth than bones, occurrence of the relatively strong slug shells and no other mollusk remains, and the similarity of the deposit to the numerous artesian springs of Meade County today all indicate that the Deer Park quarry is in deposits of a former artesian spring system. "The habitat in the neighborhood of these springs can be considered to have been similar to that characteristic of the same springs in Meade County today. The area of discharge is a death trap of boiling quick-sand, and the entire basin is a bog, in places choked with water cress and other aquatic plants that cover outlets of a part of the earlier dendritic pattern. The basin grades into a marsh that supports sedges and associated vegetation. Around the edges of the marsh and along the banks of the outlet area are trees, shrubs, and grapevines. This habitat furnishes not only a home for rodents and shrews but also a watering and feeding place for the larger grazers and browsers and for some carnivores. The remains consist chiefly of those of horses, mastodons, camels, and peccaries. The large grazers and browsers had probably ventured out too far from the edge of the basin while feeding" (Hibbard, 1956, p. 155–156). The slug *Deroceras aenigma* probably lived among the semiaquatic vegetation around the spring, along with many other snails whose shells have not been preserved.

"The climate at the time this fauna lived is regarded as interglacial because of the presence in it of the large land turtle *Testudo*, which could have inhabited the region only during a mild-temperate time" (Hibbard, 1956, p. 156).

RECENT MOLLUSKS FROM NORTHERN NEBRASKA

In the summer of 1953 R. D. Mitchell, A. L. Lamb, and D. W. Taylor collected Recent mollusks at localities in north-central Nebraska while working on the Sand Draw local fauna. They are of interest in comparison with the Sand Draw local fauna, and also because mollusks from the area have not been reported before.

LOCALITIES

Cherry County, Nebr.:

1. Fort Niobrara National Widlife Refuge, 5 miles east of Valentine. Pond and seepage area at old fort reservoir.
2. North side Niobrara River flood plain ½ miles west of U. S. Highway 20. Nearly filled old oxbow lake with seepage and slight current.
3. Sand hills pond on west side U. S. Highway 83, 7.4 miles south of junction with U. S. Highway 20. Temporary.
4. Small creek and tributary drainage ditches 4 miles northeast of Simeon. Subpermanent water.

Cherry County, Nebr.—Continued

5. Creek at junction of dirt road and paved road to Alkali Lake, 4.4 miles west of junction with U. S. Highway 83.
6. South side Red Deer Lake. Permanent water.
7. Lake on west side U. S. Highway 83, 20 miles north of Thedford. Probably temporary.

Brown County, Nebr.:

8. Wooded draw on south bluffs Niobrara River, on State Highway 7, 0.4 mile south of bridge across river.
9. Drainage ditches in northwest corner sec. 34, T. 30 N., R. 22 W. Temporary water.
10. Drainage ditch at northwest corner sec. 10, T. 29 N., R. 22 W. Water probably permanent, but ditch dug recently.
11. Seepages along stream in wooded draw 50 yards south of Long Pine Creek at bridge 2½ miles south of Long Pine.
12. Calamus River .5 mile west of State Highway 7. Seepages along south bank.

Rock County, Nebr.:

13. Drainage ditches along U. S. Highway 20, 2.8 miles west of Bassett.
14. Pond on north side U. S. Highway 20, 2.3 miles east of Bassett.

Hooker County, Nebr.:

15. Middle Loup River 5 miles east of Mullen.

Thomas County, Nebr.:

16. Stock tank beside State Highway 2, 1 mile west of Seneca.
17. Middle Loup River at south side Thedford.
18. Middle Loup River, 1 mile east of Seneca.

HABITATS

The area studied lies on the northeast side of the Sand Hills region of western Nebraska, and thus includes two physiographic types, the Sand Hills and the High Plains proper. Each of these is discussed below.

High Plains.—The part of the region collected in is typical: flat land sloping gently toward the Missouri River. Grassland is broken rarely by an occasional cottonwood tree. This flat surface is largely a plain of alluviation, probably completed sometime in the middle Pleistocene. The Niobrara River is incised well into this mantle, and its tributaries are cutting rapidly headward into the poorly consolidated sediments. The widespread sands and gravels form ideal aquifers; streamside patches of springs and seepage areas are abundant. Well-developed deciduous woodland occurs in these valleys wherever adequate water is available; pine stands cover the drier slopes. Drainage and irrigation ditches on the undissected upland dry up toward the end of summer. They often connect with ponds, also temporary. In this region land snails are largely restricted to stream valleys where cover and moisture are available. Freshwater mollusks are removed from the large streams by flooding, but are abundant in small spring-fed creeks, seepages, and upland ponds and ditches with no flood scour.

Sand Hills.—The Sand Hills region is a huge area of western Nebraska covered by shifting sand loosely held by dune grass. The hills so formed vary in shape and size, but are similar in having only sparse grass growing on them. A large proportion of the hollows in this area contain shallow ponds, many large enough to be called lakes. Permanence is proportional to size; in the worst drouth years all but the largest lakes dry up. This large area is almost devoid of land snails, and the freshwater fauna is drastically reduced by the temporary nature of the water bodies. *Stagnicola caperata*, *S. palustris*, and *Physa gyrina* occur in nearly every pond; rich localities have 7 or 8 species.

Most of the Sand Hills area is undrained, but some medium-sized streams flow from the area. The small creeks are but little more permanent than the ponds, but the rivers are perennial. The streams draining this region cannot flood, for rain sinks into the sand as soon as it falls. There are thus no accumulations of flood debris along the banks. There is essentially no mud or gravel anywhere, for the area is all sand. The only mud seen was in seepage areas along the rivers, where watercress and other semiaquatic plants have produced organic debris. As in the High Plains proper, deciduous woodland grows in the river valleys. Almost all of the few land snails occur in this habitat.

The habits are tabulated below, and the mollusks occurring in them listed in the following section.

I. Aquatic habitats.
   - A. Permanent water bodies.
     1. Marginal stations. At the edge of ponds, snails occur in a semiaquatic position, frequently as much out of water as in it.
     2. Quiet water.
        - a. Lake. Red Deer Lake (loc. 6) was the only one of this type sampled. The fauna does not differentiate it from the temporary ponds.
        - b. Backwaters or sheltered spots along rivers. This habitat is peculiar to the Sand Hills for elsewhere each flood scours the banks.
        - c. Oxbow lake. The only such station visited (loc. 2) has a permanent water supply from seepage through the valley fill, but is not cooled by it.
        - d. Spring-fed pond. At locality 1 spring waters of 15°C. were ponded. The summer-cool water is believed responsible for presence of some species in the area.
     3. Flowing water. At numerous places along streams cut into the High Plains surface small springs and seepages occur. The mollusks are usually among the mud and water cress.

B. Subpermanent water bodies.
   1. Ponds. These dry up only in drier years.
   2. Sand Hills creeks. Quiet spots along such streams are more nearly permanent than most Sand Hills ponds, which they drain.
C. Temporary water bodies.
   1. Ponds. This category includes the temporary Sand Hills ponds as well as small ponds along ditches outside the Sand Hills. Locality 16 is a metal stock tank.
   2. Ditches (irrigation and drainage). These fill up after heavy rains but because of their low gradient flow only slowly and do not flush out the snails.

II. Terrestrial habitats.
A. Marginal stations.
   1. Moist leaves around seepages.
   2. Riparian station. *Oxyloma* was almost always within a few inches of permanent water, crawling about on water cress or logs.
   3. Lake shore. At locality 7 *Succinea* was found on the wet shore several feet from the water's edge among sparse tall grass.
B. Damp ground. Among slightly damp leaves or on soil under timber or rocks.

SPECIES FOUND AT THE NORTHERN NEBRASKA LOCALITIES

The first symbol of letters and numbers indicates the habitat type, the following numbers in parentheses the localities from pages 42–43.

Sphaerium lacustre (Müller) form *ryckholti* (Normand) IA3 (11), IC1 (3)
  securis Prime, IB1(14)
Pisidium casertanum (Poli), IA2c(2), IA3(11, 18)
Valvata tricarinata (Say), IA2d(1)
Carychium exiguum (Say), IIA1(11)
Stagnicola palustris (Müller), IA2a(6), IB2(4), IC1(3, 7), IC2(13)
  caperata Say, IB2(4), IC1(3, 7), IC2(9, 13)
Fossaria obrussa (Say), IA1(1, 15, 17), IA3(11, 12)
  dalli (Baker), IA2c(2), IA3(11)
Armiger crista (Linnaeus), IB2(5)
Gyraulus circumstriatus (Tryon), IA3(11, 12), IB2(4), IC1(3)
  parvus (Say), IA2a(6), IA2d(1), IB1(14), IB2(5), IC1(3), IC2(13)
  deflectus (Say), IA2d(1)
Helisoma anceps (Menke), IA2d(1)
  trivolvis (Say), IA2a(6), IA2d(1), IB1(14), IC2(13)
Planorbula armigera (Say), IA2c(2)
Promenetus exacuous (Say), IB1(14), IB2(5)
  umbilicatellus (Cockerell), IC1(3, 7), IC2(9)
Physa anatina Lea, IA2d(1), IA3(1, 11, 12, 18)
  gyrina Say, IA2a(6), IA2b(17), IB1(14), IB2(4, 5), IC1 (3, 7, 16), IC2(10, 13)
Aplexa hypnorum (Linnaeus), IC2(9, 13)
Gastrocopta armifera (Say), IIB(1)
  cristata (Pilsbry and Vanatta), IIB(8)
  holzingeri (Sterki), IIB(1)
  tappaniana (Adams), IIA1(11), IIB(1)
Vertigo ovata (Say), IIA1(11)
Vallonia gracilicosta Reinhardt, IIB(1, 8)
  parvula Sterki, IIB(1, 8)
Cionella lubrica (Müller), IIB(8)
cf. *Succinea*, IIA3(7)
Succinea ovalis Say, IIB(8)
Oxyloma retusa (Lea), IIA1(11), IIA2(1, 2, 15, 18)
Discus cronkhitei (Newcomb), IIB(2, 11, 15)
Punctum minutissimum (Lea), IIA1(11)
Deroceras laeve (Müller), IIA1(11), IIB(1, 2, 15)
Euconulus fulvus (Müller), IIB(2, 8, 11)
Nesovitrea electrina (Gould), IIB(2, 11, 15)
Hawaiia minuscula (Binney), IIB(1, 15)
Zonitoides arboreus (Say), IIB(1, 2, 8, 11, 15)
Stenotrema leai (Binney), IIB(2)

SYSTEMATIC DESCRIPTIONS

Dates of genera and species given in the center headings have not been personally verified except in the case of extinct species. Sources are Pilsbry (1940, 1946, 1948) for the land snails and Baker (1911, 1928, 1928a) for the fresh-water mollusks.

References are intended to include all records of mollusks from the faunas considered, as well as the minimum number of general references, which were selected to indicate current taxonomic treatment and summaries of other references and of distribution.

Diagnoses (and usually descriptions) are given for all the extinct species restricted to the Blancan age, and for most of the other extinct species as well.

Distribution is based on the most reliable source known. The planorbid distributions without source indication are based upon my own examination of specimens, chiefly those in the University of Michigan Museum of Zoology.

Ecology is largely from published data. Personal observations made in northern Nebraska are added for comparison and supplement.

Occurrences cited are restricted to the faunas considered here. Numerous late Pleistocene records, for example, are not included.

Also under "Occurrences" are the abbreviation of the name of the institution, catalog number, and number of specimens represented. This last number is not the number of fragments examined, but the minimum number of shells required to furnish the fragments. Abbreviations are as follows: ANSP, Academy of Natural Sciences of Philadelphia; CNHM, Chicago Natural History Museum; UIMNH, University of Illinois Museum of Natural History; UKMNH, University of Kansas Museum of Natural History; UMMZ, University of Michigan Museum of Zoology; USGS, United States Geological Survey; USNM, United States National Museum.

H. B. Herrington identified the Sphaeriidae and contributed notes on the specimens. The data in this paper are based on his notes and Herrington and Taylor (1958).

Taxonomic changes: summarized below are the new taxa proposed, and the disposition of species synonymized or relegated to different genera.

New:

Phreatomenetus n. subgen.; type *Promenetus umbilicatellus* (Cockerell)
Gastrocopta (s. s.) *franzenae* Taylor, n. sp.
(s. s.) *scaevoscala* Taylor, n. sp.
Polygyra rexroadensis Taylor, n. sp.

Changed in status:

Amnicola walkeri Pilsbry = *A. lustrica* Say
Carychium perexiguum Baker = *C. exiguum* (Say)
Lymnaea macella Leonard = *Stagnicola exilis* (Lea)
parexilis Leonard = *Stagnicola exilis* (Lea)
diminuta Leonard = *Stagnicola bulimoides techella* (Haldeman)
turritella Leonard = *Fossaria dalli* (Baker)
Gyraulus enaulus Leonard = *G. parvus* (Say)
Menetus kansasensis Baker transferred to *Promenetus*
Promenetus blancoensis Leonard = *P. umbilicatellus* (Cockerell)
Planorbis circumlineatus Shuttleworth assigned to *Promenetus*
santacruzensis (Germain) assigned to *Promenetus*
aeruginosus Morelet assigned to *Promenetus*
Vertigo (*Angustula*) *hibbardi* Baker transferred to *Vertigo* s. s.
Angustula Sterki, subgenus considered of minor rank and synonymized with *Vertigo* s. s.

Class PELECYPODA

Order PRIONODESMACEA

Family UNIONIDAE

Subfamily ANODONTINAE

Genus ANODONTA Lamarck, 1799

Subgenus PYGANODON Crosse and Fischer, 1894

?Anodonta (Pyganodon) grandis Say, 1829

Anodonta grandis Say. Frierson, 1927, Check list of North American naiades, p. 14.
Baker, 1928, Wisconsin Geol. Nat. History Survey Bull. 70, pt. 2, p. 152, pl. 62, fig. 5.
Anodonta gigantea Lea. Baker, 1928, Wisconsin Geol. Nat. History Survey Bull. 70, pt. 2, p. 161, pl. 62, fig. 4; pl. 65, fig. 3.

Remarks.—Fragments referred to this species were found as float in the West Fork of Deep Creek, secs. 11 and 14, T. 31 N., R. 23 W., Brown County, Nebr. They are probably from the same stratigraphic position as the other material collected on Deep Creek, but a more precise locality cannot be given. One fragment shows enough of the adductor and retractor muscle scars to indicate it probably represents *Anodonta*. Thickness of shell and geographic location make *A. grandis* the most reasonable specific allocation.

Material from Sand Draw locality 2 is indeterminate, and only presumptively referred to the same species.

Occurrence and material: Sand Draw local fauna. West Fork of Deep Creek, UMMZ 184321 (1); loc. 2, UMMZ 184167 (1).

Family QUADRULIDAE

Subfamily LAMPSILINAE

Genus LIGUMIA Swainson, 1840

?Ligumia subrostrata (Say), 1831

Lampsilis subrostrata (Say). Isely, 1925, Oklahoma Acad. Sci. Proc., v. 4, p. 108.
Lampsilis subrostrata Say. Frierson, 1927, Check list of North American naiades, p. 77.

Remarks.—Dr. Henry van der Schalie identified a fragmentary valve showing beak sculpture and worn pseudocardinal teeth as probably either *Ligumia subrostrata* (Say) or *Uniomerus tetralasmus* (Say), of which the former seems more likely.

Occurrence and material: Rexroad local fauna. Rexroad loc. 3, UMMZ 183025 (1/2).

Order TELEODESMACEA

Family SPHAERIIDAE

Genus SPHAERIUM Scopoli, 1777

Sphaerium partumeium (Say), 1822

Musculium partumeium (Say). Baker, 1928, Wisconsin Geol. Nat. History Survey Bull. 70, pt. 2, p. 354, pl. 99, fig. 24–26.
Sphaerium partumeium (Say). Herrington and Taylor, 1958, Michigan Univ. Mus. Zool. Occ. Papers 596, p. 7.
Musculium truncatum (Linsley). Baker, 1928, Wisconsin Geol. Nat. History Survey Bull. 70, pt. 2, p. 356, pl. 99, fig. 21–23.

Distribution.—"Most of the United States; less common in mountainous areas. Southern Canada from Saskatchewan to Quebec" (Herrington and Taylor, 1958, p. 8).

Ecology.—"Ponds and eddies in rivers where there is considerable vegetation and a soft bottom" (Herrington and Taylor, 1958, p. 8).

Remarks.—None of the shells from the Sand Draw local fauna is complete, but several are nearly so. They compare well in every feature with a series (Herrington collection S-658) of *S. partumeium* from Baton Rouge, La., except that the Baton Rouge specimens are somewhat larger—but they are also larger than the usual northern specimens. The shells from the

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Dixon local fauna are identified certainly, even though most are only fragments.

Occurrence and material: Sand Draw and Dixon local faunas. Sand Draw loc. 1, UMMZ 186369 (77/2). Dixon loc. 2, UMMZ 191501 (114/2), 191502 (17/2).

Sphaerium lacustre (Müller), 1774

form ryckholti (Normand), 1844

Musculium ryckholti (Normand). Baker, 1928, Wisconsin Geol. Nat. History Survey Bull. 70, pt. 2, p. 359, pl. 99, fig. 6–9.

Musculium jayense (Prime). Baker, 1928, Wisconsin Geol. Nat. History Survey Bull. 70, pt. 2, p. 353, pl. 99, fig. 27, 28.

Musculium rosaceum (Prime). Baker, 1928, Wisconsin Geol. Nat. History Survey Bull. 70, pt. 2, p. 359, pl. 99, fig. 19, 20.

Sphaerium lacustre (Müller) form *ryckholti* (Normand). Herrington and Taylor, 1958, Michigan Univ. Mus. Zool. Occ. Papers 596, p. 8.

Sphaerium sp. Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151 (Kingman County loc.).

Distribution.—Holarctic. In North America from the Southern United States to the Northwest Territories. This form of *lacustre* is also found in Europe and Brazil.

Ecology.—"It seems to have a preference for ponds where there is considerable vegetation and even bog ponds that have a bottom of muck, rotting wood, grasses, and the like" (Herrington and Taylor, 1958, p. 9).

Remarks.—Shells from the Dixon local fauna are near the form *ryckholti* in shape. They are a little heavier than usual but not more so than some Recent specimens. None are whole, but a number of fragments are large and a few nearly whole. In beaks and outline these seem to be *lacustre.*

The reference by Frye and Leonard is attributed to this species because *S. lacustre* is the commonest *Sphaerium* in the Dixon local fauna.

Occurrence and material: Dixon local fauna; Recent in northern Nebraska. Dixon loc. 1, UMMZ 186386 (31/2).

Sphaerium securis (Prime), 1851

Musculium securis (Prime). Baker, 1928, Wisconsin Geol. Nat. History Survey Bull. 70, pt. 2, p. 360, pl. 99, fig. 10–13.

Distribution.—"East of the Rocky Mountains, but apparently rare in the South and wanting in the Gulf States; common in the Northeast; South Carolina" (Baker, 1928a, p. 361).

Ecology.—In northern Nebraska it was found in a small permanent or nearly permanent pond in sandy bottom among dense vegetation in shallow water.

Occurrence: Recent in northern Nebraska.

Sphaerium striatinum (Lamarck), 1818

Sphaerium striatinum (Lamarck). Baker, 1928, Wisconsin Geol. Nat. History Survey Bull. 70, pt. 2, p. 334, pl. 98, fig. 1–5.

Herrington and Taylor, 1958, Michigan Univ. Mus. Zool. Occ. Papers 596, p. 9.

Distribution.—Almost all of North America, from Great Slave Lake, Northwest Territories, to Panama.

Ecology.—Perennial water bodies with some current action are suitable habitats. It lives in large lakes or small ones, in rivers or small streams, in a bottom of gravel, sand, or mud. Ponds, lagoons, and swamps are not favorable places, probably because there is insufficient current to oxygenate the water well.

Occurence and material: Saw Rock Canyon and Sand Draw local faunas. Saw Rock Canyon, UMMZ 186408 (1/2), an infant right valve. The shell is the size of an infant recently expelled from the parent. Sand Draw loc. 1, UMMZ 186368 (5/2). The only complete valve from this locality has a reversed hinge—all the hinge characters are those of the right valve, but at opposite ends. This valve perfectly matches some Recent ones of the heavy form in the Herrington collection in shape of shell, striae, and shape of hinge characters, but the cardinal is slightly more central. Sand Draw loc. 3, UMMZ 181125 (3/2). A fragment of the anterior end of a right valve has striae which seem too coarse for *S. sulcatum.* Fragments of two more valves are referred doubtfully to *S. striatinum.*

Sphaerium sulcatum (Lamarck), 1818

Sphaerium sulcatum (Lamarck). Herrington and Taylor, 1958, Michigan Univ. Mus. Zool. Occ. Papers 596, p. 9.

Sphaerium simile (Say). Baker, 1928, Wisconsin Geol. Nat. History Survey Bull. 70, pt. 2, p. 313, pl. 96, fig. 4–7.

Sphaerium simile planatum Sterki. Baker, 1928, Wisconsin Geol. Nat. Hist. Survey Bull. 70, pt. 2, p. 317, pl. 96, fig. 8–10; pl. 98, fig. 29–33.

Sphaerium crassum Sterki. Baker, 1928, Wisconsin Geol. Nat. Hist. Survey Bull. 70, pt. 2, p. 318, pl. 96, fig. 11–13.

Sphaerium lineatum Sterki. Baker, 1928, Wisconsin Geol. Nat. History Survey Bull. 70, pt. 2, p. 321, pl. 96, fig. 18–21.

Distribution.—"Northeastern North America from Quebec to Virginia, west to Iowa, Montana, and Alberta" (Herrington and Taylor, 1958, p. 10).

Ecology.—*S. sulcatum* has a preference for a soft bottom in fairly still waters, in eddies of a creek or river, along shore in lakes, and even in lakes filling up with marl. Herrington has found it associated with *Pisidium compressum* in all these habitats.

Occurrence and material: Sand Draw local fauna. Sand Draw loc. 1, UMMZ 186370 (3/2). All are good-sized adults, but somewhat broken. The striae are normal. One left valve has both ends complete but the cardinal area is broken out.

Sphaerium transversum (Say), 1829

Musculium transversum (Say). Baker, 1928, Wisconsin Geol. Nat. History Survey Bull. 70, pt. 2, p. 351, pl. 98, fig. 22–25 [not 22–28].

Sphaerium transversum (Say). Herrington and Taylor, 1958, Michigan Univ. Mus. Zool Occ. Papers 596, p. 8.

Distribution.—"North America east of the Rocky Mountains from Mexico to the Northwest Territories" (Herrington and Taylor, 1958, p. 8).

Ecology.—"In rivers, ponds and lakes, usually in soft mud, on the surface or buried at different depths" (Baker, 1928a, p. 352).

Remarks.—A large specimen from the Dixon local fauna seems to be *transversum.* A dwarf form of this species which occurs in the Sand Draw local fauna resembles certain living individuals that appear in unfavorable habitats.

Occurrence and material: Sand Draw and Dixon local faunas. Sand Draw loc. 3, UMMZ 186378 (43/2). Dixon loc. 1, UMMZ 186385 (10/2).

Sphaerium species

Sphaerium sp. Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151 (Meade County localities).

Sphaerium indet. Herrington and Taylor, 1958, Michigan Univ. Mus. Zool. Occ. Papers 596, p. 13.

Remarks.—Some specimens from several localities are unidentifiable specifically, because they are immature or too fragmentary. They may well represent the thinner-shelled species, *partumeium*, *lacustre*, and *transversum.*

University of Michigan collections contain no *Sphaerium* from the Rexroad or Bender local faunas. The material reported by Frye and Leonard from the SW¼ sec. 22, T. 33 S., R. 29 W., Meade County, Kans. probably came from Rexroad locality 3, for Bender locality 1 has yielded few aquatic forms.

Occurence and material: Saw Rock Canyon and Sand Draw local faunas; Rexroad local fauna (Frye and Leonard). Saw Rock Canyon, UMMZ 177514 (1), 177553 (6/2). Sand Draw loc. 2, UMMZ 184168 (1/2); loc. 3, UMMZ 181124 (2/2), 186379 (31/2); loc. 4, UMMZ 186373 (8/2); loc. 5, UMMZ 186374 (18/2), 186366 (263/2); loc. 7, UMMZ 186381 (1/2), 177225 (5/2).

Genus PISIDIUM Pfeiffer, 1821

Pisidium casertanum (Poli), 1791

Pisidium casertanum (Poli). Woodward, 1913, Catalogue of British species of *Pisidium*, p. 31, pl. 1, fig. 3–6; pl. 3, fig. 3; pl. 13–18.
Herrington, 1954, Nautilus, v. 67, p. 131.
Hibbard, 1954, Michigan Acad. Sci. Papers, v. 39, p. 342.
Herrington and Taylor, 1958, Michigan Univ. Mus. Zool. Occ. Papers 596, p. 14.

Pisidium sp. Baker, 1938, Nautilus, v. 51, p. 131.
Hibbard, 1941, Kansas Univ. Sci. Bull., v. 27, p. 95.
Frye and Hibbard, 1941, Kansas Geol. Survey Bull. 38, p. 408.
McGrew, 1944, Field Mus. Nat. Hist. Geol. Ser., v. 9, p. 36.
Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151 (Meade County localities).

Psidium sp. Hibbard, 1941, Kansas Acad. Sci. Trans., v. 44, p. 265.

Distribution.—"Almost cosmopolitan: Eurasia, New Zealand, and Australia; in the Western Hemisphere from Patagonia to Alaska" (Herrington and Taylor, 1958, p. 14).

Ecology.—The wide distribution of *Pisidium casertanum* reflects a corresponding adaptability, greater than any other American sphaeriid. It lives where any other species of *Pisidium* can live, except for deep water. The typical form of the species, with relatively heavy shells, lives in rivers or fairly large creeks. Thinner shells with smoother outline are found in ponds, swamps, lagoons, bog ponds, and similar quiet water bodies. *P. casertanum* is one of the few species of *Pisidium* which can tolerate seasonal desiccation, and sometimes it may be the only aquatic mollusk in a small, temporary stream or seepage.

Remarks.—Previous records of *Pisidium* sp. from the Rexroad local fauna are probably based on *P. casertanum*, for this is the only one in University of Michigan collections. The original specimens reported by Baker and McGrew from the Sand Draw local fauna have been verified as *P. casertanum.*

Occurence and material: Buis Ranch, Saw Rock Canyon, Red Corral, Rexroad, Sand Draw, and Dixon local faunas; Recent in northern Nebraska. Buis Ranch, UMMZ 181119 (1/2). Saw Rock Canyon, UMMZ 173587 (51/2), 195838 (1 + 1398/2). This series shows much variation in shape, just as one finds in Recent shells. Some of the shells are pitted, evidently by solution. Many are in fragments, but this seems to be the result of removal from the matrix. The specimens show no signs of being rolled, for the laterals and cardinals are unbroken. Red Corral, UMMZ 182992 (58/2). These shells suggest still water. They are like those found in small, slow-moving creeks that go dry for part of the year, or in lakes filling up with marl. Rexroad loc. 2, UMMZ 186388 (3/2); loc. 3, UMMZ 186387 (11/2). Sand Draw loc. 3, UMMZ 186377 (8/2). Mostly form *roperi.* Loc. 4, UMMZ 177311 (58/2). Form *roperi* Sterki. Much broken. Some have "rest periods," like capped beaks at more than one place. Loc. 5, UMMZ 186367 (32/2), 181134 (11/2). Mostly form *roperi* Sterki; the others are close. Most have strong "rest periods" or capped beaks. Loc. 6, CNHM PE3439 (2/2). Loc. 7, UMMZ 177226 (25/2). Mostly form *roperi* Sterki. Dixon loc. 1, UMMZ 186383 (11/2).

Pisidium compressum Prime, 1851

Pisidium compressum Prime. Baker, 1928, Wisconsin Geol. Nat. History Survey Bull. 70, pt. 2, p. 370, pl. 100, fig. 9–13.
Herrington, 1954, Nautilus, v. 67, p. 135.
Herrington and Taylor, 1958, Michigan Univ. Mus. Zool. Occ. Papers 596, p. 15.

Pisidium sp. Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151 (Kingman County loc.).

Distribution.—"North America, from Mexico to Great Slave Lake, Northwest Territories" (Herrington and Taylor, 1958, p. 16).

Ecology.—This species inhabits only perennial water bodies with some current action, such as lakes, rivers and creeks; it is never found in ponds, swamps, lagoons, or bogs.

Remarks.—The reference by Frye and Leonard is attributed to this species because *P. compressum* is the most abundant *Pisidium* in the Dixon local fauna.

Occurrence and material: Sand Draw and Dixon local faunas. Sand Draw loc. 1, UMMZ 186371 (579/2). These clearly have the hinge charcters of *compressum.* The beaks are moderately narrow. A few give hints of ridges. The striation varies considerably, but suggests *compressum.* The shells are rather light in heft and, on the whole, give the impression of rather still water, not where there is swift running water with a sandy gravel or where there is heavy wave action. Loc. 3, UMMZ 177328 (1172/2). Mostly thin, many fractured, perhaps in recovering. All have narrow beaks but only the slightest number show even a hint of a ridge. These show considerable variation in outline. Loc. 6, UMMZ 186372 (1/2), 177422 (3/2). Dixon loc. 1, UMMZ 186382 (240/2). Good specimens. Striae as coarse as usual; beaks narrow, some with faint hints of ridges. A little longer than the usual form found in creeks; could have come from a creek or small lake.

Pisidium nitidum Jenyns, 1832

Pisidium nitidum Jenyns. Woodward, 1913, Catalogue of British species of *Pisidium*, p. 44, pl. 1, fig. 9; pl. 3, fig. 6; pl. 19.
Herrington, 1954, Nautilus, v. 67, p. 132.
Herrington and Taylor, 1958, Michigan Univ. Mus. Zool. Occ. Papers 596, p. 15.

Distribution.—Holarctic. Eurasia and North Africa; in North America from Hudson Bay to Mexico, except for the southeastern United States.

Ecology.—Found only in perennial water bodies, such as lakes, ponds, rivers, and large creeks.

Remarks.—The fossil specimens are of the form commonly found in lakes that are drying up or have dried up.

Occurrence and material: Sand Draw and Dixon local faunas. Sand Draw loc. 3, UMMZ 186375 (347/2), 186376 (7/2). The hinge of these varies from moderately heavy to light. Seven valves (UMMZ 186376) are of the form *pauperculum* Sterki. One of these latter has a steep posterior slope like a *pauperculum* approaching the form *contortum.* Loc. 7, UMMZ 186380 (1/2). Fragmentary. Dixon loc. 1, UMMZ 186384 (8/2).

Class GASTROPODA

Subclass PROSOBRANCHIA

Order MESOGASTROPODA

Family VALVATIDAE

Genus VALVATA Müller, 1774

Valvata tricarinata (Say), 1817

Valvata tricarinata (Say). Baker, 1928, Wisconsin Geol Nat. History Survey Bull. 70, pt. 1, p. 11, pl. 1, fig. 1–3.
Taylor, 1954, Michigan Univ. Mus. Zool. Occ. Papers 557, p. 12.
La Rocque, 1956, Nautilus, v. 70, p. 13.
Valvata tricarinata perconfusa Walker. Baker, 1928, Wisconsin Geol. Nat. History Survey Bull. 70, pt. 1, p. 16, pl. 1, fig. 4.
Valvata tricarinata unicarinata DeKay. Baker, 1928, Wisconsin Geol. Nat. History Survey Bull. 70, pt. 1, p. 16, pl. 1, fig. 5.
Valvata tricarinata mediocarinata Baker, 1928, Wisconsin Geol. Nat. History Survey Bull. 70, pt. 1, p. 17, pl. 1, fig. 7.
Valvata tricarinata basalis Vanatta. Baker, 1928, Wisconsin Geol. Nat. History Survey Bull. 70, pt. 1, p. 17, pl. 1, fig. 8, 9.
Valvata tricarinata infracarinata Vanatta. Baker, 1928, Wisconsin Geol. Nat. History Survey Bull. 70, pt. 1, p. 18.
Valvata tricarinata simplex Gould. Baker, 1928, Wisconsin Geol. Nat. History Survey Bull. 70, pt. 1, p. 18, pl. 1, fig. 10, 14.

Distribution.—"Eastern United States west to Iowa; Great Slave Lake south to Virginia and the Ohio River" (Baker, 1928, p. 14); an isolated spring occurrence in Cherry County, Nebr.

Ecology.—A species found only in permanent lakes and rivers. In northern Nebraska this species was found in a spring-fed pond of temperature 15°C. The snails were crawling on aquatic plants, largely *Ceratophyllum*, *Elodea*, and algae, near the edge of the pond.

Remarks.—*Valvata tricarinata* was found considerably south of its previously known range in a spring-fed pond at the old fort reservoir in the Fort Niobrara National Wildlife Refuge, 5 miles east of Valentine, Cherry County, Nebr. Its existence at this locality is considered possible because of the insulating effect of the cool spring water. This northern species is probably able to live here because the pond is warmed little if at all during the summer hot spells. Other permanent ponds in Cherry County, apparently similar except that they lack spring sources, were examined without finding this species.

Occurrence and material: Sand Draw and Dixon local faunas; Recent in northern Nebraska. Sand Draw loc. 2, UMMZ 184170 (65). Carinae 101, 64 specimens; carinae 001, 1 specimen. Loc. 3, UMMZ 177329 (2500). Carinae 101, about 2500 specimens; carinae 100, 12 specimens; carinae 001, 20 specimens; carinae 000, 16 specimens. Dixon loc. 2, UMMZ

191503 (33). Carinae 111. The 17 Recent specimens are tricarinate, 111.

Valvata lewisi Currier, 1868

Valvata lewisi Currier. Baker, 1928, Wisconsin Geol. Nat. History Survey Bull. 70, pt. 1, p. 26, pl. 1, fig. 28–30.
Valvata lewisi helicoidea Dall. Baker, 1938, Nautilus, v. 51, p. 130.
McGrew, 1944, Field Nat. Mus. Hist. Geol. Ser., v. 9, p. 36.

Distribution.—"Northern part of the United States from the Atlantic to the Pacific oceans, northward, in British America, to the upper Mackenzie River. Its southward range is not fully known" (Baker, 1928, p 28).

Ecology.—"* * * a lake species largely" (Baker, 1928, p. 28).

Remarks.—A higher spire in the former is the principal distinction between *V. lewisi* and *V. lewisi helicoidea.* Variation of this character in the lots examined is such that separation of the two forms does not appear practicable in this case.

Occurrence and material: Sand Draw local fauna. Sand Draw loc. 5, CNHM PE3428 (125), UIMNH P6781 (26); loc. 6, UMMZ 177423 (400), 181208 (150).

Family VIVIPARIDAE

Genus and species uncertain

Remarks.—Two small individuals represent this family, but are inadequate for closer identification.

Occurrence and material: Dixon local fauna. Dixon loc. 1, UMMZ 182193 (1); loc. 2, UMMZ 191504 (1).

Family HYDROBIIDAE

Classification of this family is still in a primitive state, and nomenclature is in flux. Shells of this group provide less information than in perhaps any other family of freshwater snails. Snails with markedly different opercula, radulae, and reproductive apparatus may have similar shells; rather different shells may contain animals of similar anatomy. Fossil shells of the Hydrobiidae are thus often very difficult to classify with any conviction of certainty.

For many years two family names have been used: Europeans have called the group Hydrobiidae, while Americans have preferred the term Amnicolidae. "Hydrobiae" Troschel, 1857 (1856–1893, v. 1, p. 106), has priority over Amnicolidae Tryon (1862, p. 452), and hence the name Hydrobiidae is preferable.

The subfamily divisions listed below are slightly modified from Morrison (1949):

Hydrobiinae: verge with one functional duct (vas deferens).

Amnicolinae: verge with two functional ducts (vas deferens, and accessory duct of secondary lobe); operculum corneous, paucispiral.

Buliminae: verge as in Amnicolinae; operculum calcareous, concentric with subspiral nucleus.

Emmericiinae: verge with three functional ducts (vas deferens, and an accessory duct in each of two secondary lobes).

The second subfamily was called Bythinellinae by Morrison (1949), but is here changed to Amnicolinae. The term Amnicolidae is the second oldest group name within the Hydrobiidae, and deserves retention in some form. Its application, however, involves the complicated question of identification of the genotype of *Amnicola* (Morrison 1947, H. B. Baker 1947), *Paludina lustrica* Say, 1821.

The original description is as follows (Say, 1821, p. 175):

P. *lustrica. Shell conic, whirls slightly wrinkled, convex; suture profoundly indented; aperture oval nearly orbicular; labrum with the superior edge not appressed to the preceding whirl, but simply touching it; umbilicus rather large, rounded. Length less than 1/10 of an inch. Cabinet of the Academy. The smallest species I have seen. The aperture somewhat resembles that of a *Valvata*, to which genus it may probably be referrible. Mr. Jessup obtained two specimens, on the shore of Cayuga Lake.

Distinctive features mentioned in this description are conical shape, very deep suture, a nearly circular aperture which simply touches the preceding whorl and is not modified in outline by it, very small size. Only two species of the general region (cf. Letson 1905) approach this character combination: *Amnicola walkeri* Pilsbry, 1898, and *Lyogyrus granum* (Say), 1822. But Say contrasted *L. granum* with *Paludina lustrica* in his description of the former, indicating that he thought of the two as distinct.

Berry (1943, p. 26) described the shell of *Amnicola walkeri* thus:

About 2.5 mm high, 2.2 mm wide, thin, broadly conic in outline. Four whorls increasing regularly in size. Apex obtuse, elevated, whorls shouldered, convex; sutures very deep. Aperture almost circular (1.04 mm wide; 1.04 mm high). Peristome continuous, adnate to the preceding whorl for only a short distance. Umbilicus rather wide, deep. Periostracum light tan, lines of growth crowded but distinct, often concealed with a deposit from its environment.

The descriptions by Say and Berry are so strikingly similar that it seems highly probable that they refer to the same species.

Accepting *Paludina lustrica* Say as being the species generally known heretofore as *Amnicola walkeri*, we find that fortunately there are no major changes in the group concept. Berry (1943) showed the close relationship between *A. walkeri*, now *A. lustrica* (Say), and *A. limosa* (Say), usually but erroneously considered the type species.

The classification and generic synonymy of groups treated by Morrison (1947) implied by synonymization of *Amnicola walkeri* with *Paludina lustrica* and by acceptance of Morrison's (1949) outline of the Hydrobiidae is as follows:

Family Hydrobiidae
- Subfamily Hydrobiinae
  - Genus *Marstonia* F. C. Baker, 1926. Type (by original designation): *Amnicola lustrica* Pilsbry, 1890 [not of Say, 1821]=*Amnicola lacustris* Morrison, 1947.
- Subfamily Amnicolinae
  - Genus *Amnicola* Haldeman, 1840. Type (by original designation): *Paludina lustrica* Say, 1821, = *Amnicola walkeri* Pilsbry, 1890.
    Subjective synonyms: *Euamnicola* Crosse and Fischer, 1891.
    Type: *Paludina lustrica* Say; the statement "(ou *Amnicola* sensu stricto)" fixed the type as that of *Amnicola*, no matter whether or not Crosse and Fischer correctly listed the type of *Amnicola*.
    Marstoniopsis Altena, 1936. Type (by original designation): *Hydrobia steinii* v. Martens, 1858.

Subfamily HYDROBIINAE

Genus MARSTONIA Baker, 1926

Marstonia crybetes (Leonard), 1952

Plate 2, figures 1–3, 7, 8

Amnicola crybetes Leonard, 1952, Nautilus, v. 66, p. 38, pl. 5, fig. A.
Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151, pl. 14, fig. h.

Types.—Holotype UKMNH 3805, Saw Rock Canyon local fauna. Paratypes UKMNH 3806.

Diagnosis.—A *Marstonia* shorter and wider than other species of the genus, with ovate-pyriform aperture and moderately impressed suture.

Description. — Shell small, ovate, conoidal, with acute spire and apex. Whorls 4 to 4½, convex, gently shouldered and slightly flattened peripherally, expanding fairly rapidly; body whorl about three-fourths of total shell length. Embryonic shell of about one whorl, not depressed to the level of the postembryonic whorls. Suture strongly impressed, slightly below periphery of whorls. Aperture simple, entire, ovate-pyriform; peristome appressed to preceding whorl or simply adnate, broadly rounded below, narrowly rounded to obtusely angular at junction of outer and parietal lips. Umbilicus small but distinct, about one-ninth of shell diameter. Sculpture consists only of very fine growth lines on the postembryonic shell.

Measurements.—A large series of specimens (UMMZ 177554) from the Saw Rock Canyon site was sampled to study variation in several size groups selected on number of whorls. Measurements are in millimeters.

	Number of whorls			
	3¾	4	4¼	4½
Number of specimens	25	44	36	25
Length:				
Mean	2.35 ±.026	2.63 ±.033	2.95 ±.027	3.23 ±.028
Standard deviation	.13 ±.018	.22 ±.023	.16 ±.019	.14 ±.020
Width:				
Mean	1.80 ±.020	1.96 ±.027	2.16 ±.027	2.30 ±.024
Standard deviation	.10 ±.014	.18 ±.019	.16 ±.019	.12 ±.017
Length aperture:				
Mean	1.20 ±.018	1.33 ±.018	1.44 ±.017	1.51 ±.014
Standard deviation	.09 ±.013	.12 ±.013	.10 ±.012	.07 ±.010
Width aperture:				
Mean	.95 ±.012	1.08 ±.017	1.15 ±.013	1.24 ±.018
Standard deviation	.06 ±.008	.11 ±.012	.08 ±.0094	.09 ±.013
Width to length ratio:				
Mean	.76 ±.0058	.74 ±.0039	.73 ±.0037	.71 ±.0042
Standard deviation	.029±.0041	.026±.0028	.022±.0026	.021±.0030
Length aperture to length ratio:				
Mean	.52 ±.0054	.51 ±.0041	.49 ±.0032	.47 ±.0028
Standard deviation	.027±.0038	.027±.0029	.019±.0022	.014±.0020

Variation.—The size range of adults is uncertain because adult shells cannot be distinguished surely from juveniles on any character other than size. Some variation is, however, evident from the fact that shells of 4¾ whorls are rare, and those of 4½ and 4¼ whorls progressively more common. Variation in shape, the most conspicuous variant, is shown under Measurements. The last part of the body whorl varies in degree of appression, so that the peristome may be appressed or adnate; rarely the last part of the body whorl is disjunct.

Remarks.—*Amnicola crybetes* Leonard is referred to the genus *Marstonia* because of its similarity to *M. decepta* (Baker), the genotype. With the latter species it shares an acute spire, undepressed nuclear whorl, narrow umbilicus, and ovate-pyriform aperture. *Cincinnatia* [as exemplified by *C. integra* (Say) and *C. peracuta* (Pilsbry and Walker)] has a shell of similar shape but larger, with a larger nuclear whorl. *Amnicola lustrica* (Say), to which Leonard compared *M. crybetes* in describing the latter, has a slightly smaller shell with more deeply incised sutures, a nearly round aperture, and more conspicuous umbilicus.

Marstonia decepta differs from *M. crybetes* by its larger size and proportionately narrower shape; otherwise shells of the two are similar.

The material recorded by Frye and Leonard (1952, p. 151) from the SW¼ sec. 22, T. 33 S., R. 29 W., Meade County, almost certainly came from Rexroad locality 3 rather than Bender locality 1. Habitat inferences from Bender locality 1 species suggest only temporary bodies of water. Rexroad locality 3 had the permanent water which *Marstonia crybetes* required.

Occurrence and material: Saw Rock Canyon and Rexroad local faunas; Dixon local fauna (Frye and Leonard). Saw Rock Canyon, UMMZ 173593 (33), 177554 (500), USGS 19089-11 (100); Rexroad loc. 1, UMMZ 183051 (1); loc. 4b, UMMZ 177597 (2), 181046 (2).

Marstonia decepta (Baker), 1928

Plate 2, figure 9

Amnicola lustrica decepta Baker, 1928, Wisconsin Geol. Nat. History Survey Bull. 70, pt. 1, p. 108, text fig. 45.
Amnicola lustrica Pilsbry. Baker, 1928, Wisconsin Geol. Nat. History Survey Bull. 70, pt. 1, p. 104, pl. 6, fig. 16, 17, 26, 27; text fig. 45.
Amnicola (Marstonia) lustrica Pilsbry. Berry, 1943, Michigan Univ. Mus. Zool. Misc. Publ. 57, p. 29, pl. 1, fig. 4–6; pl. 3, fig. 3; pl. 5, fig. 6; pl. 7, fig. 4.
Amnicola lacustris Morrison, 1947, Nautilus, v. 60, p. 86.

Distribution.—New York west to Minnesota and Iowa; north-south range uncertain (F. C. Baker, 1928, p. 106–107; USNM colln.).

Remarks.—Two specimens associated with abundant *M. crybetes* differ from that species by their narrower form and smaller aperture. Their measurements in mm: length 2.8, 2.7; width 1.8, 1.7; length aperture 1.1, 1.1; width aperture 1.0, 0.9; width/length ratio 0.66, 0.64; length aperture to length ratio 0.41, 0.42; both have 4½ whorls. Comparison of these measurements with those given under *M. crybetes* shows that the two narrow specimens fall more than three standard deviations from the mean of the characters width, length of aperture, and the length of aperture to length ratio, and close to this distance for other characters. It is therefore most unlikely that these two shells are only extreme variants of *Marstonia crybetes*. They agree well with U. S. National Museum material of *M. decepta*, except for being slightly smaller, and are referred to that species.

The species nomenclature is involved. Morrison (1947) proposed *Amnicola lacustris* as a new name for the preoccupied *A. lustrica* Pilsbry, [not Say]. In 1928, however, F. C. Baker had added two varietal names to the species: *A. lustrica decepta* and *A. lustrica perlustrica*. Both of these have priority over *A. lacustris* Morrison, and bar that name from use for the species as a whole (cf. Bull. Zool. Nomenclature, v. 4, p. 240, concl. 2, 1950). The name *decepta* is here applied to the species known as *A. lustrica* Pilsbry; *lacustris* Morrison and *perlustrica* Baker are available for the ecological variants distinguished by Baker.

Occurrence and material: Saw Rock Canyon local fauna, UMMZ 186155 (2).

Genus and species uncertain

Remarks.—Two fragmentary specimens represent an amnicolid with a high, narrow spire, distinct from *Marstonia crybetes*. It may be *Pyrgophorus* or *Fontigens*.

Occurrence and material: Dixon local fauna. Dixon loc. 1, UMMZ 182194 (2).

Subclass PULMONATA

Order BASOMMATOPHORA

Family CARYCHIIDAE

Genus CARYCHIUM Müller, 1774

Carychium exiguum (Say), 1822

Carychium exiguum (Say). Pilsbry, 1948, Acad. Nat. Sci. Philadelphia Mon. 3, v. 2, pt. 2, p. 1052, fig. 561a, b, 562.
Harry, 1952, Nautilus, v. 66, p. 5.
Carychium perexiguum Baker, 1938, Nautilus, v. 51, p. 128.
Smith, 1940, Kansas Geol. Survey Bull. 34, p. 98.
Frye and Hibbard, 1941, Kansas Geol. Survey Bull. 38, 151, pl. 14, fig. j.
Leonard, 1957, Illinois Geol. Survey Report of Investigations 201, p. 10, pl. 1, fig. 1.
Carychium perexiguum F. C. Baker. Hibbard, 1941, Kansas Univ. Sci. Bull., v. 27, p. 95.
Hibbard, 1941, Kansas Acad. Sci. Trans., v. 44, p. 265.
Frye and Hibbard, 1941, Kansas Geol. Survey Bull. 38, p. 408.

Distribution.—"Newfoundland to Colorado, south to Mobile Bay, Alabama, and near Deming, southwestern New Mexico" (Pilsbry, 1948, p. 1052.)

Ecology.—In northern Nebraska this species was found among wet leaves in seepage areas and beside a spring-fed brook.

Remarks.—Examination of the type series (UIMNH P6776, P6777) and of a series of topotypes (UMMZ 183026) shows that *C. perexiguum* is a synonym of *C. exiguum*. Baker thought it distinguished by "the shorter shell, heavier lip, and the upward bending columellar lamella." The series of topotypes, as well as the original measurements, shows a size range within that given by Pilsbry (1948, p. 1054) for *C. exiguum*. The thickening of the lip in the topotype series appears no different from that in *C. exiguum*. Only two of the types were dissected by Baker, and only one of these shows the principal columellar lamella adequately. The upward bend of this lamella referred to in the original description is a minor flare on the ventral side of the lamella within the body whorl. This feature is certainly well within the range of variation of *C. exiguum* as figured by Pilsbry (1948).

Occurrence and material: Rexroad local fauna; Dixon local fauna (Frye and Leonard); Recent in northern Nebraska. Rexroad loc. 3, UMMZ 183026 (63), UIMNH P6776 (4), P6777 (3).

Carychium sp.

Carychium perexiguum F. C. Baker. Taylor, 1954, Michigan Univ. Mus. Zool. Occ. Papers 557, p. 14 [not of Baker].

Remarks.—The single Sand Draw specimen is surely not *C. perexiguum* (=*C. exiguum*), and may be new. It is distinguished by the upper columellar fold, which is bent 90° toward the outer lip, ascends the parietal lip, and is strongly thickened. The fold thus appears as a large, transverse lamella protruding conspicuously into the aperture. Additional material is needed to determine the significance of this specimen.

Occurrence and material: Sand Draw local fauna. Sand Draw loc. 3, UMMZ 181126 (1).

Family LYMNAEIDAE

Genus STAGNICOLA Jeffreys, 1830

Subgenus STAGNICOLA s. s.

Stagnicola (s. s.) exilis (Lea), 1837

Galba exilis (Lea). Baker, 1911, Chicago Acad. Sci. Spec. Pub. 3, p. 343, pl. 35, fig. 4; pl. 36, fig. 21–22; pl. 37, fig. 1–11.

Stagnicola exilis (Lea). Baker, 1928, Wisconsin Geol. Nat. History Survey Bull. 70, pt. 1, p. 226, pl. 14, fig. 7–11; pl. 17, fig. 16.

Stagnicola reflexa (Say). Hibbard, 1941, Kansas Univ. Sci. Bull., v. 27, p. 95 [not of Say].

Hibbard, 1941, Kansas Acad. Sci. Trans., v. 44, p. 265 [not of Say].

Frye and Hibbard, 1941, Kansas Geol. Survey Bull. 38, p. 408 [not of Say].

Lymnaea macella Leonard, 1952, Nautilus, v. 66, p. 40, pl. 5, fig. J.

Lymnaea macella Leonard. Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151 [in part: Meade County localities], pl. 14, fig. q.

Lymnaea parexilis Leonard, 1952, Nautilus, v. 66, p. 41, pl. 5, fig. K.

Lymnaea parexilis Leonard. Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151 [in part: Meade County localities], pl. 14, fig. x.

Lymnaea palustris (Müller). Taylor, 1954, Michigan Univ. Mus. Zool. Occ. Papers 557, p. 3 [in part: Rexroad local fauna. Not of Müller].

Distribution.—"Ohio to Kansas, northward to northern Minnesota and northern Michigan" (Baker, 1928, p. 227).

Ecology.—"*Exilis* is an inhabitant of sloughs, ponds, and streams which dry up more or less during a portion of the year" (Baker, 1928, p. 227).

Remarks.—*Lymnaea macella* Leonard and *L. parexilis* Leonard are obviously young and adult of the same species. This is readily demonstrable by breaking the larger *L. parexilis* into a smaller shell, which is then *L. macella.* The differentiae given for *L. macella* were the smaller size, heavier varix, and larger nuclear whorl. All are invalid. Varix and nuclear whorl are not different in the specimens examined personally; if it was meant that they are relatively different, the characters are a function of size. Large series from the Rexroad local fauna clearly show the intergradation of the two forms. Leonard may have reached a similar conclusion, unless a mislabelled illustration gives an erroneous implication. Plate 6, figure f (Frye, Leonard, and Swineford, 1956) is captioned *Lymnaea macella* Leonard; but this photograph is evidently the same illustration as those published by Leonard (1952a) and Frye and Leonard (1952) as *Lymnaea parexilis.*

The Pliocene populations from the Rexroad formation, distinguished by Leonard as distinct species, are referred to *Stagnicola exilis* on the basis of large University of Michigan series and of published information. The few specimens from Rexroad locality 3, the type locality of *Lymnaea macella* and *L. parexilis*, are inadequate to show the range of variation. Series from Rexroad locality 4c, from which Frye and Leonard (1952) recorded *L. parexilis*, agree well with *Stagnicola exilis* as described and figured by Baker (1911, 1928).

According to Leonard (1952, p. 42) "The shell of *Lymnaea parexilis* is similar in general form to that of *L. exilis*, but is much smaller with a relatively more elongate aperture, and more intricate sculpture." The only significant feature of these three is the relatively longer aperture. Recent *Stagnicola exilis*, and the University of Michigan fossil series examined, have a slightly smaller aperture than *Lymnaea parexilis* as figured and described by Leonard (1952a). This character is probably not of specific value; at any rate at least some occurrences of *L. parexilis* represent *Stagnicola exilis.*

Occurrence and material: Rexroad local fauna. Rexroad loc. 1, UMMZ 183053 (100); loc. 3, UMMZ 183027 (3); loc. 4b, UMMZ 177599 (150), 181048 (125).

Stagnicola (s. s.) palustris (Müller), 1774

Galba palustris (Müller). Baker, 1911, Chicago Acad. Sci. Spec. Pub. 3, p. 298, pl. 26, fig. 17–37, pl. 33, fig. 1–25; pl. 34, fig. 20.

Distribution.—"Circumboreal. Northern Asia and Europe. North America from the Atlantic to the

Pacific Ocean, and from Alaska south to New Mexico" (Baker, 1911, p. 307).

Ecology.—In northern Nebraska it was found abundant in drainage ditches and ponds, temporary and perennial water bodies.

Occurrence: Recent in northern Nebraska.

Stagnicola (s. s.) reflexa (Say), 1821

Galba reflexa (Say). Baker, 1911, Chicago Acad. Sci. Spec. Pub. 3, p. 332, pl. 30, fig. 30, 31; pl. 35, fig. 3, 5–22, pl. 36, fig. 1–11; pl. 18, fig. 10.

Stagnicola reflexa (Say). Baker, 1928, Wisconsin Geol. Nat. Hist. Survey Bull. 70, pt. 1, p. 221, pl. 14, fig. 1–6; pl. 17, fig. 15.

Lymnaea macella Leonard. Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151, in part [Kingman County locality. Not of Leonard].

Lymnaea parexilis Leonard. Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151, in part [Kingman County locality. Not of Leonard].

Distribution.—"Eastern Quebec west to Nebraska, Manitoba south to southern Illinois and southern Kansas" (Baker, 1928, p. 224).

Ecology.—"The typical habitat of *reflexa* in northern Illinois and Wisconsin is in small pools or ponds which may become more or less dry in summer. All of the Wisconsin habitats have been in swales in woods or fields, none have been found in large streams or lakes" (Baker, 1928, p. 224).

Remarks.—Large series from the Dixon local fauna show that the *Stagnicola* has the more convex whorls and impressed sutures of *S. reflexa*, rather than *S. exilis* which was reported by Frye and Leonard.

Occurrence and material: Dixon local fauna. Dixon loc. 1, UMMZ 182197 (1500); loc. 2, UMMZ 191505 (250).

Stagnicola (s. s.) cf. S. reflexa (Say), 1821

Stagnicola cf. *reflexa* (Say). Baker, 1938, Nautilus, v. 51, p. 130.

Stagnicola sp. Baker, 1938, Nautilus, v. 51, p. 131.

Fossaria dalli grandis F. C. Baker. Baker, 1938, Nautilus, v. 51, p. 131 [in part. Not of Baker].

Stagnicola cf. *reflexa*. McGrew, 1944, Field Mus. Nat. Hist. Geol. Ser. v. 9, p. 36.

Stagnicola sp. McGrew, 1944, Field Mus. Nat. Hist. Geol. Ser., v. 9, p. 36.

Fossaria dalli grandis. McGrew, 1944, Field Mus. Nat. Hist. Geol. Ser., v. 9, p. 36 [in part].

Remarks.—Although *Stagnicola* is abundant in Sand Draw local fauna collections, almost all shells are immature or fragmentary. A few halfgrown shells from various localities suggest *S. reflexa*, but the identification is uncertain and there may even be more than one species represented.

Baker (1938) identified five juvenile specimens from the Sand Draw local fauna as *Fossaria dalli grandis*. Four (UIMNH P6796, CNHM PE3442) are *Stagnicola* cf. *S. reflexa*, the other (CNHM PE3443) *Fossaria dalli*.

Occurrence and material: Sand Draw local fauna. Sand Draw loc. 1, UMMZ 181238 (150); loc. 2, UMMZ 184172 (28); loc. 3, UMMZ 177330 (700); loc. 4, UMMZ 177313 (80); loc. 5, CNHM PE3429 (18), PE3430 (19), UIMNH P6783 (1), P6784 (3), P6782 (14), UMMZ 181136 (2000), 181227 (6500); loc. 6, CNHM PE3441 (6), PE3442 (1), UIMNH P6795 (4), P6796 (3), UMMZ 177426 (150), 181210 (1000); loc. 7, UMMZ 177227 (175).

Stagnicola (s. s.) sp.

Remarks.—Immature and fragmentary shells from several localities represent a species of the *Stagnicola palustris* group, such as *S. exilis* or *S. reflexa*, but are inadequate for precise identification.

Occurence and material: Saw Rock Canyon, Bender, and Sanders local faunas. Saw Rock Canyon, UMMZ 183655 (3); Bender loc. 1a, UMMZ 184119 (1); loc. 2, UMMZ 184149 (14); Sanders loc. 1, UMMZ 182146 (5); loc. 2, UMMZ 184161 (2); loc. 3, UMMZ 182176 (4).

Subgenus HINKLEYIA Baker, 1928

Stagnicola (Hinkleyia) caperata (Say), 1829

Stagnicola caperata (Say). Baker, 1928, Wisconsin Geol. Nat. History Survey Bull. 70, pt. 1, p. 260, pl. 18, fig. 43–47. Baker, 1938, Nautilus, v. 51, p. 130.

Stagnicola caperata. McGrew, 1944, Field Mus. Nat. Hist. Geol. Ser., v. 9, p. 36.

Lymnaea caperata Say. Hibbard, 1954, Michigan Acad. Sci. Papers, v. 39, p. 342.

?*Lymnaea diminuta* Leonard. Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151 [in part: Kingman County locality].

Distribution.—"From Quebec and Massachusetts west to California; Yukon Territory and James Bay south to Maryland, Indiana, Colorado and California" (Baker, 1928, p. 263).

Ecology.—"In the Mississippi Valley this species seems to almost invariably occupy intermittent streams or small pools, ponds and ditches which dry up in the summer. In Illinois it is usually found in association with *Aplexa hypnorum* and *Sphaerium occidentale*, either in small streams, pools or sloughs, or in spring pools in the woods which become completely dry in late spring and summer *** In these dry ponds living specimens may frequently be found by digging into the mud, leaves and other debris. In Wisconsin, *caperata* has been found almost invariably in small woodland pools which become dry in summer and fall, or in small streams which become wholly or partially dry" (Baker, 1928, p. 263). In northern Nebraska, *S. caperata* was found in similar, temporary bodies of water, such as irrigation ditches, and also in the more perennial ponds of the Sand Hills. It was commonly associated with *Stagnicola palustris*, *Promenetus umbilicatellus*, and *Aplexa hypnorum*.

Remarks.—The habitat of this species is one apparently available quite widely in the southern Plains region. It has never been recorded alive as far south as Kansas, however, and its usual common occurrence elsewhere and distinctive shape argue that its absence is reliable. The most reasonable explanation for the northern restriction of this species is that the hot summers to the south bar its southward dispersal.

Frye and Leonard (1952) reported *Lymnaea diminuta* (=*Stagnicola bulimoides techella*), but not *S. caperata*, from the Dixon local fauna. Because the two species are somewhat similar, and because University of Michigan collections contain many *S. caperata* but no *S. bulimoides techella*, their reference may well be based on *S. caperata*.

Hibbard's (1954) report of this species in the Rexroad local fauna is based upon the Bender local fauna specimens. None of the Rexroad local fauna localities studied carefully have yielded *S. caperata*, but the species occurs at at least one other site represented in University of Michigan collections.

Occurrence and material: Buis Ranch, Bender, Sand Draw, Dixon, and Sanders local faunas; Recent in northern Nebraska. Buis Ranch, UMMZ 181113 (1); Bender loc. 1, UMMZ 177504 (4); loc. 1a, UMMZ 184146 (17); loc. 1c, UMMZ 183011 (1); loc. 2, UMMZ 184148 (100); Sand Draw loc. 2, UMMZ 184171 (37); loc. 3, UMMZ 181127 (30); loc. 4, UMMZ 177312 (12); loc. 5, CNHM PE3431 (50), UIMNH P6785 (18), UMMZ 181135 (75), 181226 (450); loc. 6, UMMZ 177424 (150), 181209 (250); loc. 7, UMMZ 177228 (100); Dixon loc. 1, UMMZ 182-195 (24); loc. 2, UMMZ 191506 (41); Sanders loc. 1, UMMZ 182226 (150); loc. 2, UMMZ 184159 (10); loc. 3, UMMZ 182174 (43).

Subgenus NASONIA Baker, 1928

Stagnicola (Nasonia) bulimoides techella (Haldeman), 1867

Galba bulimoides techella (Haldeman). Baker, 1911, Chicago Acad. Sci. Spec. Pub. 3, p. 214, pl. 27, fig. 30–35; pl. 28, fig. 1–3, 8.

Lymnaea diminuta Leonard, 1952, Nautilus, v. 66, p. 39, pl. 5, fig. B.

Lymnaea diminuta Leonard. Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151 [in part: Meade County localities], pl. 14, fig. s.

Distribution.—Southwestern and south-central United States to central Mexico; from southern California through Utah, Colorado, southernmost Nebraska and Kansas to Missouri and Alabama; south to San Luis Potosi and Oaxaca.

Ecology.—In northeastern Kansas "*Lymnaea bulimoides techella* is locally abundant in roadside ditches * * * throughout the broad terraces of the lower Wakarusa valley. It may be found in ephemeral pools where it appears in large numbers for a few weeks in the early spring. Many of the adults die after the egg laying period and few adults are seen through the hot summer months; immature individuals presumably remain alive, buried in the mud" (Franzen and Leonard, 1943, p. 405).

Remarks.—*Lymnaea diminuta* Leonard is a synonym of *Stagnicola bulimoides techella*. It was compared by Leonard to *F. humilis* and others of the genus *Fossaria*, but its larger nuclear whorl, simple columella, and wide inner lip indicate that it belongs to the subgenus *Nasonia*. *L. diminuta* agrees with *S. bulimoides techella* in having the significant characters of an acutely conic spire, obese body whorl, and broadly reflected inner lip (see Baker, 1911, p. 216).

Occurrence and material: Saw Rock Canyon, Red Corral, Rexroad, Bender, and Sanders local faunas. Saw Rock Canyon, UMMZ 183656 (14); Red Corral, UMMZ 182993 (175); Rexroad loc. 1, UMMZ 183052 (600); loc. 2, UMMZ 183065 (2); Bender loc. 1a, UMMZ 184118 (32); loc. 1c, UMMZ 183012 (33); loc. 2, UMMZ 184147 (200); Sanders loc. 1, UMMZ 182145 (75); loc. 2, UMMZ 182164 (1), 184160 (17); loc. 3, UMMZ 182175 (50).

Genus FOSSARIA Westerlund, 1885

Fossaria obrussa (Say), 1825

Galbra obrussa (Say). Baker, 1911, Chicago Acad. Sci. Spec. Pub. 3, p. 270, pl. 26, fig. 8–13, pl. 31, fig. 20–37.

Fossaria obrussa (Say). Baker, 1928, Wisconsin Geol. Nat. History Survey Bull. 70, pt. 1, p. 293, pl. 16, fig. 14; pl. 18, fig. 14–24.

Distribution.—"From the Atlantic to the Pacific oceans, and from Mackenzie Territory, Canada south to Arizona and northern Mexico" (Baker, 1928, p. 296).

Ecology.—"The normal habitat of this species is in small bodies of water, as creeks, ponds, sloughs, bays, and marshy spots along river banks. It is at home on sticks, stones, and any other debris that may be in the water or along its edge" (Baker, 1928, p. 296). In northern Nebraska it was found on mud and logs just above water level, or in the mud of seepages by streams.

Occurrence and material: Sand Draw local fauna; Recent in northern Nebraska. Sand Draw loc. 3, UMMZ 181128 (54).

Fossaria dalli (Baker), 1906

Plate 2, figures 6, 10–27

Galba dalli (Baker). Baker, 1911, Chicago Acad. Sci. Spec. Pub. 3, p. 251, pl. 30, fig. 13–18.

Fossaria dalli (F. C. Baker). Baker, 1928, Wisconsin Geol. Nat. Hist. Survey Bull. 70, pt. 1, p. 288, pl. 16, fig. 11.

Fossaria dalli grandis F. C. Baker. Baker, 1938, Nautilus, v. 51, p. 131 [in part].
Fossaria dalli grandis. McGrew, 1944, Field Mus. Nat. History Geol. Ser., v. 9, p. 36.
Lymnaea turritella Leonard, 1952, Nautilus, v. 66, p. 39, pl. 5, fig. C.
Lymnaea turritella Leonard. Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151, pl. 14, fig. r.
?*Lymnaea humilis modicella* (Say). Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151.

Distribution.—"Ohio to Northern Michigan and Montana, south to Kansas and Arizona" (Baker, 1928, p. 288).

Ecology.—"* * * inhabits wet, marshy places, generally out of the water, on sticks, stones, or muddy flats" (Baker, 1928, p. 289, 287). In northern Nebraska it was found in seepage areas, in the water or in wet leaves and debris at the water's edge.

Size-shape variation in *Lymnaea turritella* topotypes is as follows:

	Number of whorls			
	3¾	4	4¼	4½
Number of specimens	18	21	16	8
Length:				
Mean	3.44 ±0.066	3.79 ±0.059	4.27 ±0.078	4.60 ±0.25
Standard deviation	.28 ± .047	.27 ± .042	.31 ± .055	.70 ± .018
Width:				
Mean	1.94 ± .028	2.09 ± .035	2.27 ± .040	2.31 ± .100
Standard deviation	.12 ± .020	.16 ± .025	.16 ± .028	.28 ± .070
Length aperture:				
Mean	1.60 ± .033	1.73 ± .028	1.89 ± .035	1.92 ± .11
Standard deviation	.14 ± .023	.13 ± .020	.14 ± .025	.30 ± .075
Width aperture:				
Mean	.99 ± .021	1.03 ± .018	1.12 ± .019	1.14 ± .060
Standard deviation	.087 ± .015	.081 ± .013	.078 ± .014	.17 ± .043
Width to length ratio:				
Mean	.566 ± .0033	.550 ± .0028	.532 ± .0023	.504 ± .0078
Standard deviation	.014 ± .0023	.013 ± .002	.0093 ± .0016	.022 ± .0055
Length aperture to length ratio:				
Mean	.465 ± .0019	.457 ± .0016	.443 ± .003	.416 ± .0053
Standard deviation	.0081 ± .0014	.0072 ± .0011	.012 ± .0021	.015 ± .0038

Series from the Saw Rock Canyon, Bender, Sand Draw, Berends, and Jinglebob local faunas are all closely similar in having sculpture of coarse, irregular growth lines and small apertures. A large series from Rexroad locality 4b differs somewhat in having a greater range of variation. Many shells matching those from the other faunas may be found, but many others cannot be so matched. These latter specimens are slightly smoother, with longer apertures; some attain both greater size and a larger number of whorls than occur in other samples. Such large specimens may be referable to *Fossaria parva* (Lea) (Baker, 1911, p. 243) or to *F. parva sterkii* (Baker) (Baker, 1911, p. 248). The Rexroad locality 4b sample provides no evidence that more than one population is represented, however. This sample may be *F. parva*, rather than *F. dalli* as here considered, or *F. dalli* may be a synonym of *F. parva*. These questions involve revision of a number of Recent species, a study outside the scope of this report. The Rexroad locality 4b material is referred to *F. dalli* because what is probably a single population contains numerous individuals morphologically indistinguishable from other samples referable to *F. dalli*.

Small series from the Dixon and Sanders local faunas, and other Rexroad local fauna localities, are inadequate to show similarities closer either to the Rexroad 4b sample or to other samples.

Other late Pleistocene material surely representing what is called here *Fossaria dalli*, and which agrees closely with the Saw Rock Canyon, Sand Draw, Berends, and Jinglebob material is in the U. S. National Museum, as follows: 570570, marl, Castalia, Erie County, Ohio; identified by F. C. Baker as *Fossaria dalli grandis*. 570542, loess, Fulton County, Ill., identified by F. C. Baker as *Fossaria parva tazewelliana*. 570573, bed of drained pond, 2 miles southeast of Northport, Wash.; identified by F. C. Baker as *Fossaria perplexa*. F. C. Baker (1938) identified five juvenile specimens as *Fossaria dalli grandis*. One (CNHM PE 3443) is *F. dalli*, the others (CNHM PE 3442, UIMNH P6796) *Stagnicola palustris*.

Frye and Leonard (1952) reported *Lymnaea humilis modicella* from some localities represented by University of Michigan collections. The form has not been recognized in this material. The reference may be based upon short-spired specimens of *F. dalli*, however.

Remarks.—*Lymnaea turritella* Leonard was originally distinguished from *F. dalli* by its somewhat larger size and slenderer form. Comparison of a large series of topotoypes with other large series of fossils, and with Recent material in the U. S. National Museum identified by F. C. Baker, shows that these differences are not constant. The description and previous illustrations of *L. turritella* are based on extremely long, narrow specimens. The accompanying table, as well as the illustrations, shows variation in shape in the Saw Rock Canyon fauna sample. Comparison of these measurements with those given by Baker reveals further that there is no significant difference in size.

Occurrence and material: Saw Rock Canyon, Rexroad, Bender, Sand Draw, Dixon, and Sanders local faunas; Recent in northern Nebraska. Saw Rock Canyon, UMMZ 173595 (12), 177555 (250); Rexroad loc. 1, UMMZ 183054 (1); loc. 2, UMMZ 183066 (4); loc. 3, UMMZ 183028 (4); loc. 4b, UMMZ 177598 (200), 181047 (125); Bender loc. 1b, UMMZ 184134 (9); loc. 1c, UMMZ 183013 (1); loc. 2, UMMZ 184150 (3); Sand Draw loc. 2, UMMZ 184187 (6); loc. 6, CNHM PE3443 (1), UMMZ 177425 (7); Dixon loc. 1, UMMZ 182198 (34); loc. 2, UMMZ 191507 (2); Sanders loc. 3, UMMZ 182177 (4).

Genus BULIMNEA Haldeman, 1841

Bulimnea megasoma (Say), 1824

Bulimnea megasoma (Say). Baker, 1911, Chicago Acad. Sci. Spec. Pub. 3, p. 184, pl. 25, fig. 1–6.
Baker, 1928, Wisconsin Geol. Nat. Hist. Survey Bull. 70, pt. 1, p. 277, pl. 8, fig. 19–23; pl. 17, fig. 31, 35.
Lymnaea cf. *stagnalis jugularis Say.* Baker, 1938, Nautilus, v. 51, p. 131.
Stagnicola sp. Baker, 1938, Nautilus, v. 51, p. 131.
Lymnaea cf. *stagnalis jugularis.* McGrew, 1944, Field Mus. Nat. History Geol. Ser., v. 9, p. 36.
Stagnicola sp. McGrew, 1944, Field Mus. Nat. Hist. Geol. Ser., v. 9, p. 36 [in part].
Lymnaea megasoma Say. Taylor, 1954, Michigan Univ. Mus. Zool. Occ. Papers 557, p. 14.

Distribution.—"Northern New England (Vermont) west to Minnesota, Iowa, and Manitoba; northern Ohio (latitude 41°) northward to about latitude 57° in British America" (Baker, 1928, p. 282).

Ecology.—"*Megasoma* is usually an inhabitant of small, quiet bodies of water or swamps" (Baker, 1928, p. 281).

Remarks.—The material which Baker (1938) reported from the Sand Draw local fauna is fragmentary, but of the species known from this fauna can be only *B. megasoma.*

Occurrence and material: Sand Draw and Dixon local faunas. Sand Draw loc. 1, UMMZ 181237 (21); loc. 2, UMMZ 184186 (1); loc. 3, UMMZ 177331 (100); loc. 4, UMMZ 177314 (4); loc. 6, CNHM PE3440 (1), UIMNH P6794 (2), P6793 (fragments); Dixon loc. 1, UMMZ 182196 (60); loc. 2, UMMZ 191508 (15).

Family PLANORBIDAE

Subfamily PLANORBINAE

Genus ANISUS Studer, 1820

Subgenus ANISUS s. s.

Anisus (s. s.) pattersoni (Baker), 1938

Gyraulus pattersoni Baker, 1938, Nautilus, v. 51, p. 129.
Gyraulus pattersoni. McGrew, 1944, Field Mus. Nat. History Geol. Ser., v. 9, p. 36.
Gyraulus pattersoni Baker. Leonard, 1950, Kansas Univ. Paleont. Contr. 8, p. 20, pl. 3, fig. I.
Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 158, pl. 15, fig. g.
Leonard, 1957, Illinois Geol. Survey Report of Investigations 201, p. 12, pl. 2, fig. 4–6.
Anisus pattersoni (Baker). Taylor, 1958, Jour. Paleont., v. 32, p. 1149.

Types.—Holotype CNHM, Sand Draw loc. 5. Paratypes CNHM (2), UIMNH P7455 (4), ANSP 169948 (2).

Diagnosis.—An *Anisus* of small size (less than 5 mm diameter), with 5–6 whorls, nearly plane on both sides, subangular at junction of left side and periphery of whorls.

Description.—Shell small, discoidal, presumably ultradextral, nearly plane on both sides; whorls 5–6, flattened on the left side, subangulate at junction of left side with periphery, rounded on periphery and right side, very slowly and regularly increasing; suture well impressed; aperture subquadrate, left side flattened to arcuate, periphery gently rounded, right side strongly rounded; lip sometimes thickened within; sculpture of numerous fine, irregular growth lines and weak spiral striation; embryonic shell of about one-half whorl, spirally striate only.

Measurements.—See table of comparative measurements below.

Distribution.—Pliocene in southwestern Idaho, northern Utah, western Wyoming; early Pleistocene in southwestern Idaho, Nebraska, and Kansas; middle Pleistocene in the central Great Plains; late Pleistocene, Ohio.

Ecology.—Known only from inference, since the species is extinct. Its association with fossils which represent living species suggests it lived in shallow, quiet waters, in the backwaters along streams or in semipermanent ponds and sloughs.

Remarks.—*Anisus pattersoni* (F. C. Baker) seems most nearly related to *A. rotundatus* (Poiret); but insufficient data for adequate comparison are available on *A. perezi* (Dupuy), to which it may be closer. *A. pattersoni* is smaller than *A. rotundatus* (see measurements), with fewer whorls than either *A. rotundatus* or *A. perezi.* No specimens of *A. pattersoni* with over 5½ whorls have been seen, whereas Germain (1931, p. 530–531) ascribes six or seven to the European species. The left side of the whorls of *A. pattersoni* is more flattened than the right side, so that there is an obtuse angle of the aperture above, but only a curve below. In most specimens examined, the left side is broader than the right. The largest specimens, however, lose the subangulation on the last whorl, and thus approach *A. rotundatus.* Like *A. rotundatus* and *A. perezi*, *A. pattersoni* possesses an internal thickening of the lip. Formation of this callus is not restricted to mature individuals; most specimens show several such calluses, the number depending on the individual's age.

Differences in size between the two species are shown by the following measurements (in millimeters). Catalogue numbers are those of the University of Michigan Museum of Zoology, as follows: 177231, Sand Draw local fauna, locality 7, Brown County, Nebr., 177290, probably Cudahy local fauna, W½ sec. 35, T. 33 S., R. 32 W., Seward County, Kans.; 90458, Recent, Menonville, France.

Differences in the two species are as follows:

	Number of whorls	Diameter	Height	Diameter of aperture	Height of aperture	Catalog No.
Anisus pattersoni (Baker)	5	3. 7	0. 8	0. 6	0. 8	177231
	4¼	3. 1	. 7	. 6	. 7	
	4¼	2. 9	. 7	. 5	. 7	
	5½	4. 6	1. 2	. 8	. 9	177290
	5¼	4. 2	. 8	. 8	. 8	
	4½	3. 2	. 7	. 6	. 7	
Anisus rotundatus (Poiret)	5½	6. 3	1. 3	1. 0	1. 3	90458
	5½	6. 3	1. 3	1. 2	1. 3	
	5	4. 9	. 9	. 9	. 9	
	4½	3. 9	. 9	. 7	. 9	
	4½	4. 2	1. 1	. 9	1. 1	

Occurrence and material: Sand Draw and Dixon local faunas. Sand Draw loc. 2, USGS 19090–1 (6); loc. 3, UMMZ 177332 (150); loc. 4, UMMZ 177316 (6); loc. 5, CNHM (3), UIMNH P7455 (4), ANSP 169948 (2); loc. 6, UMMZ 177427 (48), 181211 (500); loc. 7, UMMZ 177231 (75); Dixon loc. 1, UMMZ 182199 (26).

Genus GYRAULUS Charpentier, 1837

Gyraulus circumstriatus (Tryon), 1866

Gyraulus circumstariatus (Tryon). Baker, 1928, Wisconsin Geol. Nat. History Survey Bull. 70, pt. 1, p. 378, text fig. 162.

Distribution.—*Gyraulus circumstriatus* is found in a broad belt across central North America, in southern Canada and the northern United States between the Atlantic and Pacific oceans, southward in the Rocky Mountains to northern Arizona.

Ecology.—*Gyraulus circumstriatus* is characteristic of small, seasonal water bodies, such as woods pools, marshes, ponds on flood plains or prairie ponds. In northern Nebraska it was found in seepages beside streams, and in temporary Sand Hills ponds.

Occurrence.—Recent in northern Nebraska.

Gyraulus deflectus (Say), 1824

Gyraulus deflectus (Say). Baker, 1928, Wisconsin Geol. Nat. Hist. Survey Bull. 70, pt. 1, p. 370, pl. 23, fig. 15–21.

Distribution.—British Columbia to Nova Scotia and Mackenzie District; south in the Rocky Mountains to Montana and Idaho; eastern South Dakota and Iowa to the Atlantic Ocean; south in the Atantic Coastal Plain to the Potomac River, Virginia.

Ecology.—"A species of quiet bodies of water" (F. C. Baker, 1928, p. 370). In northern Nebraska this species was found in a spring-fed pond with a temperature of 15°C. The snails were crawling on aquatic plants, largely *Ceratophyllum*, *Elodea*, and algae, near the edge of the pond.

Remarks.—In north-central Nebraska this species is about 200 miles south of its previously recorded range. Its existence in the area is considered possible because of the insulating effect of the cool spring water. Essentially a northern species, it is probably able to live here because the pond is warmed little if at all during the summer hot spells. Other permanent ponds, apparently similar except that they lack spring sources, were examined without finding this species.

Occurrence: Recent in northern Nebraska.

Gyraulus parvus (Say), 1817

Plate 4, figs. 1–13, 17, 18

Gyraulus parvus (Say). Baker, 1928, Wisconsin Geol. Nat. History Survey Bull. 70, pt. 1, p. 374, pl. 23, fig. 27–31, 39, text fig. 162.

Gyraulus altissimus (F. C. Baker). Baker, 1938, Nautilus, v. 51, p. 130–131 [not of Baker].

Gyraulus altissimus. McGrew, 1944, Field Mus. Nat. History Geol. Ser., v. 9, p. 36.

Gyraulus enaulus Leonard, 1952, Nautilus, v. 66, p. 43, pl. 5, fig. G. H, I.

Gyraulus enaulus Leonard. Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151, pl. 14, fig. u.

Distribution.—North America, from Alaska and northern Canada to Cuba and from the Atlantic to the Pacific coast. Perhaps also in northern Eurasia.

Ecology.—"Usually in quiet bodies of water, often of small size. * * * *parvus* is partial to a habitat which has rather thick vegetation. This species is more often found in vegetation than in any other situation" (Baker, 1928, p. 376–377). In northern Nebraska it was found in permanent and temporary quiet water bodies: in permanent and temporary ponds, in temporary water in ditches, and in quiet spots at the edge of a stream.

Remarks.—*Gyraulus altissimus* Baker (1919), described from upper Pleistocene deposits in Illinois, was reported from the Sand Draw local fauna. The material is *G. parvus* rather than *G. altissimus.* The shells from the Sand Draw local fauna are characterized by a lateral flattening of the whorls, relatively close coiling, and no deflection of the body whorl. *G. altissimus* also has closely coiled whorls, but the body whorl is deflected and the flattening is at an angle of about 45 degrees to the axis of the coil.

Gyraulus enaulus Leonard was not compared to *G. parvus* in the original description, but is referable to that species as represented in University of Michigan Museum of Zoology and U. S. National Museum collections.

Occurrence and material: Saw Rock Canyon, Red Corral, Sand Draw, Dixon, and Sanders local faunas; Recent in northern Nebraska; Rexroad local fauna (Frye and Leonard). Saw Rock Canyon, UMMZ 173591 (125), 177556 (1200), uncat., USGS 19089–1 (200); Red Corral, UMMZ 182994 (200); Sand Draw loc. 1, UMMZ 181239 (250); loc. 2, USGS 19090–2 (100); loc. 3, UMMZ 177333 (2250); loc. 4, UMMZ 177317 (300); loc. 5, UMMZ 181228 (125), 177219 (24), CNHM PE3436 (175), UIMNH P6790 (41); loc. 6, UMMZ 177428 (200), 181212 (75), CNHM PE3444 (46), UIMNH P6797 (15); loc. 7, UMMZ 177-232 (150); Dixon loc. 1, UMMZ 182200 (6500), uncat.; loc. 2, UMMZ 191509 (300); Sanders loc. 1, UMMZ 182147 (5); loc. 3, UMMZ 182178 (1).

Genus ARMIGER Hartmann, 1840

Armiger crista (Linnaeus), 1758

Gyraulus crista (Linn.). Baker, 1928, Wisconsin Geol. Nat. History Survey Bull. 70, pt. 1, p. 385, text fig. 164.

Distribution.—Holarctic; in North America, north of about 41°, but south of this latitude on the Pacific Coast to San Mateo County, Calif., and southward in central Utah.

Ecology.—Kenk (1949, p. 53) found *A. crista* was common in a temporary pond in southern Michigan. "*Armiger crista* (Linnaeus) was taken in Pond 1 from March to June. Numerous individuals appeared also in the culture of a soil sample from the bottom of the pond, prepared in October. No specimens were collected from December to February. The animals obviously estivated buried in the dry mud and, after the pond had filled, remained inactive in the soil until the latter part of the winter." In northern Nebraska a single specimen was found, under culvert fill stones at the edge of a stream. Ecologic information on this species in America is scanty.

Occurrence: Recent in northern Nebraska.

Subfamily HELISOMATINAE

Genus HELISOMA Swainson, 1840

Subgenus HELISOMA s. s.

Helisoma (s. s.) anceps (Menke), 1830

Helisoma antrosa (Conrad). Baker, 1928, Wisconsin Geol. Nat. History Survey Bull. 70, pt. 1, p. 317, pl. 19, fig. 8–15.

Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151.

Helisoma anceps (Menke). Pilsbry, 1934, Acad. Nat. Sci. Philadelphia Proc., v. 86, p. 45.

Taylor, 1954, Michigan Univ. Mus. Zool. Occ. Papers 557, p. 14.

Distribution.—Oregon to Maine, southward to western Mexico and Alabama.

Ecology.—"* * * primarily a river and creek species, not living in the large lakes" (Baker, 1928, p. 319). In northern Nebraska it was found in a spring-fed pond with a temperature of 15°C.

Remarks.—Pilsbry (1934) considered the name *antrosa* as a junior synonym of *anceps.* The name *anceps* has been used by subsequent writers except Leonard (1950, p. 16, and later papers). Pilsbry (1950, p. 68) discussed the reasons for acceptance of *anceps.*

The single Recent occurrence in a summer-cool pond together with *Valvata* and *Gyraulus deflectus* might be interpreted to mean that its existence in the area is dependent upon a temperature factor. Considering its wide distribution and the number of High Plains localities given by Walker (1909), I think the controlling factor is permanent water.

The material reported by Frye and Leonard (1952, p. 151) from the SW¼ sec. 22, T. 33 S., R. 29 W., Meade County, almost certainly came from Rexroad locality 3 rather than Bender locality 1. Habitat inferences from Bender locality 1 species suggest only temporary bodies of water. Rexroad locality 3 had the permanent water which *Helisoma anceps* requires.

Occurrence and material: Sand Draw and Dixon local faunas; Saw Rock Canyon and Rexroad local faunas (Frye and Leonard); Recent in northern Nebraska. Sand Draw loc. 1, UMMZ 181240 (65); loc. 2, UMMZ 184173 (5); loc. 3, UMMZ 177334 (250); loc. 6, UMMZ 177429 (1); Dixon loc. 1, UMMZ 182201 (100); loc. 2, UMMZ 191510 (1).

Subgenus PIEROSOMA Dall, 1905

Helisoma (Pierosoma) trivolvis (Say), 1817

Helisoma trivolvis (Say). Baker, 1928, Wisconsin Geol. Nat. History Survey Bull. 70, pt. 1, p. 330, pl. 20, fig. 1–13, 22, 23.

Distribution.—"Atlantic Coast and Mississippi River drainages, northward to Arctic British America and Alaska and southward to Tennessee and Missouri. The southern distribution is not clear owing to mixing with related species" (Baker, 1928, p. 332).

Ecology.—"Typical *trivolvis* is always an inhabitant of quiet, more or less stagnant water" (Baker, 1928, p. 332). In northern Nebraska it was found in permanent ponds almost exclusively. The exception was a single specimen found in a drainage ditch where it might have come from a permanent pond.

Occurrence and material: Dixon local fauna; Recent in northern Nebraska. Dixon loc. 1, UMMZ 182202 (2, + fragments); loc. 2, UMMZ 191511 (72).

Subfamily PLANORBULINAE

Genus PLANORBULA Haldeman, 1842

Planorbula armigera (Say), 1818

Planorbula armigera (Say). Baker, 1928, Wisconsin Geol. Nat. Hist. Survey Bull. 70, pt. 1, p. 355, pl. 8, fig. 27–30.
Planorbula sp. Taylor, 1954, Michigan Univ. Mus. Zool. Occ. Papers 557, p. 15.

Distribution.—"New England west to Nebraska, south to Georgia and Louisiana, north to Great Slave Lake." (F. C. Baker, 1928, p. 359.)

Ecology.—"* * * largely a species of swales or of small and stagnant bodies of water." (F. C. Baker, 1928, p. 358). In northern Nebraska it was found in a small oxbow lake in the Niobrara River valley.

Remarks.—Sand Draw local fauna material consists chiefly of fragments and young specimens. None shows the apertural dentition, but all agree well in size and shape with *P. armigera.*

The series from Dixon locality 2 agrees well in size, shape, and lamellae with Recent specimens of *P. armigera.* The three immature specimens from Dixon locality 1 are referred to the same species, since they show no differences from the locality 2 series.

The single Recent Nebraska specimen differs from *P. armigera* as figured and described by Baker (1928) in having a lesser axial height, five whorls, and a more open spire-pit. It differs from *P. christyi* (Dall) as figured by Baker (1945, pl. 119, figs. 13–15) in having fewer whorls. The specimen probably represents normal variation within *P. armigera.*

Occurrence and material: Sand Draw and Dixon local faunas; Recent in northern Nebraska. Sand Draw loc. 1, UMMZ 181241 (44); loc. 4, UMMZ 177318 (14); Dixon loc. 1, UMMZ 182203 (3); loc. 2, UMMZ 191512 (200).

Genus PROMENETUS Baker, 1935

Subgenus PROMENETUS s. s.

Promenetus (s. s.) exacuous (Say), 1821

Menetus exacuous (Say). Baker, 1928, Wisconsin Geol. Nat. History Survey Bull. 70, pt. 1, p. 361, pl. 23, fig. 1–5.
Promenetus exacuous exacuous (Say). Baker, 1945, Molluscan family Planorbidae, p. 182.

Distribution.—North America north of about 39°; south in the Colorado Plateau and Rocky Mountains to New Mexico; south along the Atlantic Coastal Plain to North Carolina; an isolated occurrence in cool springs, Meade County, Kans.

Ecology.—*Promenetus exacuous* is found in shallow, perennial or subpermanent, quiet water bodies, such as ponds, ox-bow lakes, marshes, and sloughs or backwaters along streams. It is usually on the submerged vegetation in such habitats. The isolated occurrence in Meade County, Kans., can be explained by the summer-cool habitat furnished by artesian water in which this snail lives. In northern Nebraska it was found in permanent or nearly permanent quiet water.

Occurrence: Recent in northern Nebraska.

Promenetus (s. s.) kansasensis (Baker), 1938

Plate 3, figures 7, 8, 12–30

Menetus kansasensis Baker, 1938, Nautilus, v. 51, p. 129.
Menetus kansasensis F. C. Baker. Baker, 1938, Nautilus, v. 51, p. 130–131.
Hibbard, 1941, Kansas Univ. Sci. Bull., v. 27, p. 95.
Hibbard, 1941, Kansas Acad. Sci. Trans., v. 44, p. 265.
Frye and Hibbard, 1941, Kansas Geol. Survey Bull. 38, p. 408.
Baker, 1945, Molluscan family Planorbidae, p. 516, pl. 140, fig. 26–29.

Menetus kansasensis Baker. Smith, 1940, Kansas Geol. Survey Bull. 34, p. 408.
Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151, pl. 14, fig. t.
Leonard, 1957, Illinois Geol. Survey Report of Investigations 201, p. 13, pl. 2, fig. 1–3.
Menetus kansasensis. McGrew, 1944, Field Mus. Nat. History Geol. Ser., v. 9, p. 36.

Types.—Holotype UIMNH P6778, Rexroad loc. 3. Paratypes UIMNH P6778 (3), uncataloged (20), ANSP 169884 (not found).

Diagnosis.—Similar in shape and size to *Promenetus exacuous*, but with sculpture of numerous irregularly spaced riblets.

Distribution.—Late Pliocene to late Pleistocene (Sangamon) in the Great Plains.

Occurrence and material: Saw Rock Canyon, Red Corral, Rexroad, Sand Draw, Dixon, and Sanders local faunas. Saw Rock Canyon, UMMZ 173588 (75), 177557 (2500), uncat., USGS 19089-2 (75); Red Corral, UMMZ 182995 (8); Rexroad loc. 1, UMMZ 183055 (1); loc. 3, UIMNH P6778 (4), uncat. (20), UMMZ 183029 (12); Sand Draw loc. 1, UMMZ 181242 (100); loc. 2, USGS 19090-3 (48); loc. 3, UMMZ 177335 (1500); loc. 4, UMMZ 177319 (54); loc. 5, CNHM PE 3434 (30), UIMNH P6788 (17), UMMZ 177217 (3000), 181229 (3500); loc. 6, UIMNH P6798 (6), UMMZ 177430 (100), 181213 (600); loc. 7, UMMZ 177229 (125); Dixon loc. 1, UMMZ 182204 (1000); loc. 2, UMMZ 191513 (150); Sanders loc. 2, UMMZ 182165 (2); loc. 3, UMMZ 182179 (1).

Subgenus PHREATOMENETUS[3] Taylor, n. subg.

Type.—*Promenetus umbilicatellus* (Cockerell).

Diagnosis.—Snails fitting the definition of *Promenetus* (see Baker, 1945, p. 178–182), but distinguished conchologically as follows: shell broadly rounded peripherally; sides of whorls convex to slightly flattened; left side strongly convex or subangular at edge of spire-pit; right side sometimes strongly convex or subangular near the suture.

Referred species.—None of the species besides the type is known anatomically; others listed below are assigned on shell characters.

Promenetus umbilicatellus (Cockerell), 1887. Type.
Northern North America.
carus (Pilsbry and Ferriss), 1906.
Southwestern Texas.
circumlineatus (Shuttleworth), 1854.
Central America to the Lesser Antilles.
(Including *Planorbis santacruzensis* Germain, 1923; may be a synonym of *Planorbis aeruginosus* Morelet, 1851).

[3] Gr. phrear, -atos, n., well or reservoir; in reference to the steep-sided, well-like spire-pit of the species referred to the group.

Promenetus (Phreatomenetus) umbilicatellus (Cockerell), 1887

Gyraulus umbilicatellus (Cockerell). Baker, 1928, Wisconsin Geol. Nat. History Survey Bull. 70, pt. 1, p. 383, pl. 22, fig. 18–21.
Menetus umbilicatellus (Cockerell). Baker, 1938, Nautilus, v. 51, p. 130.
Gyraulus umbilicatellus. McGrew, 1944, Field Mus. Nat. History Geol. Ser., v. 9, p. 36.
Promenetus umbilicatellus (Cockerell). Baker, 1945, Molluscan family Planorbidae, p. 182, pl. 123, fig. 34–36.
Promenetus blancoensis Leonard, 1952, Nautilus, v. 66, p. 42, pl. 5, fig. D–F.
Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151, pl. 14, fig. o.

Distribution.—North America north of about lat. 41° from Nevada and Alaska east and southeast to western New York; south in the Rocky Mountains to southern Colorado; an isolated occurrence in the Ozark Mountains, northeastern Oklahoma.

Ecology.—"All specimens in Wisconsin have been found in swales" (Baker, 1928, p. 384). In northern Nebraska it was found common in drainage ditches and temporary ponds.

Remarks.—*Promenetus blancoensis* appears to be a synonym of *P. umbilicatellus*, easily falling within the range of variation of the latter. The differentiae given were the smaller size, lesser number of whorls (always less than 4), nonstriate nucleus, absence of spiral sculpture, and depressed spire. The great majority of Recent specimens examined have less than 4 whorls and have a diameter of approximately 4 millimeters, thus agreeing with the measurements of *P. blancoensis*. To the "nonstriate nucleus" not much significance should be atached. All other characters are in agreement with those of *P. umbilicatellus*, and the nuclear striation might easily be lost through wear. The apparent absence of spiral sculpture does not differentiate the form from *P. umbilicatellus*, for this character is often very difficult to observe in unworn Recent specimens, and in fossils faint spiral sculpture might have been lost or easily overlooked. The depressed spire is also a character which may be found in Recent specimens, although it is not common. Material from the Saw Rock Canyon local fauna, and from Rexroad local fauna localities 1 and 3 confirms the synonymization. The specimens agree well in size and form with *P. umbilicatellus*, and less worn individuals show the spiral striation and nuclear sculpture typical of that species.

The material reported by Frye and Leonard (1952, p. 151) from SW¼ sec. 22, T. 33 S., R. 29 W., Meade County, is probably from Bender locality 1 rather than Rexroad locality 3. University of Michigan collections contain numerous specimens from the Bender locality, but none from the Rexroad locality.

Occurrence and material: Saw Rock Canyon, Red Corral, Rexroad, Bender, Sand Draw, Dixon, and Sanders local faunas; Recent in northern Nebraska. Saw Rock Canyon, UMMZ 177515 (50), 177558 (600), USGS 19089-3 (75); Red Corral, UMMZ 182996 (150); Rexroad loc. 1, UMMZ 183056 (1500); Bender loc. 1, UMMZ 177505 (1); loc. 1a, UMMZ 184120 (30); loc. 1c, UMMZ 183014 (11); loc. 2, UMMZ 184151 (47); Sand Draw loc. 1, UMMZ 181243 (6); loc. 2, UMMZ 184174 (40); loc. 3, UMMZ 177336 (225); loc. 4, UMMZ 177320 (150); loc. 5, CNHM PE3435 (75), UIMNH P6789 (36), UMMZ 177218 (125), 181230 (800); loc. 6 UMMZ 177431 (300), 181214 (6000); loc. 7, UMMZ 177230 (250); Dixon loc. 1, UMMZ 182205 (9); loc. 2, UMMZ 191514 (6); Sanders loc. 1, UMMZ 182148 (300); loc. 2, UMMZ 182166 (2), 184162 (31); loc. 3, UMMZ 182180 (20).

Family ANCYLIDAE

Subfamily ACROLOXINAE

Genus ACROLOXUS Beck, 1837

Acroloxus coloradensis (Henderson), 1930

Plate 1, figures 1–4

Ancylus hendersoni Walker, 1925, Michigan Univ. Mus. Zool Occ. Papers 165, p. 1.
Mozley, 1926, Nautilus, v. 40, p. 56.
Ancylus coloradensis Henderson, 1930, Nautilus, v. 44, p. 31.
Taylor, 1954, Michigan Univ. Mus. Zool. Occ. Papers 557, p. 15.

Distribution.—Known from only two areas in the Rocky Mountains in Colorado and Alberta.

Ecology.—In high mountain lakes. "* * * only clinging to stones, etc., in very tiny inlets from the lake, where they were well protected from the waves, but in clear lake water, not in swampy ground" (Walker, 1925, p. 3).

Remarks.—The discovery of this rare and little-known species in the Pleistocene of the Great Plains is remarkable. The specimens are closely similar to a series of paratypes, however, and also to specimens collected in Alberta by Mozley.

International Commission on Zoological Nomenclature Opinion 363 (1955) fixes the type of *Ancylus* as *A. fluviatilis* Müller, 1774, and of *Acroloxus* as *Patella lacustris* Linnaeus, 1758, as interpreted by Müller, 1774. *Ancylus coloradensis* Henderson is accordingly to be called *Acroloxus coloradensis* (Henderson).

Occurrence and material: Sand Draw and Dixon local faunas. Sand Draw loc. 3, UMMZ 181129 (28); Dixon loc. 1, UMMZ 182209 (1); loc. 2, UMMZ 191515 (1).

Subfamily FERRISSIINAE

Genus FERRISSIA Walker, 1903

Ferrissia rivularis (Say), 1819

Ferrissia rivularis (Say). Baker, 1928, Wisconsin Geol. Nat. History Survey Bull. 70, pt. 1, p. 398, pl. 24, fig. 16–18.
Hibbard, 1941, Kansas Univ. Sci. Bull., v. 27, p. 95.
Hibbard, 1941, Kansas Acad. Sci. Trans., v. 44, p. 265.
Frye and Hibbard, 1941, Kansas Geol. Survey Bull. 38, p. 408.
Frye and Leonard, 1952, p. 151.
Taylor, 1954, Michigan Univ. Mus. Zool. Occ. Papers 557, p. 15.
Ferrissia rivularis? (Say). Hibbard, 1954, Michigan Acad. Sci. Papers, v. 39, p. 343.

Distribution.—"Massachusetts west to Nebraska, Ohio northward to Wisconsin and Michigan" (F. C. Baker, 1928, p. 399).

Ecology.—"Found on stones in streams" (Robertson and Blakeslee, 1948, p. 72).

Occurrence and material: Saw Rock Canyon, Rexroad, Sand Draw, and Dixon local faunas; Buis Ranch local fauna? Buis Ranch, UMMZ 181114 (1, fragmentary); Saw Rock Canyon, UMMZ 173594 (24), 177559 (350), USGS 19089-9 (100); Red Corral, UMMZ 182997 (5); Rexroad loc. 3, UMMZ 183031 (8); Sand Draw loc. 1, UMMZ 181245 (57); loc. 2, UMMZ 184175 (1); loc. 3, UMMZ 181111 (250); Dixon loc. 1, UMMZ 182210 (56).

Ferrissia parallela (Haldeman), 1841

Ferrissia parallela (Haldeman). Baker, 1928, Wisconsin Geol. Nat. History Survey Bull. 70, pt. 1, p. 395, pl. 24, fig. 1–5.
Hibbard, 1941, Kansas Univ. Sci. Bull., v. 27, p. 95.
Hibbard, 1941, Kansas Acad. Sci. Trans., v. 44, p. 265.
Frye and Hibbard, 1941, Kansas Geol. Survey Bull. 38, p. 408.
Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151, pl. 14, fig. n.

Distribution.—Nova Scotia and New England west to Manitoba and northeastern Illinois (F. C. Baker, 1928, p. 397).

Ecology.—"*Ferrissia parallela* is usually found in quiet water, on plants, the water in such places ranging from .3–2 meters in depth. The animal is usually found near the surface but may occur on the lower part of such plants as *Scirpus*, near the bottom. *Parallela* appears to be a pond or lake species, at least in Wisconsin" (F. C. Baker, 1928).

Occurrence: Rexroad local fauna (Hibbard).

Ferrissia meekiana (Stimpson), 1863

Gundlachia meekiana Stimpson, 1863, Boston Soc. Nat. History Proc., v. 9, p. 250.
Binney, 1865, Smithsonian Misc. Coll. 143, p. 150.
Pilsbry, *in* Hedley and Pilsbry, 1895, Nautilus, v. 9, p. 63.
Ancylus pumilus Sterki. Walker, 1904, Nautilus, v. 18, p. 82, pl. 6, fig. 20–22.
Walker, 1914, Nautilus, v. 27, p. 129.

Ferrissia cf. *pumila* (Sterki). Taylor, 1954, Michigan Univ. Mus. Zool. Occ. Papers 557, p. 15.

Distribution.—Probably the species ranges over most of the eastern United States. It is known from scattered localities in Alabama, Missouri, Virginia, the District of Columbia, and from Iowa eastward to New York.

Ecology.—Uncertain. It has been found in temporary pools, ponds, and sloughs, but may occur in other habitats as well.

Remarks.—The kinds of shells called *Ferrissia meekiana* in this paper have been found at several localities in Pleistocene deposits of the Great Plains. Frequently the very small, septate, immature shells are as-associated with larger, non-septate shells similar to *F. pumila*. Only one sample large enough to show the range of variation adequately has been collected; it is from Dixon locality 2 (UMMZ 191516). On the basis of the range of variation in this fossil sample, the range of variation in Recent material in the University of Michigan Museum of Zoology, and the similarity of the fossils to specimens identified by Walker as *Gundlachia meekiana* it appears that the small, septate shells and larger nonseptate specimens represent one species, and that *Ancylus pumilus* Sterki represents the nonseptate form of "*Gundlachia*" *meekiana*. Walker (1914, p. 129) reached similar conclusions from study of Recent shells.

Watson (in Connolly, 1938, p. 525-526) presented evidence to indicate that reference of all septum-forming Ancylidae to *Gundlachia* is unjustified. He restricted *Gundlachia* to tropical American and West Indian species with a smooth apex and an asymmetrical central tooth, and placed apically striate septum-forming species (*Kincaidilla*) in *Ferrissia*. In accordance with this classification *Gundlachia meekiana* (including *Ancylus pumilus*) is referred to *Ferrissia*.

Occurrence and material: Sand Draw and Dixon local faunas. Sand Draw loc. 1, UMMZ 181244 (7), 181246 (2); loc. 3, UMMZ 177338 (13); Dixon loc. 1, UMMZ 182211 (5); loc. 2, UMMZ 191516 (44).

Sand Draw loc. 1: Only one of the nine specimens is septate. Loc. 3: all 13 lack septa. Dixon loc. 1: Of the 5 specimens 3 are septate. Loc. 2: 7 of the 44 are septate. The series from Dixon loc. 2 is the only one large enough to give a reasonably adequate idea of variation within the population. It may be divided into five groups, as follows:

(a) Five small specimens, 1.7–2.3 mm long, with the septum covering about three-quarters of the aperture. These are similar to the two small, septate specimens from Dixon loc. 1. Three are striate anteriorly.

(b) Four small specimens, 2.3–2.5 mm long, nonseptate. These are similar in shape to those of group (a), and to one specimen from Sand Draw loc. 3. All four are smooth.

(c) Two immature specimens, 2.5 and 3.3 mm long. Both apparently formed a septum over about one-fifth of the aperture before continuing growth. The larger is striate anteriorly.

(d) Four mature specimens, 3.0–3.2 mm long, nonseptate, with nearly straight sides roughly parallel or slightly divergent anteriorly. Three are anteriorly striate.

(e) Twenty-nine specimens, immature and mature, reaching a size of 3.3 × 1.9 mm. The lateral outline of the shell varies from only slightly to moderately curved. One only is anteriorly striate. The apex is about one-fourth of the shell length from the posterior end and somewhat to the right of the median line. The right slope is straight or gently concave; the left slope straight or gently convex. The height of the shell varies from less to more elevated than *F. pumila* as figured by Walker (1904, pl. 6, fig. 20). Most shells are more depressed, however, with a slightly more concave posterior slope. The anterior end of the shell is symmetrical in outline, the posterior end usually so. The slight flattening of the dextroposterior margin is not as marked as in the specimens from Sand Draw loc. (UMMZ 181244). This group agrees well with a series (UMMZ 67269) from Clear Lake, La Porte, La Porte County, Ind., identified as *Gundlachia meekiana* by Bryant Walker.

Family PHYSIDAE

Genus PHYSA Draparnaud, 1801

Physa anatina Lea, 1864

Physella anatina Lea. Baker, 1928, Wisconsin Geol. Nat. History Survey Bull. 70, pt. 1, p. 470, pl. 19, fig. 5 [not 7].

Physa species, young and fragments. Baker, 1938, Nautilus, v. 51, p. 130.

Physa anatina Lea. Hibbard, 1941, Kansas Univ. Sci. Bull., v. 27, p. 95.

Hibbard, 1941, Kansas Acad. Sci. Trans., v. 44, p. 265.

Frye and Hibbard, 1941, Kansas Geol. Survey Bull. 38, p. 408.

Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151, pl. 14, fig. z.

Physa sp. McGrew, 1944, Field Mus. Nat. Hist. Geol. Ser., v. 9, p. 36 [in part].

Distribution.—Very poorly known, on account of the lack of study of the genus. Probably it will be found in most of the central and southern Great Plains. Crandall (1901, p. 57) states, "It is plentiful around Wichita, Kansas, and has been reported from Missouri, Kansas, Nebraska, and Michigan. It probably inhabits all the intervening territory."

Ecology.—This species is found in almost any sort of perennial, shallow water body, in either flowing or standing water. In Meade County, southwestern Kansas, it can be found in small streams, in the spring-fed ponds in the State Park, or in stock tanks. In northern Nebraska it was not found in still water, but only in seepages or spring-fed streams.

Occurrence and material: Saw Rock Canyon, Red Corral, Rexroad, Bender, Sand Draw, Dixon, and Sanders local faunas; Recent in northern Nebraska. Saw Rock Canyon, UMMZ 172364 (31), 177560 (2500), USGS 19089-4 (800);

Red Corral, UMMZ 182998 (150); Rexroad loc. 1, UMMZ 183057 (35); loc. 2, UMMZ 183067 (1); loc. 3, UMMZ 183030 (60); loc. 4b, UMMZ 177600 (3000), 181049 (1500); Bender loc. 1a, UMMZ 184121 (3); loc. 1b, UMMZ 184135 (1); loc. 2, UMMZ 184152 (50); Sand Draw loc. 2, UMMZ 184176 (1); loc. 3, UMMZ 177340 (55); loc. 4, UMMZ 177321 (8); loc. 5, CNHM PE3432 (4), UIMNH P6786 (3), UMMZ 181231 (25); loc. 6, UMMZ 177432 (1), 181215 (1); Dixon loc. 1, UMMZ 182206 (150); Sanders loc. 1, UMMZ 182149 (13); loc. 2, UMMZ 184163 (2); loc. 3, UMMZ 182181 (3 + fragments).

Physa gyrina Say, 1821, form hildrethiana Lea, 1841

Physella gyrina hildrethiana (Lea). Baker, 1928, Wisconsin Geol. Nat. History Survey Bull. 70, pt. 1, p. 453, pl. 27, fig. 36; pl. 28, fig. 2–4, 7–14.

Physa elliptica Lea. Taylor, 1954, Michigan Univ. Mus. Zool. Occ. Papers 557, p. 15.

Distribution.—Probably found in most of North America north of Mexico. According to Baker (1928), *P. gyrina* is found "from the Arctic regions south to Alabama and Texas;" the form *hildrethiana* " * * * is common east of the Mississippi River from western New York and Pennsylvania to Illinois and south to Alabama. Occurs also in Iowa and possibly in other states west of the Mississippi River."

Ecology.—"*Hildrethiana* is characteristic of swales and summer-dry ponds, where it is deprived of moisture for a large part of the year. The variety in such localities rarely reaches maturity, the usual form being a small, short, shell with dome-shaped spire, greatly resembling *oleacea* and *elliptica*. These small forms usually show no rest marks, living only as long as the water remains in the pool. Mature shells may often be found by digging in the mud or in cracks in the bottom of the pool where the mollusk has descended for moisture" (Baker, 1928, p. 454). In northern Nebraska this snail was common at many places, in temporary ponds and drainage ditches, permanent ponds and a stock tank. *P. gyrina* and *P. anatina* were never found together. *P. anatina* occured only in seepages and streams.

Occurrence and material: Sand Draw and Dixon local faunas: Recent in northern Nebraska. Sand Draw loc. 1, UMMZ 181247 (13); loc. 2, UMMZ 184177 (3); Dixon loc. 1, UMMZ 182207 (60); loc. 2, UMMZ 191517 (65).

Physa skinneri Taylor, 1954

Plate 3, figures 5, 6, 9–11

Physa species, young of small, narrow species. Baker, 1938, Nautilus, v. 51, p. 130.

Physa sp. McGrew, 1944, Field Mus. Nat. Hist. Geol. Ser., v. 9, p. 36 [in part].

Physa skinneri Taylor, 1954, Michigan Univ. Mus. Zool. Occ. Papers 557, p. 9, 15.

Types.—Holotype UMMZ 181292, Berends local fauna. Paratypes UMMZ 177533 (31), MCZ 198177 (68), USNM 562010 (12).

Diagnosis.—A species distinguished by its small size (less than 7.5 mm), narrow ovoid form, and obtusely rounded apex. It is most similar to *P. fontinalis* (Linné) and *P. hordacea* Lea.

Description of types.—Shell small, narrowly ovoid, polished; apex obtusely rounded. Whorls about three, gently and regularly convex, slowly enlarging, at first overlapping; body whorl over three-fourths of total shell length. Suture weakly impressed, slightly descending at first but later more strongly; above periphery of first whorl, at periphery of later whorls. Aperture narrowly elongate; outer lip slightly convex, more strongly so toward base; base strongly rounded; inner lip nearly straight or with a pronouced angle at junction of columella and parietal lip; peristome usually heavily callused in larger specimens, in which case the suture descends slightly at the callus; parietal wall covered by a thin callus. Nucleus smooth; later sculpture of very fine, indistinct growth lines occasionally cut by very faint, short segments of spiral striae between which growth lines may be locally more prominent.

Measurements.—The mean of 21 adult paratypes of 3 whorls is followed by the range in parentheses. These are judged to be adult because they usually have a heavy peristome callus and because specimens with more whorls are rare. Measurements are given in millimeters. Length, 3.7 (3.0–4.3); width, 2.0 (1.7–2.5); length of aperture, 2.2 (1.7–2.6); width of aperture, 1.1 (0.8–1.3).

The measurements in millimeters of 10 Recent specimens from Utah (USNM 533484) are as follows:

Length	*Width*	*Length of aperture*	*Width of aperture*	*Number of whorls*
6.4	3.4	4.0	1.8	3½
6.7	3.7	4.4	2.1	4
7.3	4.0	4.6	2.1	4
6.9	3.7	4.1	2.0	4
7.1	3.9	4.3	2.1	4
6.6	3.6	3.9	1.9	4
6.7	3.7	4.1	2.0	4
6.6	3.6	3.9	1.9	4
7.1	3.9	4.1	1.8	4¼
6.9	3.7	4.0	2.0	4¼

These are the largest specimens seen, in both size and number of whorls.

Variation.—The proportions vary slightly, as indicated by the measurements, but the obtuse apex is constant. In the shorter shells the shallow suture gives an almost unbroken curve from apex to base. Sometimes an earlier peristomal callus is visible through the shell. The callus is accompanied by the usual brief descent of the suture, which thereafter ascends and resumes the former angle of descent.

Distribution.—Alaska southward to northern Utah; eastward across southern Canada to western Ontario and northern Minnesota.

Ecology.—The scanty information from the Recent occurrences suggests this species lives in shallow bodies of water, either perennial or seasonal, such as temporary ponds, sloughs, and backwaters along streams.

Remarks.—A number of Recent series of *P. skinneri* are now known which demonstrate that the species is not extinct, as was first thought, and that it has a wide distribution in North America. This living material also helps to establish the range of variation in *P. skinneri.*

Two of the larger series of adults from the Uinta Mountains, Wyoming and Utah, differ from the type series in being slightly larger, thinner shelled and with weak or absent peristomal calluses. The larger series (USNM uncat., 72 specimens) is from the Heward ranch, Uinta County, Wyo., from a slough by the Bear River 1 mile above the Utah border. Numerous adult shells agree well in proportions with the type series. They attain 3½–4 whorls, and reach a length of 6 mm. There are no peristomal calluses. Sculpture consists of weak growth lines, and many spiral series of very short, axial, impressed lines.

Another lot (USNM 533484, 10 specimens) is from Lost Creek, Summit County, Utah, T. 1 S., R 5 E., 6,000 feet elevation. All ten shells are adult, and larger than those of the type series or those from Uinta County (see measurements). They are also proportionally higher spired, but not more so than the extreme observed in fossil material. Sculpture is as in the Uinta County material. Several individuals have a thin callus around the peristome and another one about ¾–1 whorl earlier. The suture descends slightly to the earlier callus, as it does in the type series.

In the Pleistocene of the Great Plains, *Physa skinneri* is commonly associated with *P. anatina* Lea and *P. gyrina* Say. It differs from these two species in its smaller size, narrower form, obtuse and rounded apex, regularly convex whorls, and proportionally smaller aperture. It apparently has no close relatives living in the Great Plains.

Physa jennessi Dall (1919, p. 20A) differs from *P. skinneri* by being nearly twice as long, with 1–1¼ more whorls, a deeper suture, and a proportionally longer spire and shorter aperture. The columella may be markedly gyrate, a feature not seen in *P. skinneri;* no trace of peristomal callus is visible. The only localities known surely are Bernard Harbor, Northwest Territories (type locality), White Horse, Yukon Territory (USNM 251936), and a pond at lat. 69° 40′ N., long., 141° W., on the coast of Yukon Territory (USNM 251938).

Physa hordacea Lea (1864, p. 116; 1866, p. 176; 1867, p. 132; this paper, pl. 3, figs. 1–4) is similar to *P. skinneri* in size, sculpture and general shape, but has an acute apex instead of a blunt, rounded one. The only known material with precise locality data is the type lot from Columbia River, Vancouver Island, at Vancouver, Clark County, Wash. (USNM 170764, holotype and 111 paratypes).

The European *Physa fontinalis* (Linné) is perhaps the species most closely related to *P. skinneri.* It shares the blunt, rounded apex of the latter, but has usually another whorl and is half again as long. It is proportionally wider, globose rather than narrowly ovoid as is *P. skinneri,* and thus has a wider aperture with the inner lip markedly angular at the junction of columellar and parietal portions.

The grouping of *Physa* species is very diffcult, because the limits of variation of the species are poorly understood, and biological information is not available for more than a very few species, however they are delimited. The relations of *P. skinneri,* as inferred from a single shell character, may be viewed in two ways: The blunt, rounded apex of *P. skinneri* and *P. fontinalis* indicates their close relation. *P. hordacea* is similar only by convergence, for its acute apex indicates a quite different ancestry. *P. hordacea* and *P. skinneri* are so similar that they must be closely related no matter what apical differences there may be. *P. fontinalis* is similar only in the not-too-significant feature of a rounded apex.

When anatomical data are available on the American species, it will be possible to evaluate these shell characters, and perhaps even to recognize subgenera of *Physa.*

Types.—Holotype UMMZ 181292, Berends local fauna. Paratypes UMMZ 177533 (31), MCZ 198177 (68), USNM 562010 (12).

Occurrence: Sand Draw, Dixon, and Sanders local faunas. Sand Draw loc. 2, USGS 19090–4 (9); loc. 3, UMMZ 177339 (100); loc. 4, UMMZ 177322 (3); loc. 5, CNHM PE3433 (3), UMNH P6787 (3), UMMZ 181137 (25), 181232 (100); loc. 6, UMMZ 177433 (4), 181216 (100); loc. 7, UMMZ 177233 (20); Dixon loc. 1, UMMZ 182208 (36); loc. 2, UMMZ 191518 (22); Sanders loc. 1, UMMZ 182150 (1); loc. 3, UMMZ 182-182 (4).

Genus APLEXA Fleming, 1820

Aplexa hypnorum (Linnaeus), 1758

Aplexa hypnorum (Linné). Baker, 1928, Wisconsin Geol. Nat. History Survey Bull. 70, pt. 1, p. 473, pl. 19, fig. 1–4.

Taylor, 1954, Michigan Univ. Mus. Zool. Occ. Papers 557, p. 15.

Distribution.—Holarctic. In North America "* * * from east of the Cascade Mountains to the Atlantic and from Alaska and Hudson Bay south to the vicinity of the Ohio River" (Baker, 1928, p. 474).

Ecology.—"*Aplexa hypnorum* is a species of swales and intermittent streams or stagnant pools in Wisconsin, as far as present data goes. It is especially abundant in woodland pools which become dry in summer * * *" (Baker, 1928, p. 474). In northern Nebraska it was locally abundant in roadside drainage ditches with temporary water.

Occurrence and material: Sand Draw and Sanders local faunas; Recent in northern Nebraska. Sand Draw loc. 3, UMMZ 181202 (1); loc. 4, UMMZ 177323 (2); loc. 5, UMMZ 181138 (100), 181233 (300); loc. 6, UMMZ 181217 (1); Sanders loc. 1, UMMZ 182151 (16).

Order STYLOMMATOPHORA

Family STROBILOPSIDAE

Genus STROBILOPS Pilsbry, 1893

Subgenus STROBILOPS s. s.

Strobilops (s. s.) labyrinthica (Say), 1817

Plate 1, figures 5, 6

Strobilops labyrinthica (Say). Pilsbry, 1948, Acad. Nat. Sci. Philadelphia Mon. 3, v. 2, pt. 2, p. 854, fig. 463.

Strobilops cf. *labyrinthica.* Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151 [in part: Seward County loc.].

Strobilops sparsicosta Baker. Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151 [in part: Seward County loc.].

Distribution.—"Maine and Quebec west to Manitoba, Minnesota, Kansas and Arkansas, south to Georgia and Alabama" (Pilsbry, 1948, p. 854).

Ecology.—"Its usual stations are 'under loose bark of logs, in half-decayed wood, among dead leaves and in sod at bases of trees'" (Pilsbry, 1948, p. 854).

Remarks.—Specimens from the Saw Rock Canyon local fauna differ from *S. texasiana* and *S. sparsicostata*, and agree with *S. labyrinthica*, in that the axial riblets are small, not widely spaced, and usually cover about half the base, and also that the parietal lamellae enter only one-half whorl. They are also smaller (diameter 2.5 mm.) than *S. sparsicostata* topotypes or referred specimens. These specimens are thus considered referable to *S. labyrinthica.*

Sculpture on the base is variable. The riblets may pass over the periphery to cover the whole base, or only about a quarter of a whorl behind the aperture. Ten specimens were dissected for examination of the basopalatal folds. These folds are as usual for the *S. labyrinthica-texasiana* group; they differ from those observed in *S. sparsicostata* topotypes in that the first and second basals are not so large, the third through fifth basopalatals are stronger, and the sixth basopalatal is sometimes absent. Six specimens examined have parietal lamellae entering half a whorl.

Frye and Leonard (1952) reported *S. cf. labyrinthica* in association with *S. sparsicostata* from the Saw Rock Canyon local fauna. University of Michigan material from the same locality justifies recognition of only one species, *S. labyrinthica* (Say).

For discussion of the differences between *S. labyrinthica* and *S. sparsicostata*, see under the latter species.

Occurrence and material: Saw Rock Canyon local fauna. UMMZ 177561 (35).

Strobilops (s. s.) sparsicostata Baker, 1938

Plate 1, figures 7–10

Strobilops sparsicostata Baker, 1938, Nautilus, v. 51, p. 127. Smith, 1940, Kansas Geol. Survey Bull. 34, p. 98.
Leonard, 1957, Illinois Geol. Survey Report of Investigations 201, p. 18, pl. 1, fig. 4–6.

Strobilops sparsicostata F. C. Baker. Hibbard, 1941, Kansas Univ. Sci. Bull., v. 27, p. 95.
Hibbard, 1941, Kansas Acad. Sci. Trans., v. 44, p. 265.
Frye and Hibbard, 1941, Kansas Geol. Survey Bull. 38, p. 408.

Strobilops sparsicosta Baker. Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151 [in part: Meade County loc.].

Strobilops densecostata F. C. Baker. Pilsbry, 1948, Acad. Nat. Sci. Philadelphia Mon. 3, v. 2, pt. 2, p. 851 [lapsus for *sparsicostata*].

Strobilops cf. *labyrinthica.* Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151 [in part: Meade County loc.].

Types.—Holotype UIMNH P6774, Rexroad loc. 3. Paratypes UIMNH P6774 (51), P6775 (4), ANSP 169886 (not found).

Diagnosis.—A *Strobilops* (s.s.) characterized by 5–6 strongly unequal basopalatal folds, the sixth (when present) above the periphery, and by axial sculpture of strong, widely spaced riblets not extending onto the base of the shell.

Description.—Shell broadly conic, subangular at periphery. Whorls about 5½, embryonic 1½ weakly and finely granular with faint axial striation; later whorls with axial riblets, small and closely but irregularly spaced from 1½–3 whorls, becoming stronger and wider spaced thereafter; last 2 whorls with strong, irregularly and widely spaced riblets, occasionally with 1 or 2 weak riblets between. Base smooth, or with a few weakening riblets extending over the periphery on the last quarter whorl; umbilicus contained 7 times in shell diameter. Aperture roughly semicircular, with a prominent, massive, parietal lamella extending forward to fuse with a thick parietal callus; a low, inconspicuous, infraparietal lamella almost reaching the parietal callus, visible externally; lip reflected, thickened. Parietal and infraparietal lamellae entering three-fourths of a whorl; a weak interparietal lamella about a quarter whorl long nearly reaching the inner ends of the other parietal lamellae; interparietal and inner halves of parietal and infraparietal lamellae with prickly nodes at intervals of about 1½ times their length; columellar lamella low, about half a whorl long, beginning at about a quarter whorl within aperture, increasing and decreasing in size gradually; basopalatal folds parallel, arranged in an arc from about two-thirds of a whorl within aperture nearest the columella to one-third of a whorl within at the periphery, 5–6 in number, the sixth above the periphery if present; first 2 basal folds much larger than others, the first nearly horizontal, roughly triangular or tongue shaped, the second longer, erect, lamellar; other folds short and low, the sixth basopalatal weak or absent.

Measurements. — Five randomly chosen topotypes measure as follows, the mean being followed by the range in parentheses. Measurements are in millimeters. Length, 2.26 (2.1–2.5); width, 2.70 (2.6–2.8); number of whorls, 5.5 (5¼–5¾).

Variation.—The chief observed variables are axial ribbing and basopalatal folds. Most of the major series of riblets extend from suture to periphery, at least. Some are shorter, however, and reach only halfway to the periphery from suture, or vice versa. The minor series is variably developed, from none to two small riblets being present between the larger ones. The columellar lamella varies in length and size. Both first and second basal folds vary greatly in size and shape. The first is usually subhorizontal, but sometimes nearly erect; almost always shorter than the second basal fold, never longer; and triangular to linguiform. The second basal fold varies chiefly in slope of its ends; these may slope equally, or either one may be steeper. The upper side of the fold may be parallel to the base for much of its length, or it may slope toward the ends from a subcentral point. The sixth basopalatal fold may be present or absent. Two specimens have supernumerary basopalatal folds between the first and second (recognized by their characteristic shape and position) of a more usual series. One specimen has a small, tubercular fold approximate to the second basal and fused to the peripheral end of the first basal fold. Other basopalatal folds in this specimen are typical. The other specimen has 4 supernumerary basopalatal folds, 3 between the first and second of the usual series, 1 between the second and third. The most axiad supernumerary fold is fused to the first basal fold, but the next two are distinct. The fourth supernumerary fold is fused to the second basal fold. The third basal is present and typical, but the fourth through sixth are absent. (The description and the above discussion of variation are based on about 250 topotypes, UMMZ 183032; 15 specimens were dissected to observe the basopalatal folds, 10 for the parietal lamellae.)

Distribution.—Middle Pliocene to lower Pleistocene (perhaps middle Pleistocene also) of the High Plains.

Remarks.—*Strobilops sparsicostata* is closely related to both *S. labyrinthica* (Say) and *S. texasiana* Pilsbry and Ferriss. It differs from *S. labyrinthica* by the slightly larger size, deeper penetration of the parietal lamellae, coarser and more widely spaced axial riblets, and sometimes smoother base. It differs from *S. texasiana* in the slightly larger size and smooth base.

Frye and Leonard (1952) reported *S. cf. labyrinthica* in association with *S. sparsicostata* from Rexroad localities 2 and 3. University of Michigan material from locality 3 justifies recognition of only *S. sparsicostata*, and for this reason both references to *S. cf. labyrinthica* are assigned to *S. sparsicostata*.

Leonard (1950, 1952) has reported *S. sparsicostata* from middle Pleistocene deposits, but I have not examined material from these higher levels.

Occurrence: Buis Ranch, Red Corral, Rexroad, Sand Draw and Dixon local faunas.

Discussion of material: Rexroad loc. 1, UMMZ 183058 (1). The single, juvenile (3¾ whorls) specimen shows coarse ribbing, and may be referred to *S. sparsicostata*.

Rexroad loc. 4b, UMMZ 181056 (1). The single specimen (adult) was not dissected, but is similar to *S. sparsicostata* topotypes in external features.

Buis Ranch, UMMZ 181116 (3). The material consists of 3 adult body whorls only, 2 slightly broken. The axial riblets are as strong as those in *S. sparsicostata* topotypes, and stronger than those of *S. labyrinthica*. They are spaced more widely than those of *S. labyrinthica* and more closely than those of *S. sparsicostata* topotypes. The one specimen on which the adult diameter can be measured is 2.7 mm in diameter, larger than *S. labyrinthica* but within the size range of *S. sparsicostata* topotypes. Only one specimen retains the parietal lamella; it enters three-fourths of a whorl, as in *S. sparsicostata*. This material is referred to *S. sparsicostata*.

Red Corral, UMMZ 182999 (1). The single specimen (adult) was not dissected, but is similar to *S. sparsicostata* topotypes in external features.

Sand Draw loc. 2, UMMZ 184178 (11). A series of specimens has ribs weaker than in *S. sparsicostata* topotypes but stronger than those of *S. labyrinthica*. These specimens agree with *S. sparsicostata* and differ further from *S. labyrinthica* in size (diameter 2.7–2.8 mm) penetration of the parietal lamellae for a distance of three-fourths whorl, and smoothness of base. They are therefore referred to *S. sparsicostata* for the present.

Sand Draw loc. 3, UMMZ 181203 (2). Two specimens (one adult, one subadult) agree in external features with those from Sand Draw loc. 2. The inner ends of the parietal lamellae of the adult are broken away.

Dixon loc. 1, UMMZ 182213 (3). The single adult specimen was not dissected. It agrees with *S. sparsicostata* topotypes and differs from *S. labyrinthica* in the following respects: large size (diameter 2.9 mm), smooth base, and widely spaced riblets. The strength of the riblets is, however, intermediate between that of *S. sparsicostata* and *S. labyrinthica*. Specimens from the Dixon local fauna are referred to *S. sparsicostata* for the present.

Family PUPILLIDAE

Subfamily GASTROCOPTINAE

Genus GASTROCOPTA Wollaston, 1878

Subgenus GASTROCOPTA s. s.

Gastrocopta (s. s.) procera (Gould), 1840

Plate 1, figure 27

Gastrocopta procera (Gould). Pilsbry, 1948, Acad. Nat. Sci. Philadelphia Mon. 3, v. 2, pt. 2, p. 907, fig. 492:1–5.
Gastrocopta procera (Gould). Franzen and Leonard, 1947, Kans. Univ. Sci. Bull., v. 31, p. 341 [in part], pl. 18, fig. 3 [not fig. 6].

Distribution.—Maryland to South Carolina and Alabama; west to South Dakota and Arizona (Pilsbry, 1948, p. 907, 910).

Ecology.—"This pupillid lives on timbered slopes of streams. Its general distribution in Kansas indicates an ability to withstand periods of summer drought" (Franzen and Leonard, 1947, p. 342).

Remarks.—For discussion of the species and of this material see under *G. franzenae*.

Occurrence and material: Dixon local fauna. Dixon loc. 1, UMMZ 182217 (1); loc. 2, UMMZ 191520 (11).

Gastrocopta (s. s.) franzenae[4] Taylor, n. sp.

Plate 1, figure 29

Gastrocopta cristata Pilsbry and Vanatta. Hibbard, 1941, Kansas Univ. Sci. Bull., v. 27, p. 95 [not of Pilsbry and Vanatta].
Hibbard, 1941, Kansas Acad. Sci. Trans. v. 44, p. 265 [not of Pilsbry and Vanatta].
Frye and Hibbard, 1941, Kansas Geol. Survey Bull. 38, p. 408 [not of Pilsbry and Vanatta].
Gastrocopta cristata (Pilsbry and Vanatta). Franzen and Leonard, 1947, Kansas Univ. Sci. Bull., v. 31, p. 344 [in part: Rexroad fauna material. Not of Pilsbry and Vanatta].
Gastrocopta procera (Gould). Franzen and Leonard, 1947, Kansas Univ. Sci. Bull., v. 31, p. 341 [in part: Saw Rock Canyon fauna material], pl. 18, fig. 6 [not of Gould].

[4] Named for Dr. Dorothea S. Franzen.

Types.—Holotype: UMMZ 183033a, Rexroad loc. 3. Hypodigm: Material from Saw Rock Canyon, Red Corral, and Rexroad local faunas and from Bender local fauna localities 1b and 2 in University of Michigan collections.

Diagnosis.—A *Gastrocopta* of the *G. cristata* group with a strong labial callus, an anguloparietal lamella either bifid or simple; some individuals with a tubercle on the outer lip.

Distribution.—Upper Pliocene of the southern High Plains.

Remarks.—Late Pliocene samples of the *Gastrocopta cristata* group are unusual in that several populations include the diagnostic characters of distinct, Recent species, as well as characters not found in these living species. For reasons set forth below, the late Pliocene populations are considered representative of an extinct, probably ancestral species.

Gastrocopta cristata and *G. procera* are two wide-ranging Eastern North American land snails of similar habitat. Each occurs separately in much of its range, but the 2 are also found together in a large area (see under the 2 species for details of distribution). They are now distinct species, although closely related; and their association in the Nebraskan age Dixon local fauna indicates their separate status throughout nearly the entire Pleistocene epoch.

Distinction of these two species is based chiefly on the anguloparietal lamella (straight or slightly sinuous in *G. cristata*, bifid in *G. procera*) and on the labial callus (weak or absent in *G. cristata*, strong in *G. procera*). Other, less diagnostic features are the stronger, more proximal crest and greater diameter of *G. cristata* shells. Late Pliocene samples, however (especially those from the Rexroad local fauna), are markedly more variable than Recent series. The Pliocene samples include shells like those of *G. cristata* and *G. procera*, specimens intermediate in the degree of fusion of the anguloparietal lamella (not seen in Recent or Pleistocene material), shells like *G. cristata* but with a strong labial callus as in *G. procera*, and shells like *G. procera* but with a strong tubercle on the outer lip next to the sinulus. The frequency distributions of these character combinations suggest that only one population is represented in the Rexroad local fauna and at Bender local fauna localities 1b and 2. The sample from Saw Rock Canyon is inadequate for analysis.

In figure 2, Pliocene specimens of the *Gastrocopta cristata* group are distributed according to arbitrarily selected segments of the range of variation of two characters: development of the labial tubercle (absent, weak, or strong), and degree of fusion of the anguloparietal lamella (straight or slightly sinuous, strongly

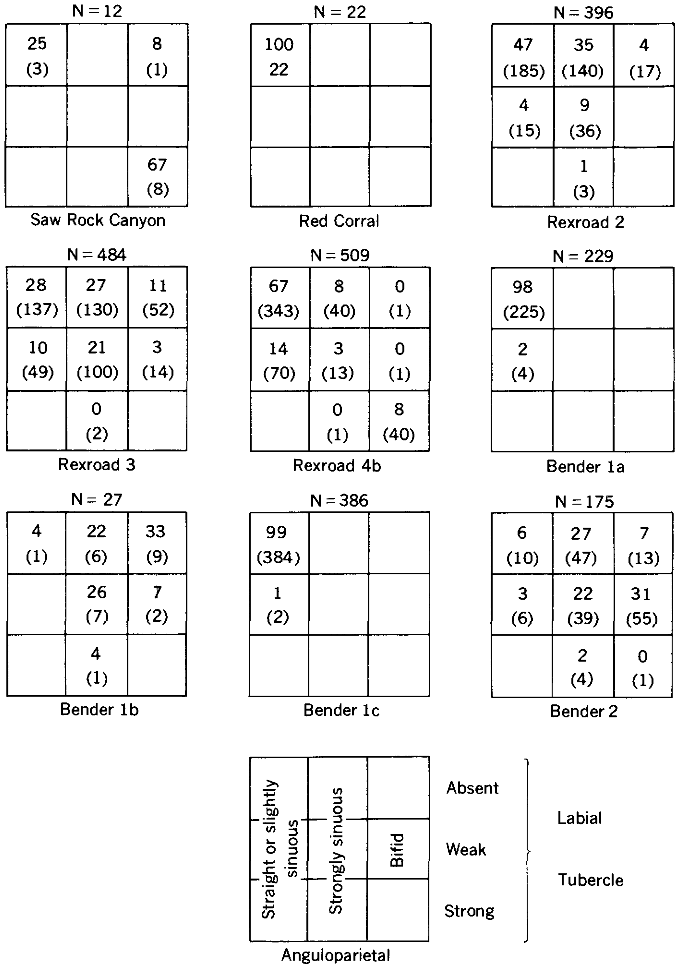

FIGURE 2.—Frequency distribution of Pliocene *Gastrocopta cristata* group.

sinuous, or bifid). The groups with straight and bifid anguloparietal lamella were established to correspond with the range of variation in Recent *G. cristata* and *G. procera*, respectively.

The Rexroad local fauna has yielded ample series from three localities. Each series is considered representative of but one population. The slight bimodality in the locality 4b sample is ascribed to error and (or) intraspecific variation. The general similarity between the three populations is such that reference to one species is justified. Contemporaneity of these three is established to the degree of refinement possible by mammalian and stratigraphic correlation; but within such limits there is surely enough time that minor genetic changes may account for some or all of the observed differences.

The holotype of *G. franzenae* is selected from the specimens intermediate in development of labial callus and in degree of fusion of the anguloparietal lamella.

The Saw Rock Canyon sample, although inadequate, is of interest because two-thirds of the specimens have a bifid anguloparietal lamella and a strong labial tubercle. This combination of characters is markedly infrequent in other samples. In this connection it should be noted that apparently all specimens from this locality available to Franzen and Leonard (1947, p. 341) are of this extreme type.

The Red Corral sample is also inadequate. All shells are similar to *G. cristata*, except that some have a strong labial callus. The material is believed representative of a population similar to those of the Rexroad local fauna, however; observed differences may be accounted for by geographic separation of the sample sites, possible temporal difference between the samples, small size of the Red Corral sample, and large percentage of similar shells in the Rexroad locality 4b sample.

Bender local fauna samples are considered significantly different among themselves. Localities 1a, 1b, and 1c are about one-eighth of a mile apart and at the same stratigraphic horizon. There is presumably some difference in mean age of the three samples, but it is considered inadequate to account for the striking differences observed. Material from localities 1a and 1c is referred to one population (*G.* cf. *cristata*), similar to *G. cristata* but with frequent development of a strong labial callus. This strong callus occurs in a smaller percentae of specimens than it does in the Rexroad local fauna. Locality 1b material is believed to represent another population, referred to *G. franzenae*. Bender locality 2 material is referred to *G. franzenae* also.

Early Pleistocene samples (Sand Draw, Dixon, Sanders local faunas) of the *G. cristata* group are all typical of the Recent *G. cristata* and *G. procera*. Large series of *G. cristata* from the Sanders local fauna have a straight or slightly sinuous anguloparietal lamella and no strong labial callus; the same is true of a small series from Dixon and two specimens from Sand Draw. One specimen of *G. procera* from Dixon has a bifid anguloparietal lamella, thick labial callus, and no labial tubercle.

Gastrocopta franzenae is a satisfactory structural ancestor for both *G. cristata* and *G. procera*. for its range of variation includes specimens similar to both of these Recent species. Further support for a *franzenae-cristata* and *procera* lineage is the presence at Bender localities 1a and 1c of a population intermediate between *G. franzenae* and *G. cristata*, but apparently distinct from associated *G. franzenae*. Specimens from Bender localities 1a, 1b, and 1c may therefore have lived shortly after the derivation of *G. cristata* from *G. franzenae*.

The evidence is inconclusive, but does suggest that *G. franzenae* gave rise to both *G. procera* and *G. cristata* during the late Pliocene, that it became extinct shortly thereafter (perhaps with the climatic changes associated with the onset of continental glaciation), and that the two descendants have lived to the present day. The time, place, and method of origin of the two younger species are uncertain. The Bender sample suggests that *G. franzenae* had already given rise to a species with which it did not interbreed, and which has subsequently changed into *G. cristata*. *G. procera*, if already distinct, is not known from this interval.

One possible method of origin of the two descendants is by selection of their particular gene combinations from the *G. franzenae* "pool". There seems no need to postulate mutation, although this may have occurred. Assuming that the labial tubercle is genetically produced, its genes were left behind in selecting out *G. cristata* and *G. procera*. The evolution of the two species may possibly have been caused by climatic changes which "filtered" them out of *G. franzenae*.

Occurrence and material: Saw Rock Canyon, Red Corral, Rexroad, and Bender local faunas. Saw Rock Canyon, UMMZ 177516 (1), 177563 (9), 183654 (2); Red Corral, UMMZ 183-001 (24); Rexroad loc. 2, UMMZ 183068 (575); loc. 3, UMMZ 183033 (825); loc. 4b, UMMZ 177601 (371), 181052 (509); Bender loc. 1b, UMMZ 184136 (31); loc. 2, UMMZ 184153 (175).

Gastrocopta (s. s.) cristata (Pilsbry and Vanatta), 1900

Plate 1, figures 24–26

Gastrocopta cristata Pilsbry and Vanatta. Baker, 1938, Nautilus v. 51, p. 130.
Gastrocopta cristata. McGrew, 1944, Field Mus. Nat. Hist. Geol. Ser., v. 9, p. 36.
Gastrocopta cristata (Pilsbry and Vanatta). Franzen and Leonard, 1947, Kansas Univ. Sci. Bull., v. 31, p. 344, pl. 19, fig. 1; pl. 20, fig. 1.
Pilsbry, 1948, Acad. Nat. Sci. Philadelphia Mon. 3, v. 2, pt. 2, p. 911, fig. 493:6, 8–12.

Distribution.—Northern Nebraska to southern Texas, west to Arizona.

Ecology.—"Gastrocopta cristata has, in Kansas, usually been found associated with *G. procera* (Gould) on timbered slopes near streams" (Franzen and Leonard, 1947, p. 345). In northern Brown County, Nebr., it was found in a wooded ravine, among damp leaves and dead wood.

Remarks.—The Recent specimens from Nebraska differ from other material examined in being paler and in lacking a subcolumellar tubercle. These differences probably represent normal variation, rather than specific characters.

The record by Taylor (1954a, p. 12) of this species in the Clarendonian Laverne local fauna is considered erroneous. The single specimen (UMMZ 181273) shows no trace of coloring on the peristome, as do all the other fossil *Gastrocopta* from the same locality. It is almost surely a Recent specimen. The only species of *Gastrocopta* (s. s.) known in the Laverne local fauna are *G. riograndensis* (Pilsbry and Vanatta) (Franzen and Leonard, 1947, p. 349, and University of Michigan collections) and *G. lavernensis* Taylor (1954a, p. 11).

For discussion of fossil material see under *G. franzenae*.

Occurrence and material: Bender, Sand Draw, Sanders, and Dixon local faunas; Recent in northern Nebraska. Sand Draw loc. 5, CNHM PE3437 (1); loc. 6, UMMZ 177435 (1); Dixon loc. 1, UMMZ 182216 (36); loc. 2, UMMZ 191519 (2); Sanders loc. 1, UMMZ 182153 (400); loc. 2, UMMZ 182167 (125); loc. 3, UMMZ 182183 (600). *G. cf. cristata:* Bender loc. 1, UMMZ 177506 (111); loc. 1a, UMMZ 184122 (1750); loc. 1c. UMMZ 183015 (2000).

Gastrocopta (s. s.) paracristata Franzen and Leonard, 1947, emend.

Plate 1, figures 31, 32

Gastrocopta paracristata Franzen and Leonard, 1947, Kansas Univ. Sci. Bull., v. 31, p. 346, pl. 19, fig. 2, 3 [in part: dextral shells only].
Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151.

Types.—Holotype UKMNH 3929, Rexroad loc. 4b. Paratypes UKMNH.

Diagnosis.—A *Gastrocopta* of the *G. cristata* group with massive folds and lamellae, three equally immersed platal folds adjacent to the palatal callus, and no subcolumellar lamella.

Description of holotype.—"Shell elongate-oval, summit obtuse; rimate, minutely perforate; suture sharply and deeply incised; whorls 5¾; convex, regularly and slowly increasing in size; the 1½ nuclear whorls finely granular; remaining whorls finely and irregularly striate; height of body whorl less than one-half of the total height of the shell, constricted at the base and expanding rapidly toward the aperture; prominent, rounded crest paralleling the peristome from which it is somewhat removed; aperture rounded, slightly oblique, expanding toward the peristome; denticles 5: a fused, sinuous, anguloparietal, the angular portion continuous with a parietal callus and outer lip; 3 equally entering palatal folds, connected anteriorly by a low callus, a tubercular upper palatal, a higher, elongate lower palatal, its highest point about midway of its length, and a low, tubercular basal fold; the columella lamella high, elongate, entering horizontally and ascending the spire at its extreme innermost portion; peristome reflected, thickened along its inner border, margin sharp" (Franzen and Leonard, 1947, p. 346).

Measurements.—Franzen and Leonard gave dimensions of five specimens from the type series. The mean of these (in millimeters) is followed by the range in parentheses. Length, 3.0 (2.7–3.4); width, 1.4 (1.3–1.5); length of aperture, 1.1 (0); width of aperture, 1.0 (0.9–1.1); number of whorls, 5.9 (5¼–6½).

Variation.—"The range in height of the shells of *Gastrocopta paracristata* is from 2.7 mm to 3.4 mm. The width varies independently of the height, therefore, shells vary in shape from elongate-ovate to elongate-conic. The basal fold, usually prominent, is sometimes very low and occasionally wanting. The callus of the peristome varies in prominence. A prominent, rounded crest on the ultimate whorl, paralleling the peristome is usually present, rarely wanting, sometimes low and sharp. The distance between the peristome and the center of the crest varies from 0.5 to 0.25 mm." (Franzen and Leonard, 1947, p. 347).

Distribution.—Upper Pliocene and lower Pleistocene of the High Plains.

Remarks.—Sinistral specimens from the SW¼ sec. 22, T. 33 S.; R. 29 W., Meade County, Kans., were included in *G. paracristata* by Franzen and Leonard in their original description of the species. These sinistral specimens are described as *G. scaevoscala* Taylor, n. sp., in this report.

Occurrence and material: Saw Rock Canyon, Red Corral, Rexroad, Bender, and Sanders local faunas. Saw Rock Canyon, UMMZ 173590 (1), 177562 (35), USGS 19089-5 (1); Red Corral, UMMZ 183003 (1); Rexroad loc. 1, UMMZ 183060 (1); loc. 2, UMMZ 183071 (8); loc. 3, UMMZ 183036 (10); loc. 4b, UMMZ 177602 (35), 181051 (50); Bender loc. 1, UMMZ 177507 (114); loc. 1a, UMMZ 184124 (600); loc. 1b, UMMZ 184138 (300); loc. 1c, UMMZ 184145 (150); loc. 2, UMMZ 184154 (200); Sanders loc. 1, UMMZ 182154 (27); loc. 2, UMMZ 182168 (1).

Gastrocopta (s. s.) scaevoscala Taylor, n. sp.[5]

Plate 1, figures 33, 34

Gastrocopta paracristata Franzen and Leonard, 1947, Kansas Univ. Sci. Bull., v. 31, p. 346–347 [in part: sinistral specimens].

Types.—Holotype UMMZ 184320, Bender loc. 1. Paratypes UMMZ 184125 (9), 183017 (13).

Diagnosis.—A sinistral *Gastrocopta* of the *G. cristata* group with massive folds and lamellae, three equally immersed palatal folds adjacent to the palatal callus, no subcolumellar lamella, slightly ascending columellar lamella, and relatively steeply inclined suture.

Description.—The shell is so similar to *G. paracristata* that it can be described best by comparison. It differs from *G. paracristata* by its sinistral coiling, more steeply inclined suture, and gradually ascending columellar lamella.

Measurements.—The mean of the 11 whole specimens in the type series is followed by the range in parentheses. Measurements are in millimeters. Length, 2.82 (2.6–2.9); length of aperture, 0.97 (0.9–1.0); width, 1.28 (1.2–1.3); width of aperture, 0.88 (0.8–0.9); number of whorls, 5.7 (5¼–6).

Variation.—*G. scaevoscala* seems relatively invariable, but this may be an artifact of small sample size. Observed variation is like that in *G. paracristata*: in size (see measurements), prominence of basal fold and crest, and in degree of fusion of the anguloparietal lamella.

Distribution.—Latest Pliocene and early Pleistocene of southern Kansas.

Remarks.—The record of sinistral *Gastrocopta paracristata* in the Rexroad local fauna (Franzen and Leonard, 1947, p. 347) is almost certainly based on *G. scaevoscala* from the Bender local fauna. University of Michigan collections from both assemblages contain the sinistral *G. scaevoscala* from the Bender local fauna only. University of Kansas material reported from the SW¼ sec. 22, T. 33 S., R. 29 W., Rexroad Ranch, Meade County, is largely from Bender localities 1a, 1b, and 1c, according to C. W. Hibbard (written communication Nov. 29, 1954), who helped collect the fossils.

G. scaevoscala is apparently the only sinistral species of *Gastrocopta* (s. s.), although the subgenera *Immersidens* and *Sinalbinula* have such forms. The similarity to *G. paracristata* suggests it is a species derived through mutation in direction of coil, and so reproductively isolated. The differences indicated in the description are minor, but constant, so that it is difficult to regard the specimens from the Bender local fauna simply as sinistral individuals of *G. paracristata*. Furthermore, *G. scaevoscala* occurs in the Dixon local fauna unaccompanied by *G. paracristata*.

Occurrence and material: Bender and Dixon local faunas. Bender loc. 1, UMMZ 184320 (1); loc. 1a, UMMZ 184125 (9, only 4 whole); loc. 1c, UMMZ 183017 (13, only 7 whole); Dixon loc. 2, UMMZ 191522 (6).

Gastrocopta (s. s.) chauliodonta Taylor, 1954

Plate 1, figures 11–16

Gastrocopta chauliodonta Taylor, 1954, Michigan Univ. Mus. Zool. Occ. Papers 557, p. 12, 15.

Types.—Holotype UMMZ 181120, Sand Draw loc. 6. Paratypes UMMZ 181121 (11).

[5] L. *scaevus*, on or toward the left, *scala*, flight of stairs.

Diagnosis.—A species most closely related to the lower Pliocene *Gastrocopta lavernensis* Taylor and to the Recent *G. curacoana* Pilsbry. It is characterized by the massive anguloparietal lamella which almost hides the deeply immersed palatal folds, the descending columellar lamella, the absence of a subcolumellar lamella, and the relatively broad, cylindrical form.

Description of types.—Shell small, cylindric, rimate; apex obtuse. About 5½ whorls, convex, slowly and regularly enlarging; sutures strongly impressed; body whorl less than half of total shell length, about one-half whorl behind aperture becoming flattened and then slightly concave in the middle of the outer side, convex again at a prominent, rounded crest just behind the reflected peristome. Sculpture of nuclear whorl minutely granular; postnuclear sculpture of fine, irregular, oblique growth lines. Aperture slightly oblique, rounded, with dentition of five folds and lamellae, as follows: a prominent, massive, sinuous anguloparietal lamella, gradually increasing in height and terminating abruptly, the angular part continuous with the parietal lip; a deeply immersed, small, lamelliform upper palatal fold of about equal length and height; a still more deeply immersed (dorsal in position) long, angulate, deeply entering, lower palatal fold, of about the same height as the upper palatal fold, increasing in height abruptly and decreasing gradually, the outer third ascending slightly, the inner two-thirds approximately parallel to the base and roof of the body whorl; a tubercular basal fold immersed equally with, or slightly more than, the lower palatal fold; all palatal folds situated well behind the palatal callus; columellar lamella heavy, elongate, descending the columella to its base. Inner and outer lips heavily callused except in the conspicuous sinulus.

Measurements.—The mean of the 11 whole specimens in the type series is followed by the range in parentheses. Measurements are given in millimeters. Height, 2.51 (2.2–2.7); width, 1.22 (1.1–1.3); height of aperture, 0.86 (0.7–0.9); width of aperture, 0.87 (0.8–0.9); number of whorls, 5½ (5–6).

Variation.—The anguloparietal lamella varies in shape considerably. Usually the angular part is represented by a slightly prominent ridge which gives the lamella a sinuous appearance; sometimes this ridge is curved toward the outer lip and the lamella is bifid, the sinulus almost completely enclosed; occasionally the whole lamella is nearly straight. The anguloparietal varies in width also, from about one-fourth to one-sixth of the internal width of the aperture. The columellar lamella may enter horizontally, in which case the inner half turns downward abruptly, or it may descend gradually.

Distribution: Lower Pleistocene of the High Plains.

Remarks.—*Gastrocopta chauliodonta* appears most nearly related to *G. lavernensis* Taylor, 1954, from the Pliocene of Oklahoma, and *G. curacoana* Pilsbry, 1924, living in the Dutch West Indies. It differs from the former by its more massive lamellae and peristome callus, simpler anguloparietal lamella, more deeply immersed basal fold, and lamelliform upper palatal fold. It differs from *G. curacoana* (see Pilsbry, 1922–26, p. 202–204) by its less tapering shape and more conspicuous anguloparietal lamella.

The long, deeply immersed lower palatal fold and the descending columellar lamella of *Gastrocopta chauliodonta*, *G. lavernensis*, and *G. curacoana* might be considered evidence indicating close relationship with *Immersidens*, which sometimes has these characters. These species agree with *Gastrocopta* s. s. in the differentiating characters of apertural callus and simpler anguloparietal lamellae, however. *G. octonaria* Pilsbry (1922–26, p. 204–205) is transitional from this species group to others of *Gastrocopta* s. s. by having a subcolumellar lamella partially united with the columellar. This fact, and the greater development of the columellar lamella in *Immersidens*, suggests that the descending columellar lamella of the *G. curacoana* group may represent a fusion of columellar and subcolumellar lamellae, whereas in *Immersidens* the descending columellar lamella originated as a unit.

Occurrence and material: Sand Draw, Dixon, and Sanders local faunas. Sand Draw loc. 2, USGS 19090–5 (23); loc. 3, UMMZ 181204 (1); loc. 6, UMMZ 181120 (1), 181121 (11), 181218 (1); loc. 7, UMMZ 177236 (2½); Dixon loc. 1, UMMZ 182215 (13); Sanders loc. 1, UMMZ 182152 (30).

Gastrocopta (s. s.) pellucida hordeacella (Pilsbry), 1890

Plate 1, figure 28

Gastrocopta pellucida hordeacella (Pilsbry). Franzen and Leonard, 1947, Kansas Univ. Sci. Bull., v. 31, p. 349, pl. 19, fig. 8.

Pilsbry, 1948, Acad. Nat. Sci. Philadelphia Mon. 3, v. 2, pt. 2, p. 913, fig. 494:a–d, 495.

Pilsbry, 1953, Acad. Nat. Sci. Philadelphia Proc., v. 105, p. 162.

Distribution.—Southern and Baja California (locally) through southeast Colorado and Kansas to Florida; south to Sinaloa and Tampico, Mexico; north on the Atlantic Coastal Plain to southern New Jersey (Franzen and Leonard, 1947; Pilsbry, 1948, 1953). "The northward extension along the Atlantic Coast is very narrow, discontinuous so far as known, and perhaps mainly confined to the coastal islands" (Pilsbry, 1948, p. 914).

Ecology.—Uncertain. From the geographic distribution, frequent occurrence in stream drift in the southern Great Plains, and occasional occurrence in samples of fossils washed from bulk collections of matrix it appears this species may live among the grass roots, occasionally even on exposed slopes. So far as known, the snail has not been collected alive in the Plains.

Occurrence and material: Red Corral, Rexroad, and Dixon local faunas. Red Corral, UMMZ 183002 (4); Rexroad loc. 3, UMMZ 183037 (3); Dixon loc. 2, UMMZ 191521 (3).

Subgenus ALBINULA Sterki, 1892

Gastrocopta (Albinula) armifera (Say), 1821

Gastrocopta armifera (Say). Franzen and Leonard, 1947, Kansas Univ. Sci. Bull., v. 31, p. 328, pl. 17, fig. 3–5.
Pilsbry, 1948, Acad. Nat. Sci. Philadelphia Mon. 3, v. 2, pt. 2, p. 874, fig. 472:1–4.

Distribution.—Quebec to northern Florida, west to the Rocky Mountains (Pilsbry, 1948, p. 875).

Ecology.—"*Gastrocopta armifera* is a gregarious species occurring commonly on wooded slopes, near or removed from a stream. It is to be found under dead wood, limestone rocks, or light cover of leaf mold or other debris. *G. armifera* frequently occurs under boards or rocks in gardens" (Franzen and Leonard, 1947, p. 329). In northern Nebraska it was found under logs, barks, and stones in moist grass around seepages.

Occurrence and material: Dixon local fauna; Recent in northern Nebraska. Dixon loc. 1, UMMZ 182214 (10).

Gastrocopta (Albinula) holzingeri (Sterki), 1889

Gastrocopta holzingeri (Sterki). Hibbard, 1941, Kansas Univ. Sci. Bull., v. 27, p. 95.
Hibbard, 1941, Kansas Acad. Sci. Trans., v. 44, p. 265.
Frye and Hibbard, 1941, Kansas Geol. Survey Bull. 38, p. 408.
Pilsbry, 1948, Acad. Nat. Sci. Philadelphia Mon. 3, v. 2, pt. 2, p. 883, fig. 474:4–6, 475.
Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151.
Gastrocopta holzingeri Sterki. Franzen and Leonard, 1947, Kansas Univ. Sci. Bull., v. 31, p. 333, pl. 18, fig. 2.

Distribution.—"Ontario and western New York to Helena, Montana, south to Illinois, Kansas, and Albuquerque and Mesilla, New Mexico" (Pilsbry, 1948, p. 883).

Ecology.—"*Gastrocopta holzingeri* is found on timbered slopes under leaf mold. Although it may occur in large numbers, it is probably overlooked because of its small size * * * In order to remain established in northwestern Kansas, as it is doing to some extent, it must be tolerant of the hot, dry climatic conditions which obtain in the summertime. *G. holzingeri* is not one of the predominating species of the fauna of Kansas. According to its general distribution in North America, it prefers decidedly cooler climates" (Franzen and Leonard, 1947, p. 334–335). In northern Nebraska it was found under logs, bark, and stones in a moist tall-grass area around seepages.

Occurrence and material: Rexroad local fauna; Saw Rock Canyon local fauna (Franzen and Leonard); Recent in northern Nebraska. Rexroad loc. 1, UMMZ 183059 (1); loc. 2, UMMZ 183070 (16); loc. 3, UMMZ 183035 (150).

Subgenus VERTIGOPSIS Sterki, 1893

Gastrocopta (Vertigopsis) tappaniana (Adams), 1842

Gastrocopta tappaniana (C. B. Adams). Baker, 1938, Nautilus, v. 51, p. 131.
Franzen and Leonard, 1947, Kansas Univ. Sci. Bull., v. 31, p. 336, pl. 18, fig. 8.
Pilsbry, 1948, Acad. Nat. Sci. Philadelphia Mon. 3, v. 2, pt. 2, p. 889, fig. 477:9.
Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151, pl. 14, fig. k.
Gastrocopta tappaniana C. B. Adams. Hibbard, 1941, Kansas Univ. Sci. Bull., v. 27, p. 95.
Hibbard, 1941, Kansas Acad. Sci. Trans., v. 44, p. 265.
Frye and Hibbard, 1941, Kansas Geol. Survey Bull. 38, p. 408.
Gastrocopta tappaniana. McGrew, 1944, Field Mus. Nat. Hist. Geol. Ser., v. 9, p. 36.

Distribution.—"Ontario and Maine to Virginia and Alabama, west to South Dakota and Kansas, southwest to Arizona, but not known from the southeastern Atlantic states, Virginia to Florida" (Pilsbry, 1948, p. 889).

Ecology.—"Its most frequent habitat is on shaded slopes near streams. However, it has been taken from among the grass roots on an unshaded slope near a pasture pond" (Franzen and Leonard, 1947, p. 337). In northern Nebraska it was found among moist leaves or under logs in moist grass near seepages.

Occurrence and material: Saw Rock Canyon, Rexroad, Bender, Sand Draw, Dixon, and Sanders local faunas; Recent in northern Nebraska. Saw Rock Canyon, UMMZ 177517 (1), 177564 (23); Rexroad loc. 2, UMMZ 183072 (20); loc. 3, UMMZ 183038 (27); loc. 4b, UMMZ 177604 (3), 181053 (1); Bender loc. 1, UMMZ 177508 (1); loc. 1a, UMMZ 184126 (1); loc. 1b, UMMZ 184139 (39); Sand Draw loc. 3, UMMZ 181205 (2); loc. 5, UMMZ 181251 (1); loc. 6, CNHM PE3445 (1), UMMZ 177436 (15), 181219 (9); Dixon loc. 1, UMMZ 182218 (75); loc 2, UMMZ 191523 (32); Sanders loc. 1, UMMZ 182155 (150); loc. 2, UMMZ 184164 (5); loc. 3, 182184 (17).

Subgenus IMMERSIDENS Pilsbry and Vanatta, 1900

Gastrocopta (Immersidens) rexroadensis Franzen and Leonard, 1947

Plate 1, figure 30

Gastrocopta rexroadensis Franzen and Leonard, 1947, Kansas Univ. Sci. Bull., v. 31, p. 338, pl. 18, fig. 4, 5.

Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151, pl. 14, fig. e.

Types.—Holotype UKMNH 3781, Rexroad loc. 3. Paratypes UKMNH.

Diagnosis.—An *Immersidens* with a short, straight, oblique parietal lamella placed behind a much smaller angular lamella not fused to it, an oblique, descending columellar lamella, no basal fold, and a deeply immersed lower palatal fold.

Description of holotype.—"Shell small, elongate-conic; summit obtuse; rimate; suture sharply incised; 4¾ whorls; apical whorls strongly convex, lower whorls slightly convex; whorls slowly and regularly increasing in size; the 1½-nuclear whorls finely granular; remaining whorls irregularly and finely striate; height of body whorl exceeding one-half of the total height, contracted basally and expanding rapidly toward the aperture; a prominent, rounded crest paralleling the peristome from which it is separated by a deep, wide groove; aperture triangularly rounded, scarcely oblique, widely expanding; denticles 5; a prominent, oblique, arched, deeply immersed parietal lamella extending toward the periphery below the angular lamella; an elongate, prominent angular lamella arising from the peristome, approximate to but not fused posteriorly with the parietal lamella; the upper palatal fold immersed, fused with a triangular callus on the outer border of the peristome; a prominent, shortly elongate, deeply immersed, oblique lower palatal fold; a prominent columellar lamella, entering horizontally with the posterior half turned downward; margin of peristome very narrowly reflected; ends of peristome approaching, connected by a thin callus upon the parietal wall" (Franzen and Leonard, 1947, p. 338).

Measurements.—Franzen and Leonard gave dimensions of five specimens. The mean of these (in millimeters) is followed by the range in parentheses. Length, 2.35 (2.25–2.4); width, 1.29 (1.25–1.35); length of aperture, 0.88 (0.8–0.9); width of aperture, 0.80 (0.7–0.9); number of whorls, 5.0 (4¾–5¼).

Distribution.—Late Pliocene of the southern High Plains.

Remarks.—*G. rexroadensis* appears most closely related to *G. cochisensis* (Pilsbry and Ferriss), *G. oligobasodon* (Pilsbry and Ferriss), and *G. prototypus* (Pilsbry). It differs from *G. cochisensis* by the separation of the angular and parietal lamellae, the shorter and straight parietal lamella, absence of a basal fold, and the fusion of the upper palatal fold with the palatal callus. It differs from *G. oligobasodon* by the separation of the angular and parietal lamellae, obliqueness of the parietal lamella, larger columellar lamella, absence of a basal fold, and the fusion of the upper palatal fold with the palatal callus. It differs from *G. prototypus* by the separation of the angular and parietal lamellae, straight and oblique parietal lamella, larger and descending columellar lamella with no callus above, more deeply immersed, larger, and oblique lower palatal fold, and larger upper palatal fold fused with the palatal callus.

Franzen and Leonard (1947, p. 339) considered this species closely related to *G. bilamellata* (Sterki and Clapp). It differs from the latter in being shorter and relatively broader in shell form; by the shorter and simpler angular and parietal lamellae, separate and straight, the parietal oblique; the absence of a basal fold; the oblique lower palatal; and the less deeply immersed upper palatal, fused to the palatal callus. The differences between *G. rexroadensis* and *G. bilamellata* seem greater than those between *G. rexroadensis* and *G. cochisensis*, *G. oligobasodon*, and *G. prototypus*.

Occurrence and material: Saw Rock Canyon local fauna (Frye and Leonard); Red Corral local fauna; Rexroad local fauna (Franzen and Leonard). Red Corral, UMMZ 183004 (2).

New genus and species?

Description.—Shell conical, perforate, apex obtuse. Whorls five, convex, separated by well impressed suture. Aperture subtrigonal, basally regularly rounded, inconspicuously dentate. Folds and lamellae five, weak: anguloparietal low, elongate, sinuous; columellar elongate-tubercular, entering horizontally; basal and lower palatal both low, tubercular, and immersed equally with the columellar; upper palatal tubercular, slightly elongate parallel to suture, very deeply immersed, dorsal in position; peristome reflected, not thickened; a weak palatal callus behind the reflection but in front of the folds. Umbilicus small, about one-seventh of the diameter, perforate to the apex, slightly covered by body whorl. First whorl minutely punctate; later whorls with many nearly regular, low, rounded, but relatively coarse raised lines between which lie weak growth lines. Length, 2.5 mm; width, 1.4; length aperture, 0.8; width aperture, 0.7; whorls 5.

Remarks.—Only one specimen of this unusual pupillid was found. The weak teeth and palatal callus and unthickened peristome suggest that it may be not quite mature or else that it may be like *Gastrocopta* (*Privatula*) or *Microstele* in having reduced dentition. Of associated forms *Gastrocopta tappaniana* is closest in having a conical shape, but dentition, umbilicus, and sculpture are so different that it seems unlikely that the specimen is simply a monstrosity of *G. tappaniana*. Perhaps this individual represents an extinct derivative of *Gastrocopta* (*Vertigopsis*) with an enlarged umbilicus, paralleling *Chaenaxis* in that respect. More material is needed for a decision.

Occurrence and material: Sanders local fauna, loc. 3, UMMZ 182187 (1).

Subfamily PUPILLINAE

Genus PUPOIDES Pfeiffer, 1854

Subgenus PUPOIDES s. s.

Pupoides (s. s.) albilabris (Adams), 1841

Plate 1, figures 36, 37

Pupoides marginatus (Say). Hibbard, 1941, Kansas Univ. Sci. Bull., v. 27, p. 95.
Hibbard, 1941, Kansas Acad. Sci. Trans., v. 44, p. 265.
Frye and Hibbard, 1941, Kansas Geol. Survey Bull. 38, p. 408.
Franzen and Leonard, 1947, Kansas Univ. Sci. Bull., v. 31, p. 370, pl. 21, fig. 3–4.
Pupoides albilabris (C. B. Adams). Pilsbry, 1948, Acad. Nat. Sci. Philadelphia Mon. 3, v. 2, pt. 2, p. 921, fig. 499:1–7.
Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151, pl. 14, fig. b.
Taylor, 1954, Michigan Univ. Mus. Zool. Occ. Papers 557, p. 15.

Distribution.—Maine to the West Indies, west to North Dakota, Arizona, and northern Mexico (Pilsbry, 1948, p. 923).

Ecology.—"It lives under stones or at the roots of grass, in well-drained but often sunny places; following rains it is sometimes found on trees a few feet from the ground" (Pilsbry, 1948).

Occurrence and material: Saw Rock Canyon, Rexroad, Bender, Sand Draw, Dixon, and Sanders local faunas. Saw Rock Canyon, UMMZ 177565 (4); Rexroad loc. 1, UMMZ 183061 (14); loc. 2, UMMZ 183073 (75); loc. 3, UMMZ 183039 (100); loc. 4a, UMMZ 177571 (22); loc. 4b, UMMZ 177605 (80), 181054 (12); Bender loc. 1, UMMZ 177509 (23); loc. 1a, UMMZ 184127 (350); loc. 1b, UMMZ 184140 (75); loc. 1c, UMMZ 183018 (200); loc. 2, UMMZ 184155 (11); Sand Draw loc. 2, UMMZ 184179 (2); loc. 6, UMMZ 177437 (15), 181220 (1); Dixon loc. 1, UMMZ 182221 (21); loc. 2, UMMZ 191524 (16); Sanders loc. 1, UMMZ 182158 (500); loc. 2, UMMZ 182170 (53); loc. 3, UMMZ 182186 (150).

Subgenus ISCHNOPUPOIDES Pilsbry, 1926

Pupoides (Ischnopupoides) inornatus Vanatta, 1915

Plate 1, figure 35

Pupoides inornatus Vanatta. Hibbard, 1941, Kansas Univ. Sci. Bull., v. 27, p. 95.
Hibbard, 1941, Kansas Acad. Sci. Trans., v. 44, p. 265.
Frye and Hibbard, 1941, Kansas Geol. Survey Bull. 38, p. 408.
Franzen and Leonard, 1947, Kansas Univ. Sci. Bull., v. 31, p. 374.
Pilsbry, 1948, Acad. Nat. Sci. Philadelphia Mon. 3, v. 2, pt. 2, p. 926, fig. 499:10.

Distribution.—Only two definitely Recent occurrences are known: Pikes Peak, El Paso County, Colo. (Pilsbry, 1948, p. 926); Sidney, Cheyenne County, Nebr. (USNM 424028, 363054).

Ecology.—Uncertain.

Occurrence and material: Red Corral, Rexroad, and Sand Draw local faunas. Red Corral, UMMZ 183005 (1); Rexroad loc. 2, UMMZ 183074 (16); loc. 3, UMMZ 183040 (41); Sand Draw loc. 2, UMMZ 184180 (2).

Subfamily VERTIGININAE

Genus VERTIGO Müller, 1774

Vertigo ovata Say, 1822

Vertigo ovata Say. Baker, 1938, Nautilus, v. 51, p. 130.
Franzen and Leonard, 1947, Kansas Univ. Sci. Bull., v. 31, p. 354, pl. 19, fig. 6.
Pilsbry, 1948, Acad. Nat. Sci. Philadelphia Mon. 3, v. 2, pt. 2, p. 952, fig. 513:1-3, 4, 7.
Vertigo ovata. McGrew, 1944, Field Mus. Nat. Hist. Geol. Ser., v. 9, p. 36.
Vertigo ovata (Say). Hibbard, 1954, Michigan Acad. Sci. Papers, v. 39, p. 343.
Vertigo hibbardi Baker. Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151 [in part: Kingman County loc. Not of Baker].

Distribution.—Laborador to the West Indies, west to Arizona, Utah, Oregon, and Alaska (Pilsbry, 1948, p. 953).

Ecology.—"***only in moist environs afforded by shaded slopes near streams and shores of ponds" (Franzen and Leonard, 1947, p. 355). In northern Nebraska it was found on sticks and in wet leaves in seepages and immediately adjacent to a stream, associated with *Carychium*, *Fossaria*, and *Pisidium*.

Remarks.—Frye and Leonard reported *V. hibbardi*, but not *V. ovata*, from the Dixon local fauna. University of Michigan collections, however, contain about 200 specimens of *V. ovata*, but no *V. hibbardi*. Furthermore, *V. ovata* and *V. hibbardi* have never been found together, a fact which suggests ecologic replacement since their geologic ranges overlap. In addition the two species are superficially similar, and careful examination of the apertural lamellae is necessary for their discrimination. The Dixon local fauna reference to *V. hibbardi*, therefore, is probably based on *V. ovata*. (Compare Frye and others, 1943, p. 42, with Franzen and Leonard, 1947, p. 354).

Occurrence and material: Buis Ranch, Sand Draw, Dixon, and Sanders local faunas; Recent in northern Nebraska. Buis Ranch, UMMZ 181115 (1); Sand Draw loc. 2, UMMZ 184181 (4); loc. 3, UMMZ 181131 (29); loc. 4, UMMZ 177326 (30); loc. 5, CNHM PE3438 (2), UIMNH P6791 (1), UMMZ 181140 (31), 181235 (100); loc. 6, UMMZ 177438 (8), 181222 (12); loc. 7, UMMZ 177235 (3); Dixon loc. 1, UMMZ 182219 (200); loc. 2, UMMZ 191526 (4); Sanders loc. 1, UMMZ 182-157 (1).

Vertigo hibbardi Baker, 1938

Plate 1, figures 18–22

Vertigo hibbardi Baker, 1938, Nautilus, v. 51, p. 126.
Smith, 1940, Kansas Geol. Survey Bull. 34, p. 98.
Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151 [in part: Meade County loc.].
Leonard, 1957, Illinois Geol. Survey Report of Investigations 201, p. 21, pl. 1, fig. 3.
Vertigo hibbardi F. C. Baker. Hibbard, 1941, Kansas Univ. Sci. Bull., v. 27, p. 95.
Hibbard, 1941, Kansas Acad. Sci. Trans., v. 44, p. 265.
Frye and Hibbard, 1941, Kansas Geol. Survey Bull. 38, p. 408.
Franzen and Leonard, 1947, Kansas Univ. Sci. Bull., v. 31, p. 367, pl. 20, fig. 9, 10.

Types.—Holotype UIMNH P6773, Rexroad loc. 3. Paratypes UIMNH P6773 (5), ANSP 169883 (not found).

Diagnosis.—A moderately large, ovate *Vertigo* with seven folds and lamellae, the palatals deeply entering, the columellar descending and spoon shaped; the body whorl flattened laterally and flaring in basal view.

Description.—"Shell moderate in size for the genus; ovately conic; rimate; whorls typically 5, convex; suture sharply incised; nuclear whorl finely granulose; remaining whorls glossy, and finely striate in well-preserved shells, regularly and rapidly increasing in size; body whorl as much as three-fifths of total height; aperture biarcuate. expanding toward the peristome; peristome narrowly reflected, margins sharp, terminations approaching and connected across parietal wall by a thin callus; denticles 7: 2 elongate lamellae on parietal wall, the parietal lamella the more deeply immersed, the innermost third deflected at a right angle toward the outer lip; the angular about one-third as long as the parietal, less deeply immersed; suprapalatal fold, when present, tubercular; upper palatal fold lamelliform, high, long and sinuous; lower palatal fold lamelliform, more deeply immersed than the upper palatal, increasing in height up to its midpoint and then declining, partially forked anteriorly; infrapalatal low, elongate, as deeply immersed, and about half as long as the lower palatal; basal lamelliform, elongate, increasing in height inwardly and terminating rather abruptly; the folds connected by a low callus; columellar lamella large, heavy, crescentic, ascending slightly toward the columella, then turning downward and recurving slightly forward at the base; crest behind the peristome prominent, rounded, separated from the peristome by a groove; body whorl indented at level of the upper and lower palatals resulting in the contraction of the body whorls at its base" (Franzen and Leonard, 1947, p. 367–368).

Measurements.—The mean of the series measured is followed by the range in parentheses. Measurements are in millimeters.

	Length	*Length aperture*	*Width*	*Width aperture*	*Number of whorls*
Rexroad loc. 3	2.00	0.8	1.3	0.77	4½
(3 specimens)	(1.9–2.0)	(.8)	(1.3)	(.7–.8)	(4½)
Saw Rock Canyon	2.19	.84	1.41	.84	4¾
(7 specimens)	(2.0–2.3)	(.7–.9)	(1.3–1.5)	(.8–.9)	(4½–5)

Variation.—The shape of the shell varies from ovate to conical, as shown by the measurements. The folds and lamellae are relatively stable for pupillids. The infrapalatal fold is rarely absent. The inner end of the parietal lamella may be bent towards either lip, or not at all. Shells from the Saw Rock Canyon local fauna are larger than topotypes (see measurements), and their apertures are not so nearly closed by the dentition. Some topotypes have the base trumpetlike when viewed from below, as Baker noted, but others are less extreme. The Saw Rock Canyon specimens do not have this pronounced constriction in the body whorl.

Distribution: Late Pliocene of southwestern Kansas.

Remarks.—For discussion of the reported occurrence of *V. hibbardi* in the Dixon local fauna see under *V. ovata*.

F. C. Baker and subsequent writers who have dealt with *V. hibbardi* have considered it as one of the subgenus *Angustula* Sterki, 1888. The species has most of the characters in the subgeneric definition given by Pilsbry (1948, p. 944), but other features seem to show that this resemblance is only convergent. Furthermore, *V. milium* (type of *Angustula*) appears to have close relationships with other species which are not recognized by present taxonomy.

Vertigo hibbardi agrees with the diagnosis of *Angustula* (based on apertural dentition) in all respects save one: the inner end of the lower palatal fold does not curve downward. It differs radically from the other species heretofore placed in *Angustula* by its larger size, conical or ovate-conic shape, and laterally flattened body whorl. The difference in shape, not necessarily significant in all gastropod genera, is important because the other species-groups in *Vertigo* have unity in external form, the species differing primarily in lamellar characters. *V. hibbardi* is probably most closely related to the *V. ovata* group, although not nearly. It is similar in shape to species of this group, differing slightly by the laterally compressed body whorl. The strongly developed folds and lamellae are similar to those of *V. ovata diaboli* Pilsbry (Pilsbry, 1948, p. 953), from which it differs in the absence of an infraparietal lamella and in the spoonshaped, descending columellar lamella.

The criteria previously used for definition of *Angustula* therefore seem artificial, because they associate otherwise dissimilar and apparently unrelated species. But it appears that these characters have also excluded a related species from the *V. milium* group: *V. numellata*. Pilsbry (1918–20, p. 149–150) compared *V. bermudensis* of the *V. milium* group with *V. numellata* (then placed in its own species group) as follows: "The much larger *V. numellata* has a similar crest, the lower palatal fold is long, also, and the angular and parietal lamellae similar in position; yet it has not the peculiarly shaped columellar lamella of *Angustula*." By the same token as used with *V. hibbardi*, it seems that the strictly lamellar characters have resulted in an unnatural grouping of species. From the similarities of both dentition and external form, the *V. milium* group includes *V. numellata* and *V. bermudensis*, but not *V. hibbardi*. It appears that a descending columellar lamella has developed more than once in *Vertigo*. Whether *Angustula* merits subgeneric rank seems questionable, if its unique character of a descending columellar lamella is no longer unique. It seems best to synonymize it with *Vertigo* s. s., and to consider *V. milium* and its relatives coordinate with other species groups, such as those of *V. ovata*, and *V. modesta*.

Occurrence and material: Saw Rock Canyon and Rexroad local faunas. Saw Rock Canyon, UMMZ 173589 (10), 177566 (400), USGS 19089-6 (125), Rexroad loc. 2, UMMZ 183075 (3); loc. 3, UMMZ 183041 (11), UIMNH P6773 (6).

Vertigo milium (Gould), 1840

Vertigo milium Gould. Hibbard, 1941, Kansas Univ. Sci. Bull., v. 27, p. 95.
Hibbard, 1941, Kansas Acad. Sci. Trans., v. 44, p. 265.
Frye and Leonard, 1941, Kansas Geol. Survey Bull. 38, p. 408.
Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151.
Vertigo milium (Gould). Franzen and Leonard, 1947, Kansas Univ. Sci. Bull., v. 31, p. 365, pl. 20, fig. 8.
Pilsbry, 1948, Acad. Nat. Sci. Philadelphia Mon. 3, v. 2, pt. 2, p. 944, fig. 509.
Taylor, 1954, Michigan Univ. Mus. Zool. Occ. Papers 557, p. 15.

Distribution.—Maine to South Dakota, south to Arizona, Mexico, and the West Indies (Pilsbry, 1948, p. 945).

Ecology.—"Moist situations afforded by timbered stream banks, or marshes. It is not found in areas of low relative humidity or low annual precipitation and high summer tempertures * * *" (Franzen and Leonard, 1947, p. 367).

Occurrence and material: Red Corral, Rexroad, Bender, Sand Draw, Dixon, and Sanders local faunas; Saw Rock Canyon local fauna (Franzen and Leonard). Red Corral, UMMZ 183006 (27); Rexroad loc. 2, UMMZ 183076 (15); loc. 3, UMMZ 183042 (57); loc. 4b, UMMZ 177606 (1), 181055 (2); Bender loc. 1, UMMZ 177510 (15); loc. 1a, UMMZ 184128 (75); loc. 1b, UMMZ 184141 (3); loc. 1c, UMMZ 183019 (75); Sand Draw loc. 2, UMMZ 184182 (2); loc. 3, UMMZ 181132 (7); loc. 4, UMMZ 177325 (2); loc. 5, UMMZ 181141 (4), 181234 (18); loc. 6, UMMZ 177439 (1), 181221 (20); Dixon loc. 1, UMMZ 182220 (100); loc. 2, UMMZ 191525 (25); Sanders loc. 1, UMMZ 182156 (500); loc. 2, UMMZ 182169 (5); loc. 3, UMMZ 182185 (500).

Family PUPILLIDAE?

Remarks.—A fragmentary specimen consisting of the apical whorls only may represent a pupillid. It is distinct from the other species listed from the local fauna.

Occurrence: Red Corral local fauna. UMMZ 183000 (1).

Family VALLONIIDAE

Genus VALLONIA Risso, 1826

Vallonia pulchella (Müller), 1774

Vallonia pulchella (Müller). Pilsbry, 1948, Acad. Nat. Sci. Philadelphia Mon. 3, v. 2, pt. 2, p. 1023, fig. 545a.
Taylor, 1954, Michigan Univ. Mus. Zool. Occ. Papers 557, p. 15.

Distribution.—Holarctic. In North America east of the Rocky Mountains from Nova Scotia and Manitoba south to Missouri and Kentucky (Pilsbry, 1948, p. 1024).

Ecology.—"Found plentifully under wood, leaves, stones, old logs, in moss and on the banks of streams" (Baker, 1902, p. 251).

Occurrence and material: Sand Draw local fauna. Sand Draw loc. 3, UMMZ 181133 (6); loc. 6, UMMZ 181223 (1).

Vallonia gracilicosta Reinhardt, 1883

Vallonia gracilicosta Reinhardt. Hibbard, 1941, Kansas Univ. Sci. Bull., v. 27, p. 95.
Hibbard, 1941, Kansas Acad. Sci. Trans., v. 44, p. 265.
Frye and Hibbard, 1941, Kansas Geol. Survey Bull. 38, p. 408.
Pilsbry, 1948, Acad. Nat. Sci. Philadelphia Mon. 3, v. 2, pt. 2, p. 1028, fig. 549.
Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151, pl. 14, fig. f.

Distribution.—Minnesota to Montana, south and southwest to Nebraska, New Mexico, Arizona, and California (Pilsbry, 1948, p. 1029–1030).

Ecology.—In northern Nebraska this species occurs under logs, bark, and stones on slightly moist leaf mold in wooded areas.

Occurrence and material: Rexroad local fauna; Recent in northern Nebraska. Rexroad loc. 3, UMMZ 183043 (1800).

Vallonia parvula Sterki, 1893

Vallonia parvula Sterki. Pilsbry, 1948, Acad. Nat. Sci. Philadelphia Mon. 3, v. 2, pt. 2, p. 1027, fig. 547.

Distribution.—Great Plains from South Dakota to north-central Oklahoma; eastward to northern Missouri, northern Ohio, southern Ontario, and western New York.

Ecology.—In northern Nebraska *V. parvula* occurs under logs, bark, and stones on slightly moist leaf mold in wooded areas.

Occurrence and material: Bender local fauna; Recent in northern Nebraska. Bender loc. 1a, UMMZ 184129 (31); loc. 1c, UMMZ 183020 (1).

Vallonia perspectiva Sterki, 1893

Vallonia perspectiva Sterki. Pilsbry, 1948, Acad. Nat. Sci. Philadelphia Mon. 3, v. 2, pt. 2, p. 1033, fig. 553.

Distribution.—Sparsely recorded from New Jersey and Alabama to the Rocky Mountains. More abundant in Arizona and New Mexico; Chihuahua (Pilsbry, 1948, p. 1034).

Ecology.—Uncertain.

Occurrence and material: Saw Rock Canyon, Rexroad, Dixon, and Sanders local faunas. Saw Rock Canyon, UMMZ 177567 (2); Rexroad loc. 2, UMMZ 183077 (29); loc. 3, UMMZ 183044 (150); Dixon loc. 1, UMMZ 182222 (1); Sanders loc. 1, UMMZ 182159 (150); loc. 2, UMMZ 184165 (1); loc. 3, UMMZ 182188 (1).

Family CIONELLIDAE

Genus CIONELLA Jeffreys, 1829

Cionella lubrica (Müller), 1774

Cionella lubrica (Müller). Pilsbry, 1948, Acad. Nat. Sci. Philadelphia Mon. 3, v. 2, pt. 2, p. 1047.
Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151.

Distribution.—Holarctic. "Point Barrow, Alaska, and Queen Charlotte Islands to Labrador and Newfoundland, south in the East to Washington, D.C., and southern Missouri; in all the Western and Mountain States except California; to the Mexican boundary in Arizona; in the Sierra Madre of western Chihuahua." (Pilsbry, 1948, p. 1048; see also Pilsbry, 1953, p. 165).

Ecology.—"*C. lubrica* lives among the damp underleaves in densely shaded places; under wood, such as old board sidewalks; in chinks of stone walls and under stones" (Pilsbry, 1948, p. 1049). In northern Nebraska it was found among damp leaves and small logs in a wooded ravine.

Occurrence: Rexroad or Bender local fauna (Frye and Leonard); Recent in northern Nebraska.

Family SUCCINEIDAE

Land snails of the family Succineidae are common and often conspicuous members of the Recent molluscan fauna of the central Great Plains. Their shells are likewise common as fossils in both Pliocene and Pleistocene deposits of this region. Even the best preserved fossils may be unidentifiable, however, because the shells alone are often not specifically diagnostic. After studying the Succineidae of Kansas, Miles (1958) found that most species can not be identified by shell characters, and that two of the three genera are indistinguishable from their shells. *Oxyloma*, with the one species *Oxyloma retusa* in Kansas, may be distinguished from *Succinea* and *Quickella; Succinea ovalis* and adult specimens of *Succinea concordialis* can be identified by shell features; but the other species of *Succinea* and *Quickella* must be determined by anatomical criteria.

The fossil succineid shells considered in this paper include only one of the specifically identifiable types: *Oxyloma retusa.* At least for the present, all others are lumped as "cf. *Succinea.*" Perhaps future detailed study of the shells of dissected Recent snails will enable more of the fossils to be identified specifically.

Genus SUCCINEA Draparnaud, 1801

Succinea ovalis Say, 1817

Succinea ovalis Say. Pilsbry, 1948, Acad. Nat. Sci. Philadelphia Mon. 3, v. 2, pt. 2, p. 801, fig. 430–433.

Distribution.—"Newfoundland and James Bay to North Dakota and Nebraska, south to Alabama" (Pilsbry, 1948, p. 803).

Ecology.—"*S. ovalis* is usually found on low ground near streams, in summer often upon the weedy herbage of such places, a foot or two from the ground" (Pilsbry, 1948, p. 804). In northern Nebraska it was found under logs among damp leaves, in a wooded ravine well above the flood-plain of the Niobrara River.

Remarks.—The locality in northern Brown County, Nebraska, recorded in this paper is farther southwest than previously known occurrences.

Occurrence: Recent in northern Nebraska.

cf. Succinea

Succinea grosvenori Lea. Hibbard, 1941, Kansas Univ. Sci. Bull., v. 27, p. 95.
Hibbard, 1941, Kansas Acad. Sci. Trans., v. 44, p. 265.
Frye and Hibbard, 1941, Kansas Geol. Survey Bull. 38, p. 408.
Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151.

Succinea grosvenori gelida F. C. Baker. Hibbard, 1941, Kansas Univ. Sci. Bull., v. 27, p. 95.
Hibbard, 1941, Kansas Acad. Sci. Trans., v. 44, p. 265.
Frye and Hibbard, 1941, Kansas Geol. Survey Bull. 38, p. 408.

Succinea sp. Taylor, 1954, Michigan Univ. Mus. Zool. Occ. Papers 557, p. 15.

Occurrence: Saw Rock Canyon, Red Corral, Rexroad, Bender, Sand Draw, Dixon, and Sanders local faunas; Recent in northern Nebraska.

Discussion of materials.—Saw Rock Canyon, UMMZ 172363 (12), 177568 (200), USGS 19089-7 (17). Three fairly large specimens have short spires, elongate apertures, and slightly impressed sutures. These shells agree well with *Succinea concordialis* Gould (Pilsbry, 1948, p. 833).

Red Corral, UMMZ 183007 (1). The single juvenile specimen is indeterminate.

Rexroad loc. 1, UMMZ 183062 (54); loc. 2, UMMZ 183078 (10); loc. 3, UMMZ 183045 (300); loc. 4b, UMMZ 177607 (6), 181057 (1). About a dozen specimens from locality 3 may be only half grown. They differ from the Saw Rock Canyon material in having a narrow shell, relatively large pointed spire with moderate suture, and smaller, ovate aperture. These specimens resemble *S. grosvenori gelida* and *S. avara* in having a relatively prominent spire and small aperture, but differ by their narrower spire and shallower suture. They are closest to *S. luteola* Gould (Pilsbry, 1948, p. 830). One other specimen from locality 4b is of similar form, but the remaining Rexroad material is indeterminate.

Bender loc. 1, UMMZ 177511 (5); loc. 1a, UMMZ 184130 (32); loc. 1c, UMMZ 183021 (9); loc. 2, UMMZ 184156 (75). Seven adult specimens from locality 2 show considerable variation in proportions, but share a high, narrow spire, moderately deep suture, and fairly smooth shell surface. They are higher spired and narrower than the Saw Rock Canyon specimens, similar to the Rexroad locality 3 material, and may represent *Succinea luteola* Gould also. Bender locality 1 material is not diagnostic.

Sand Draw loc. 1, UMMZ 181248 (7); loc. 2, UMMZ 184183 (13); loc. 3, UMMZ 181130 (34); loc. 4, UMMZ 177324 (10); loc. 5, UMMZ 181139 (45), 181236 (150); loc. 6, UMMZ 177434 (11), 181224 (7); loc. 7, UMMZ 177234 (21). Almost all the material is indeterminate. One specimen from locality 1 and two from locality 6 (UMMZ 177434) are similar to the Rexroad material.

Dixon loc. 1, UMMZ 182223 (7); loc. 2, UMMZ 191527 (12). The few immature specimens collected are closer to the Rexroad than to the Saw Rock Canyon material.

Sanders loc. 1, UMMZ 182160 (500); loc. 2, UMMZ 184166 (10); loc. 3, UMMZ 182189 (44). About a dozen adult specimens, and others nearly adult, show considerable variation in spire and aperture proportions. They overlap the Rexroad locality 3 material, but are mostly slightly lower spired. These also are like *S. luteola* Gould. Sanders locality 3 specimens are not determinable, but seem conspecific.

Genus OXYLOMA Westerlund, 1885

Oxyloma retusa (Lea), 1834

Oxyloma retusa (Lea). Pilsbry, 1948, Acad Nat. Sci. Philadelphia Mon. 3, v. 2, pt. 2, p. 785, fig. 421, 422c.
Miles, 1958, Kansas Univ. Sci. Bull., v. 38, p. 1521, pl. 1, fig. G, H; fig. 6, 7.

Oxyloma haydeni (W. G. Binney). Pilsbry, 1948, Acad. Nat. Sci. Philadelphia Mon. 3, v. 2, pt. 2, p. 797, fig. 427e.

Distribution.—Ohio west to Montana, south to Kansas. If *Oxyloma sillimani* is a synonym, as suggested by Pilsbry (1948, p. 796), the range may include parts of Nevada and Washington.

Ecology.—In northern Nebraska this species was always found within about 6 inches of permanent water, crawling about on dead wood or among riparian vegetation and debris. Although not strictly aquatic, its habitat overlaps that of the semiaquatic

Fossaria dalli. In Meade County State Park, Kansas, "this snail thrives on the moist marshes and borders of the pools in the artesian basin, where it is frequently found on watercress" (Leonard, A. E., 1943, p. 240).

Remarks.—Miles (1958) has demonstrated the great variation in shell form of *Oxyloma retusa*, even within single populations. The original illustrations of *Oxyloma haydeni* (Pilsbry, 1948, p. 796, fig. 427e) show striking resemblance to those of established *O. retusa* (Miles, 1958, p. 1537, pl. 1, fig. H). *O. haydeni* was originally distinguished by shell features which are evidently invalid.

Occurrence and material: Dixon local fauna; Recent in northern Nebraska. Dixon loc. 1, UMMZ 182212 (37); loc. 2, UMMZ 191528 (27).

Family ENDODONTIDAE

Subfamily ENDODONTINAE

Genus DISCUS Fitzinger, 1833

Subgenus DISCUS s. s.

Discus (s. s.) cronkhitei (Newcomb), 1865

Discus cronkhitei (Newcomb). Pilsbry, 1948, Acad. Nat. Sci. Philadelphia Mon. 3, v. 2, pt. 2, p. 601, fig. 328a–d.

Distribution.—Alaska to the mountains of southern California; Rocky Mountains south into Arizona and New Mexico; Colorado and northern Canada east to northern Illinois, Maryland, Newfoundland, and Labrador; also Missouri (Pilsbry, 1948, p. 602–603).

Ecology.—"In the east it lives in humid forest, under dead wood, and among rotting leaves or grass in rather wet situations" (Pilsbry, 1948, p. 604). In northern Nebraska it occurred under sticks and logs on moist leaf mold, always close to running water.

Remarks.—The localities in northern Nebraska reported in this paper are the most southern known Recent occurrences of this species in the High Plains.

Occurrence: Recent in northern Nebraska.

Subfamily HELICODISCINAE

Genus HELICODISCUS Morse, 1864

Subgenus HELICODISCUS s. s.

Helicodiscus (s. s.) parallelus (Say), 1821

Helicodiscus parallelus (Say). Pilsbry, 1948, Acad. Nat. Sci. Philadelphia Mon. 3, v. 2, pt. 2, p. 625, fig. 338c, 339.
Leonard and Goble, 1952, Kansas Univ. Sci. Bull., v. 34, p. 1039, pl. 101, fig. 24, 25.

Distribution.—Eastern North America, from Newfoundland south to Georgia and Alabama; westward to South Dakota and Oklahoma (Pilsbry, 1948, p. 626).

Ecology.—"It lives on decaying wood in shady or humid places, also on damp leaves" (Pilsbry, 1948, p. 627). "In eastern Kansas the species may occur in grassy fields, on sparsely timbered slopes, and on rocky ledges as well as in more moist places. In the more arid parts of the state, however, *H. parallelus* is limited to woodland cover, and usually occurs around decaying timber" (Leonard and Goble, 1952, p. 1039).

Occurrence and material: Dixon local fauna. Dixon loc. 2, UMMZ 191529 (18).

Subgenus HEBETODISCUS Baker, 1929

Helicodiscus (Hebetodiscus) singleyanus (Pilsbry), 1890

Helicodiscus singleyanus Pilsbry. Hibbard, 1941, Kansas Univ. Sci. Bull., v. 27, p. 95.
Hibbard, 1941, Kansas Acad. Sci. Trans., v. 44, p. 265.
Frye and Hibbard, 1941, Kansas Geol. Survey Bull. 38, p. 408.
Helicodiscus singleyanus (Pilsbry). Pilsbry, 1948, Acad. Nat. Sci. Philadelphia Mon. 3, v. 2, pt. 2, p. 636, fig. 346.
Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151.

Distribution.—New Jersey to Florida, west to South Dakota, Colorado, and Arizona (Pilsbry, 1948, p. 636).

Ecology.—This species has apparently never been collected alive in the High Plains. In southwestern Kansas fresh shells have been found frequently by University of Michigan field parties in the course of collecting fossils by washing bulk matrix through screens. In this process any Recent shells which may be present are recovered along with the fossils. From the localities so represented, it appears probable that *Helicodiscus singleyanus* lives among grass roots, even on exposed slopes that become hot and dry during the summer.

Occurrence and material: Saw Rock Canyon, Rexroad, Bender, Sand Draw, Dixon, and Sanders local faunas. Saw Rock Canyon, UMMZ 181289 (2); Rexroad loc. 2, UMMZ 183079 (7); loc. 3, UMMZ 183046 (500); loc. 4b, UMMZ 181287 (20); Bender loc. 1, UMMZ 181288 (24); loc. 1a, UMMZ 184131 (38); loc. 1b, UMMZ 184142 (300); loc. 1c, UMMZ 183022 (100); loc. 2, UMMZ 184157 (5); Sand Draw loc. 2, UMMZ 184184 (4); Dixon loc. 2, UMMZ 191530 (400); Sanders loc. 2, UMMZ 182171 (100); loc. 3, UMMZ 182190 (3).

Subfamily PUNCTINAE

Genus PUNCTUM Morse, 1864

Punctum minutissimum (Lea), 1841

Punctum minutissimum (Lea). Pilsbry, 1948, Acad. Nat. Sci. Philadelphia Mon. 3, v. 2, pt. 2, p. 644, fig. 350.

Distribution.—Newfoundland to Florida, west to Oregon, Colorado, New Mexico, and Puebla, Mexico (Pilsbry, 1948, p. 644–645).

Ecology.—"This dwarf among pygmies lives on damp leaves, around decaying logs, and is chiefly to be obtained by sifting leaves, according to my experience. Morse states that [in Maine] 'dense, hardwood growths appear to be their favorite position. They prefer the rotten bark of beech trees, and frequently are found in the large forms of fungi, such as Polyporus and Boletus.'" (Pilsbry, 1948, p. 645). In northern Nebraska it was taken among moist leaves beside a spring-fed brook.

Occurrence: Recent in northern Nebraska.

Family **LIMACIDAE**

Genus **DEROCERAS** Rafinesque, 1820

Subgenus uncertain

Deroceras aenigma Leonard, 1950

Plate 4, figures 14-16, 19-26

Deroceras aenigma Leonard, 1950, Kansas Univ. Paleont. Contr. 8, p. 38, pl. 5, fig. E.
Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151, pl. 14, fig. c.
Taylor, 1954, Michigan Univ. Mus. Zool. Occ. Papers 557, p. 6, 15.
Hibbard, 1956, Michigan Acad. Sci. Papers, v. 41, p. 171.

Distribution.—Upper Pliocene to upper Pleistocene in the High Plains (Taylor, 1954a).

Ecology.—Like living species of *Deroceras*, *D. aenigma* probably favored damp riparian habitats.

Occurrence and material: Saw Rock Canyon, Red Corral, Rexroad, Bender, Sand Draw, Dixon, Deer Park, and Sanders local faunas. Saw Rock Canyon, UMMZ 172365 (1), 177569 (125, 2 sinistral), USGS 19089-10 (17); Red Corral, UMMZ 183008 (50); Rexroad loc. 1, UMMZ 183063 (40); loc. 2, UMMZ 183080 (5); loc. 3, UMMZ 183047 (400); loc. 4a, UMMZ 177442 (500), 177572 (500); loc. 4b, UMMZ 177608 (2); Bender loc. 1, UMMZ 177513 (5); loc. 1a, UMMZ 184132 (100); loc. 1c, UMMZ 183023 (100); Sand Draw loc. 1, UMMZ 181249 (6); loc. 3, UMMZ 181206 (2); loc. 4, UMMZ 177327 (100); loc. 6, UMMZ 177440 (10); loc. 7, UMMZ 177238 (3); Dixon loc. 1, UMMZ 182224 (75); loc. 2, UMMZ 191531 (6); Deer Park, UMMZ 185798 (65); Sanders loc. 1, UMMZ 182161 (57); loc. 2, UMMZ 182172 (3); loc. 3, UMMZ 182191 (24).

Family **ZONITIDAE**

Subfamily **EUCONULINAE**

Genus **EUCONULUS** Reinhardt, 1883

Euconulus fulvus (Müller), 1774

Euconulus fulvus (Müller). Pilsbry, 1946, Acad. Nat. Sci. Philadelphia Mon. 3, v. 2, pt. 1, p. 235, fig. 116, 117.

Distribution.—"Almost throughout the Holarctic realm, but wanting in the Gulf and South Atlantic States from Texas to North Carolina" (Pilsbry, 1946, p. 236).

Ecology.—"*E. fulvus* lives among damp leaves in well-shaded places, and may usually be obtained by leaf sifting where its presence would otherwise be unsuspected" (Pilsbry, 1946, p. 236). In northern Nebraska it was found in damp leaves or under logs and bark on moist ground.

Occurrence: Recent in northern Nebraska.

Subfamily **ZONITINAE**

Genus **NESOVITREA** Cooke, 1921

Subgenus **PERPOLITA** Baker, 1928

Nesovitrea (Perpolita) electrina (Gould), 1841

Retinella electrina (Gould). Hibbard, 1941, Kansas Univ. Sci. Bull., v. 27, p. 95.
Hibbard, 1941, Kansas Acad. Sci. Trans., v. 44, p. 265.
Frye and Hibbard, 1941, Kansas Geol. Survey Bull. 38, p. 408.
Pilsbry, 1946, Acad. Nat. Sci. Philadelphia Mon. 3, v. 2, pt. 1, p. 256, fig. 126.
Leonard, 1950, Kansas Univ. Paleont. Contr. 8, p. 36, pl. 5, fig. H.
Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151, pl. 14, fig. l.

Nesovitrea (Perpolita) electrina (Gould). Forcart, 1957, Archiv für Molluskenkunde, v. 86, p. 110.

Distribution.—North America north of about lat 38° N., southward in the Rocky Mountains to Arizona and New Mexico.

Ecology.—"*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" (Leonard, 1950, p. 37). In northern Nebraska it was found only under dead wood or among leaves on damp ground close to running water.

Occurrence and material: Rexroad local fauna; Dixon local fauna (Frye and Leonard); Recent in northern Nebraska. Rexroad loc. 3, UMMZ 183049 (75).

Nesovitrea? sp.

Remarks.—A single juvenile shell is indeterminate. It may represent one of the species of *Retinella* in the

Rexroad local fauna, but perhaps more likely *Nesovitrea electrina.*

Occurrence and material: Saw Rock Canyon local fauna, UMMZ 183010 (1).

Genus RETINELLA Fischer, 1877

Subgenus GLYPHYALUS Baker, 1928

Retinella (Glyphyalus) wheatleyi (Bland), 1883

Retinella wheatleyi Bland. Hibbard, 1941, Kansas Univ. Sci. Bull., v. 27, p. 95.
Hibbard, 1941, Kansas Acad. Sci. Trans., v. 44, p. 265.
Frye and Hibbard, 1941, Kansas Geol. Survey Bull. 38, p. 408.
Retinella wheatleyi (Bland). Pilsbry, 1946, Acad. Nat. Sci. Philadelphia Mon. 3, v. 2, pt. 1, p. 272, fig. 134, 141:1–3.

Distribution.—Sporadically from Rhode Island and North Carolina west to Michigan, Missouri, and northern Alabama (Pilsbry, 1946, p. 272–273).

Ecology.—In Knox County, Tenn., "Even in the spring, it was rare except in a shallow valley on the west-facing (more humid) slope of the ridge, where one or two individuals per square meter were obtained under the decaying leaves in the oak-chestnut woods" (Baker, quoted in Pilsbry, 1946, p. 273).

Occurrence: Rexroad local fauna (Hibbard).

Subgenus GLYPHYALOPS Baker, 1928

Retinella (Glyphyalops) rhoadsi (Pilsbry), 1899

Retinella rhoadsi Pilsbry. Hibbard, 1941, Kansas Univ. Sci. Bull., v. 27, p. 95.
Hibbard, 1941, Kansas Acad. Sci. Trans., v. 44, p. 265.
Frye and Hibbard, 1941, Kansas Geol. Survey Bull. 38, p. 408.
Retinella rhoadsi (Pilsbry). Pilsbry, 1946, Acad. Nat. Sci. Philadelphia Mon. 3, v. 2, pt. 1, p. 286, fig. 145.

Distribution.—Maine to North Carolina, west to Michigan (Pilsbry, 1946, p. 286); Jackson County, Ill. (Baker, 1939, p. 70).

Ecology.—Uncertain; presumably similar to that of *R. wheatleyi.*

Occurrence: Rexroad local fauna (Hibbard).

Genus HAWAIIA Gude, 1911

Hawaiia minuscula (Binney), 1840

Hawaii miniscula Binney. Hibbard, 1941, Kansas Univ. Sci. Bull., v. 27, p. 95.
Hibbard, 1941, Kansas Acad. Sci. Trans., v. 44, p. 265.
Frye and Hibbard, 1941, Kansas Geol. Survey Bull. 38, p. 408.
Hawaiia minuscula (Binney). Pilsbry, 1946, Acad. Nat. Sci. Philadelphia Mon. 3, v. 2, pt. 1, p. 420, fig. 228a, b, 229:1–3.
Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151, pl. 14, fig. m.
Taylor, 1954, Michigan Univ. Mus. Zool. Occ. Papers 557, p. 15.

Distribution.—North America from Alaska and Maine to Costa Rica. "It is generally spread over every eastern and midwestern state, and in Florida as far south as Miami and Cape Sable, though not seen from the keys. It becomes rather local in the Rocky Mountain States, and has not been seen from Washington, Oregon, Idaho, Nevada and Utah, and only towards the south in California, where some of the records are probably owing to importation with plants" (Pilsbry, 1946, p. 421–423).

Ecology.—The wide geographic range of this common snail is correlated with adaptability to various habitats. In northeastern Kansas, Franzen and Leonard (1943) found that it "* * * is a common snail in the Wakarusa valley, where it lives in rocky ledges or among dead leaves and under fallen logs. It thrives in piles of moist drift where it has been cast by flood waters." In Meade and Clark counties, Kansas, "This species is widely distributed over the area, being nowhere numerous. It withstands arid conditions successfully but is most numerous in wooded places where moisture conditions are better than on the treeless prairies" (Leonard, A. E., 1943, p. 238). In northern Nebraska it was found under logs and bark on damp ground near running water.

Occurrence and material: Saw Rock Canyon, Red Corral, Rexroad, Bender, Sand Draw, Dixon, and Sanders local faunas; Recent in northern Nebraska. Saw Rock Canyon, UMMZ 173592 (1); 177570 (34); Red Corral, UMMZ 183009 (4); Rexroad loc. 1, UMMZ 183064 (11); loc. 2, UMMZ 183-081 (200); loc. 3, UMMZ 183048 (1000); loc. 4b, UMMZ 177609 (200), 181058 (125); Bender loc. 1, UMMZ 177512 (285); loc. 1a, UMMZ 184133 (3200); loc. 1b, UMMZ 184143 (150); loc. 1c, UMMZ 183024 (1600); loc. 2, UMMZ 184158 (60); Sand Draw loc. 1, UMMZ 181250 (2); loc. 2, UMMZ 184185 (6); loc. 3, UMMZ 181207 (2); loc. 6, UMMZ 177441 (8); 181225 (1); loc. 7, UMMZ 177237 (12); Dixon loc. 1, UMMZ 182225 (49); loc. 2, UMMZ 191532 (150); Sanders loc. 1, UMMZ 182-163 (600); loc. 2, UMMZ 182173 (26); loc. 3, UMMZ 182192 (300).

Subfamily GASTRODONTINAE

Genus ZONITOIDES Lehmann, 1862

Zonitoides (s. s.) arboreus (Say), 1816

Zonitoides arboreus (Say). Pilsbry, 1946, Acad. Nat. Sci. Philadelphia Mon. 3, v. 2, pt. 1, p. 480, fig. 261, 262.
Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151, pl. 14, fig. p.

Distribution.—North America from northern Canada to Costa Rica (Pilsbry, 1946, p. 481).

Ecology.—"* * * occurs in woodlands, living under loosened bark, leaves, and stones, and other cover affording protection from the sun, and providing at least moderate moisture" (Leonard, 1950, p. 37). In northern Nebraska it was found under logs and bark and among leaves on damp ground, usually in wooded areas.

Occurrence: Rexroad or Bender and Dixon local faunas (Frye and Leonard); Recent in northern Nebraska.

Family POLYGYRIDAE

Subfamily POLYGYRINAE

Genus POLYGYRA Say, 1818

Subgenus ERYMODON Pilsbry, 1956

Polygyra (Erymodon) rexroadensis[6] Taylor, n. sp.

Plate 1, figures 17, 23; Plate 2, figures 4, 5

Polygyra mooreana tholus (Binney). Hibbard, 1941, Kansas Univ. Sci. Bull., v. 27, p. 95 [not of Binney].
Hibbard, 1941, Kansas Acad. Sci. Trans., v. 44, p. 265 [not of Binney].
Frye and Hibbard, 1941, Kansas Geol. Survey Bull. 38, p. 408 [not of Binney].
Polygyra mooreana (Binney). Frye and Leonard, 1952, Kansas Geol. Survey Bull. 99, p. 151, pl. 14, fig. v [not of Binney].

Types.—Holotype UMMZ 177610a, Rexroad loc. 4b. Paratypes: UMMZ 177610 (1); 183050 (4), loc. 3; 183082 (2), loc. 2.

Diagnosis.—A *Polygyra of* the *P. texasiana* group characterized by its weak axial sculpture, spiral striae, high and asymmetrical parietal tooth, and absence of columellar tubercle.

Description of types.—Shell depressed, plane or with low spire above; periphery rounded; whorls 5, strongly descending to aperture; umbilicus at first steep sided, perforate to apex, expanding in last whorl to about one-third of shell diameter, with a shallow groove parallel to suture for last half whorl; aperture semicircular except for dental barrier; outer lip thickened, reflected following marked constriction of body whorl, bearing 2 laterally compressed teeth of equal size separated by deep sinus; from each tooth a broad, thick, ridge extends toward lip insertions; parietal callus bearing a large, asymmetrical biramose tooth opposite palatal teeth; branch toward columella about 4 times as long as that toward the upper lip insertion, straight, high and even for nearly two-thirds its length, descending sharply toward columella; no columellar tubercle; first (embryonic) whorl with fine growth lines, becoming coarse and irregular on later whorls, slightly coarsening behind lip; umbilical side of whorls with numerous, raised, dotlike papillae; last whorl with fine, close, irregular, wavy, impressed, spiral striae. Measurements in millimeters: paratype (UMMZ 183050) diameter 9.5, height 4.5, whorls 5; holotype diameter 7.8, height 4.0, whorls 5.

Variation.—The spire height varies slightly, but not as much as the measurements might indicate. The holotype has a relatively high body whorl and a low spire, rather than a much higher spire than the measured paratype. Umbilical width varies from a little more than one-third shell diameter (paratype) to one-fourth (holotype). The inner, permeable portion of the umbilicus varies correspondingly in width. Spiral striation on the slightly worn paratype is visible on only the last one-third whorl, but on the holotype it is visible on all the base exposed (slightly over one whorl). On this paratype this sculpture extends over the whorl, but on the holotype it is restricted below the periphery. The other unworn paratype shows the spiral sculpture but it is imperfect and the whorls cannot be counted.

Distribution.—Late Pliocene of southwestern Kansas.

Remarks.—*P. rexroadensis* is most similar to *P. texasiana texasensis* and *P. chisosensis.* It differs from the former by the weaker axial sculpture, the spiral striae on the last whorl, the umbilical papillae, and the shape of the parietal tooth. In *P. t. texasensis* this tooth is roughly v-shaped, and both branches descend gradually toward their distal ends. In *P. rexroadensis* this tooth is asymmetrical, with a long, high, columellar branch which descends sharply at its distal end. *P. chisosensis* has minutely granular sculpture and a columellar tubercle; both of these characters are absent in *P. rexroadensis. P. chisosensis* also lacks the umbilical papillation and spiral striation of *P. rexroadensis. P. mooreana* and *P. tholus* have stronger sculpture, a columellar tubercle, a V-shaped parietal tooth, and lack the spiral striae and umbilical papillae.

Material from the Bender local fauna consists only of small fragments. These show the spiral striae and umbilical papillae of *P. rexroadensis*, but suggest palatal teeth of subequal size. This difference may be a character of immaturity, however, and the specimens are considered referable to the Rexroad species.

Occurrence and material: Rexroad and Bender local faunas. Rexroad loc. 2, UMMZ 183082 (8, including 2 fragmentary subadult paratypes); loc. 3, UMMZ 183050 (67, including 1 adult paratype (measured) and 3 subadult paratypes); loc. 4b, UMMZ 177610 (6, including holotype and 1 fragmentary subadult paratype), 181059 (3); Bender loc. 1b, UMMZ 184144 (10).

[6] Named for its occurrence in the Rexroad local fauna.

Genus STENOTREMA Rafinesque, 1819

Stenotrema leai leai (Binney), 1840

Stenotrema monodon (Rackett). Pilsbry, 1940, Acad. Nat. Sci. Philadelphia Mon. 3, v. 1, pt. 2, p. 676, fig. 421a, b.
Leonard, 1950, Kansas Univ. Paleont. Contr. 8, p. 36.
Stenotrema leai (Binney). Pilsbry, 1948, Acad. Nat. Sci. Philadelphia Mon. 3, v. 2, pt. 2, p. 1099.

Distribution.—New York to Maryland, west to South Dakota and Nebraska.

Ecology.—"*S. monodon* is a snail of damp places near the water" (Pilsbry, 1940, p. 678). "*Stenotrema monodon* thrives in rather humid forests, and may be found on low terraces and flood plains of streams, under leaves, logs, and stones" (Leonard, 1950, p. 36). In northern Nebraska it was found under boards on damp ground, on the floodplain of the Niobrara River.

Remarks.—The Nebraska specimens have the open umbilicus and broader aperture of *Stenotrema leai leai*, rather than *S. leai aliciae*. The occurrence in northern Cherry County, Nebr., reported in this paper is farther west than previously known localities.

Pilsbry (1940, p. 678) listed two Kansas records for this form, but Leonard (1950, p. 36) referred all Kansas material to *S. leai aliciae*.

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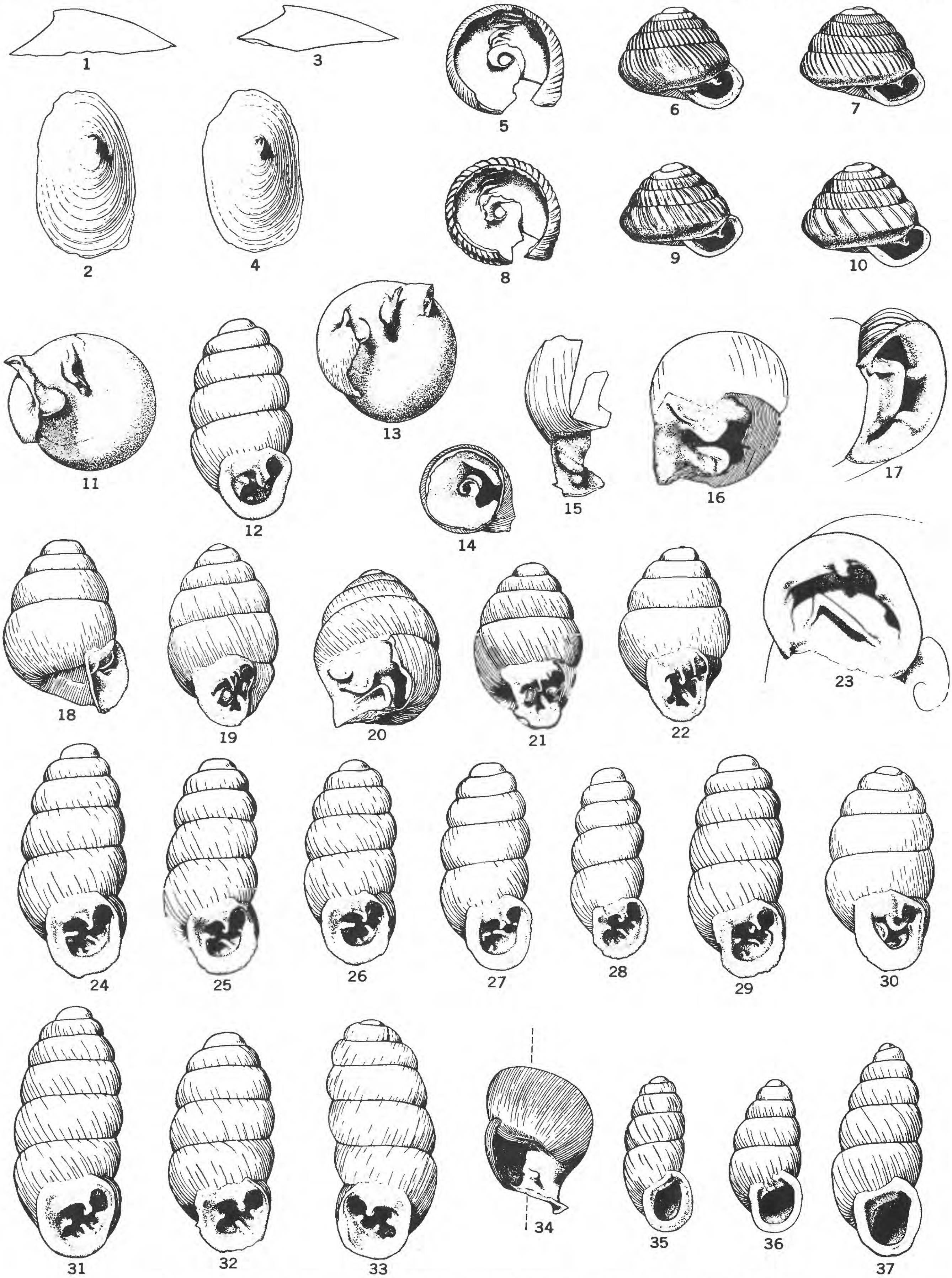
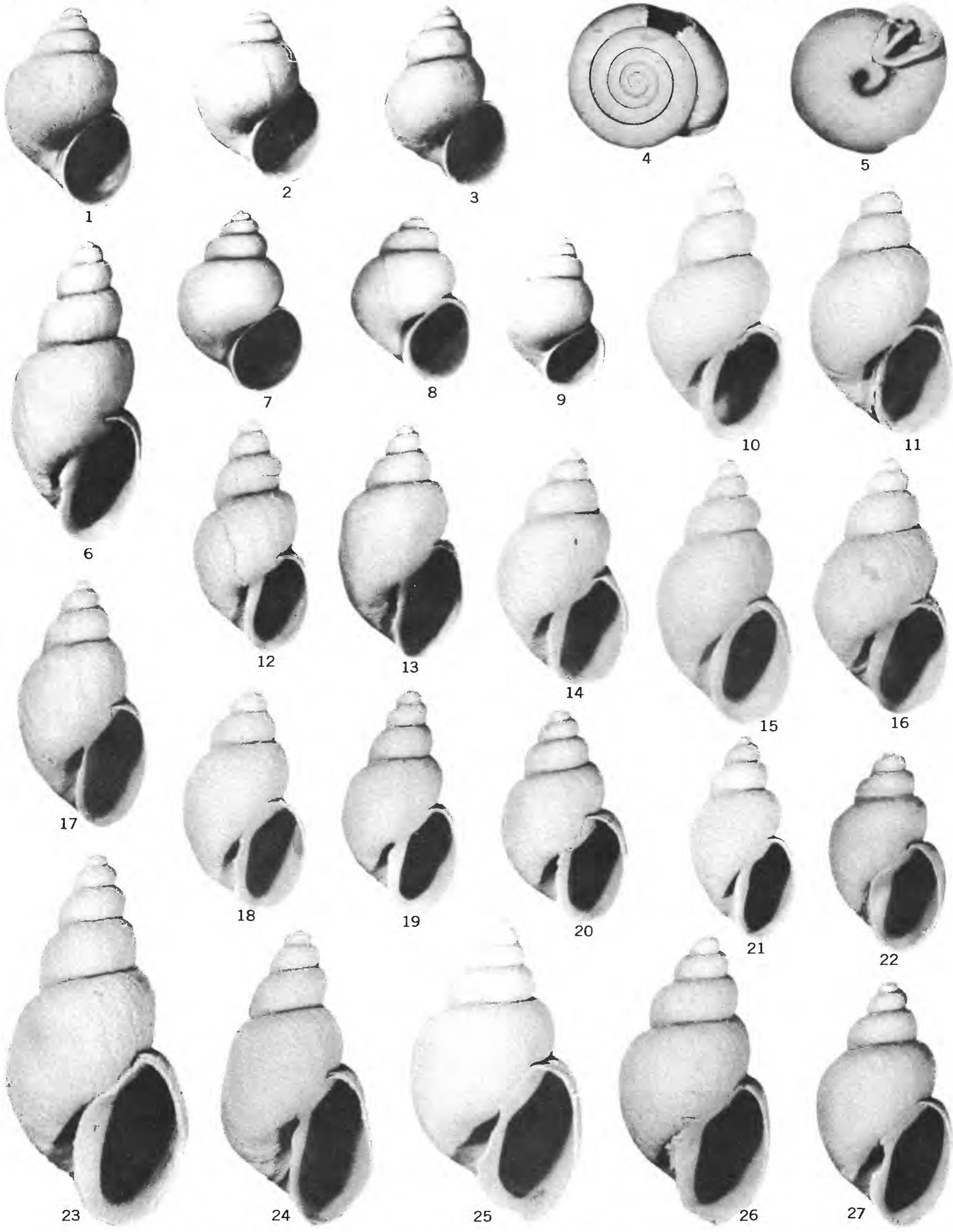


LATE PLIOCENE AND PLEISTOCENE MOLLUSKS FROM THE HIGH PLAINS



LATE PLIOCENE AND PLEISTOCENE MOLLUSKS FROM THE HIGH PLAINS

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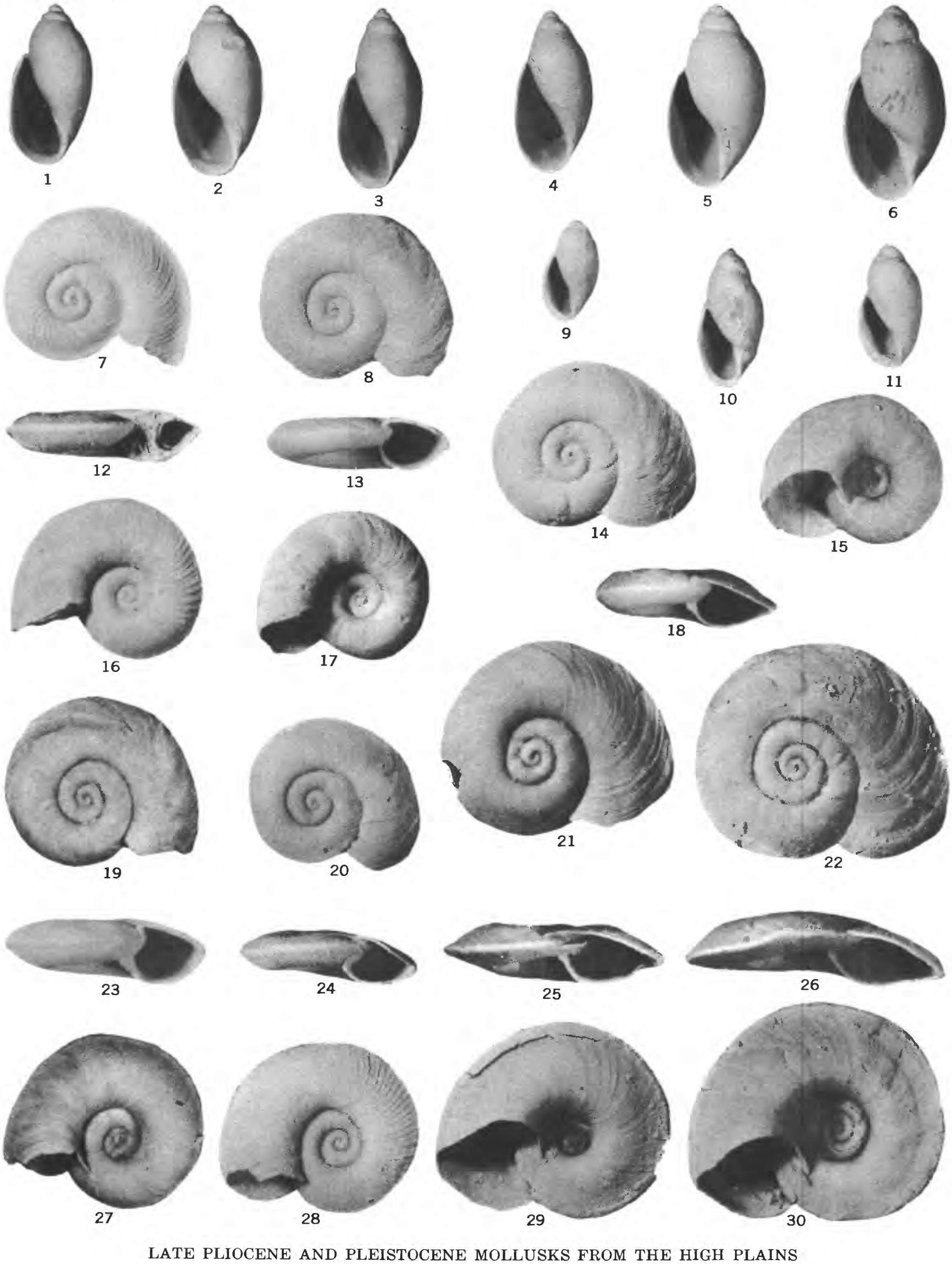
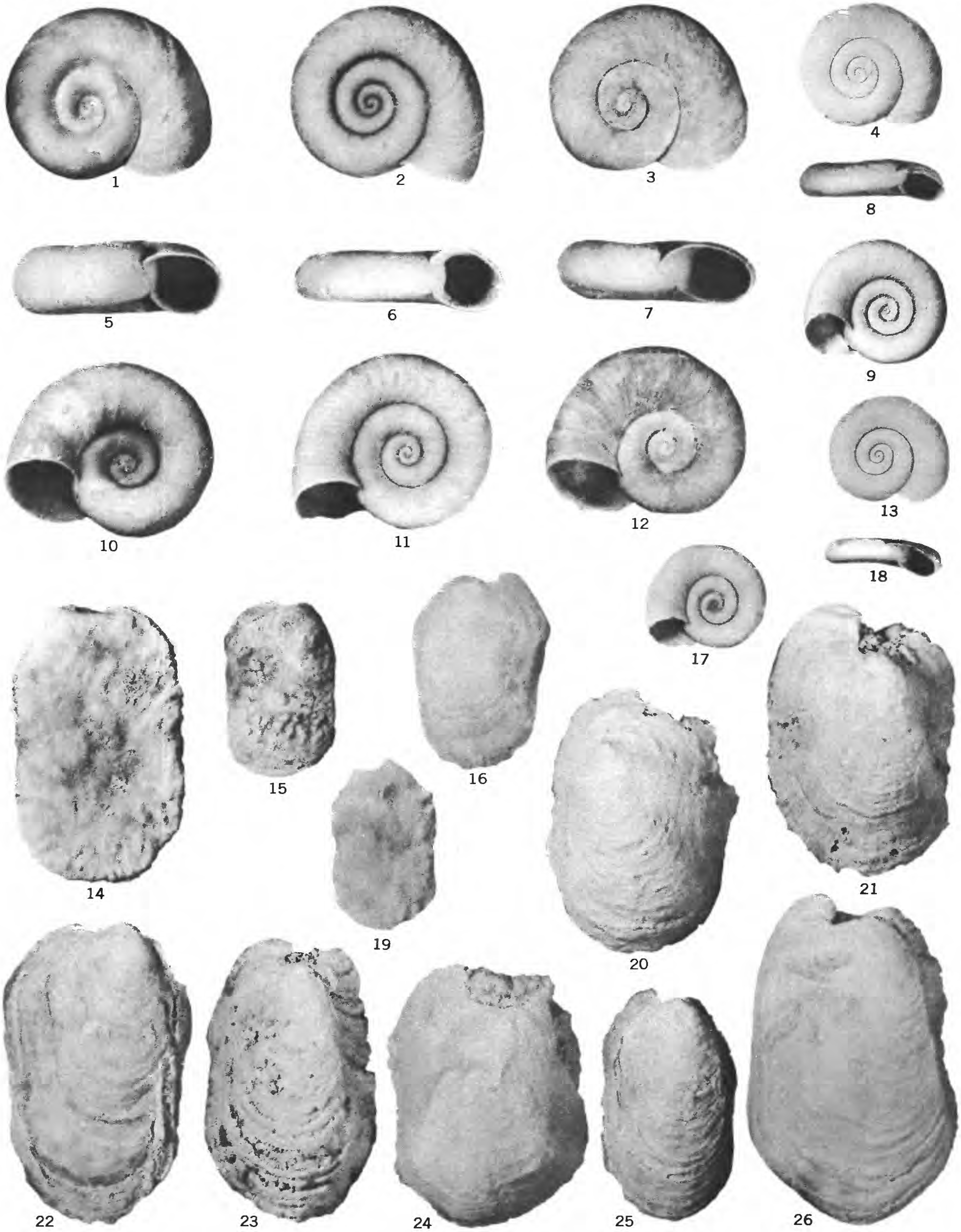
20, 24, 28. UMMZ 177430c.

21, 22, 25, 26, 29, 30. *Promenetus kansasensis* (Baker), × 20 (p. 59).
Sand Draw local fauna loc. 2. Unusually large specimens with expanded body whorl, analogous to *P. exacuous* (Say) form *megas* (Dall).
21, 25, 29. USNM uncat.
22, 26, 30. USNM uncat.



LATE PLIOCENE AND PLEISTOCENE MOLLUSKS FROM THE HIGH PLAINS



LATE PLIOCENE AND PLEISTOCENE MOLLUSKS FROM THE HIGH PLAINS

PLATE 4

FIGURES 1–3, 5–7, 10–12. *Gyraulus parvus* (Say), × 20 (p. 58).
Dixon local fauna loc. 1.
1, 5, 10. UMMZ 182200b.
2, 6, 11. UMMZ 182200a.
3, 7, 12. UMMZ 182200c.

4, 8, 9, 13, 17, 18 *Gyraulus parvus* (Say), × 5 (p. 58)
Topotypes of *G. enaulus* Leonard, Saw Rock Canyon local fauna.
4, 8, 9. UMMZ 177556a.
13, 17, 18. UMMZ 177556b.

14–16, 19–26. *Deroceras aenigma* Leonard, × 10 (p. 80).
Topotypes, Rexroad local fauna loc. 3.
14. UMMZ 183047d Ventral view.
15. UMMZ 183047k Dorsal view.
16. UMMZ 183047h Dorsal view, sinistral specimen.
19. UMMZ 183047j Ventral view.
20. UMMZ 183047e Dorsal view.
21. UMMZ 183047i Dorsal view.
22. UMMZ 183047b Dorsal view.
23. UMMZ 183047c Dorsal view.
24. UMMZ 183047f Dorsal view.
25. UMMZ 183047g Dorsal view.
26. UMMZ 183047a Dorsal view.

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