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FIVE ILLINOIAN MOLLUSCAN FAUNAS FROM THE SOUTHERN GREAT PLAINS

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ABSTRACT

The mollusks from 5 late Cenozoic (Illinoian) assemblages in the southwestern Kansas-northwestern Oklahoma area: the Berends local fauna, of Beaver County, Oklahoma; the Doby Springs local fauna, of Harper County, Oklahoma; and the Adams, Butler Spring and Mount Scott local faunas, of Meade County, Kansas, are listed.

A summary of information consisting of geologic range, distribution and ecology is given for all of the mollusks in the Mount Scott and Doby Springs local faunas, and for previously unreported species from the Berends, Adams and Butler Spring local faunas.

Taxonomic changes include assignment of *Promenetus exacuous* and *Promenetus kansasensis* to a single species complex. There is no satisfactory way of separating these 2 "species" in Recent and fossil populations that contain individuals with both riblet and non-riblet type surface ornamentation. The riblet type is designated *Promenetus exacuous* form *kansasensis* and the non-riblet form *Promenetus exacuous* form *exacuous*.

Interpretation of these molluscan assemblages is predicated on the assumptions that climatic factors are the primary agents controlling the distribution of non-marine mollusks; that fossil shells similar to those of living species represent the same species and were subject to the same limiting factors; and that the areas in the Great Plains presently containing associations of mollusks most similar to those found in these fossil assemblages, probably closely simulate the climatic conditions that existed at the time these fossils lived. Reconstruction of local habitat and climatic conditions under which these faunas lived has been based on a synthesis of information obtained from the fossil mollusks, pollen and vertebrates. In no case have interpretations based on the mollusks conflicted with conclusions reached independently from other fossil data.

The 5 Illinoian assemblages show compositional differences that are probably related to climatic changes during the Illinoian. The relatively large number of species with predominantly northern distributions, together with the low representation of exclusively southern faunal elements, indicate that the Doby Springs local fauna represents the coolest of the assemblages studied, and probably lived during maximum Illinoian glaciation. The Mount Scott local fauna contains a greater number of species with southern distributions than any of the other faunas studied, suggesting that it represents the warmest of these Illinoian faunas. There is no evidence in this area indicating that these faunas lived during more than one substage. Assuming that the transition from maximum glacial conditions, represented by the Doby Springs local fauna, towards warmer inter-

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[2]Adapted from a dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at the University of Michigan.

glacial conditions, represented by the Mount Scott local fauna, was unidirectional, then the climatic conditions implied by the Adams and Butler Spring assemblages must have occurred sometime between the time represented by the Doby Springs and Mount Scott local faunas. The first and last appearances of molluscan species and climatic implications of the Berends local fauna suggests that this assemblage is probably the oldest of these 5 Illinoian faunas.

The Berends assemblage contains 45 species of mollusks, 15 of which are new to this local fauna. One species, *Sphaerium securis,* represents the first fossil occurrence of this species from the southern Plains. This fauna lived in and around the margin of a small, shallow lake where the vegetation cover probably consisted mainly of conifers, grasses and composites, with only scattered patches of deciduous trees. The climate at the time this assemblage lived was probably similar to that presently occurring in the northeastern Nebraska-northwestern Iowa region of the Great Plains.

The Doby Springs local fauna contains 59 species of mollusks, one of which, *Vertigo elatior* is recorded for the first time as a fossil in the southern Plains. The mollusks indicate the existence of a cool, upstream lake, bordered by a marsh containing cattails, sedges and scattered deciduous and coniferous trees, which graded into a better drained shrub and tree community further back from the lake. The inferred former local climate combined shorter, cooler summers, with winters that were slightly cooler and longer than those presently prevailing in this region.

The Adams molluscan assemblage contains 22 species, one of which, *Lasmigona complanata* is first recorded as fossil from this area. The medium to coarse, cross-bedded sands from which the fauna was recovered, together with the occurrence of molluscan species requiring continuity of aquatic habitat, indicate the existence of a stream. The presence of only 1 woodland species among the terrestrial gastropods suggests that there was only a thin covering of trees and shrubs. The climate probably combined winters perhaps no more severe than those presently occuring in northeastern Nebraska, with cooler, more moist summers, similar to those in the Dakotas and eastern Montana.

There are 54 species of mollusks in the Butler Spring local fauna, one of which, *Ligumia* cf *recta,* is new to the southern Great Plains. This fauna lived in or near a medium sized river, with a slow to moderate current and a probable depth of several feet. There were scattered groups of trees along the river, but the predominant vegetation consisted of grasses and shrubs. The climate suggested by the assemblage consisted of cooler summers, similar to those now occurring in the eastern North Dakota region. Winters were probably no more severe than those in northcentral Nebraska.

The Mount Scott molluscan fauna, containing 63 species, is the largest such assemblage known from the southern Plains. It contains the only fossil record of *Zonitoides nitidus* from the Great Plains. Sedimentary and paleontologic evidence indicate that 5 major habitat associations are represented. The climate at that time probably combined summers similar to those now occurring in the Lake Okoboji region of northwest Iowa, with winters no more severe than those in the northeast Kansas-southeast Nebraska area.

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INTRODUCTION

Under supervision of Claude W. Hibbard, field parties from the University of Kansas (1936-1946) and University of Michigan (from 1947 onwards) have been engaged in an intensive study of the late Cenozoic fossils and stratigraphic sequence of the southwest Kansas-northwest Oklahoma area. During the 27-year period from 1936-1963, 13 Pleistocene faunas ranging in age from Aftonian to Wisconsin, have been studied (see Fig. 1, and summaries in Taylor, 1960; Hibbard & Taylor, 1960). Correlation of the Pleistocene sequence in this area with that of the glaciated region to the north and northeast, is based on the inferred climatic changes and stratigraphic position of these faunas. Four cooler-climate intervals separated by 3 warmer-climate intervals have been recognized in the Meade County area, which are believed to correlate with the Nebraskan-Kansan-Illinoian-Wisconsin glacial and Aftonian-Yarmouth-Sangamon interglacial stages in the classical Mississippi Valley sequence.

The washing technique developed by Hibbard (1949b) has made possible the recovery of extensive collections of fossils which have included ostracods, mollusks, fishes, amphibians, reptiles, birds and mammals. Detailed study of the pollen associated with these faunas has recently been undertaken by Kapp (1965). Some of these groups have barely been studied, while others have been fairly intensively described and illustrated. In this respect the mollusks from these faunas are comparatively well known. With the exception of the Deer Park and Borchers local faunas,

AGE		ROCK UNIT		FAUNA
PLEISTOCENE	WISCONSIN	VANHEM FM.		JONES L. F.
PLEISTOCENE	SANGAMON ILLINOIAN	KINGSDOWN FM.		JINGLEBOB L.F. CRAGIN QUARRY L. F. MOUNT SCOTT L. F. BUTLER SPRING L. F. ADAMS L. F. DOBY SPRINGS L. F. BERENDS L. F.
PLEISTOCENE	YARMOUTH KANSAN	CROOKED CREEK FM.	ATWATER MEMBER	BORCHERS L. F.
			PEARLETTE ASH	CUDAHY F.
			STUMP ARROYO MEMBER	SEGER GRAVEL PIT L. F.
PLEISTOCENE	AFTONIAN NEBRASKAN	BALLARD FM.	MISSLER MEMBER	SANDERS L. F. DEER PARK L. F.
			ANGELL MEMBER	
PLIOCENE	UPPER	REXROAD FM.		BENDER L. F. REXROAD L. F. SAW ROCK CANYON L. F.

FIG. 1. Late Cenozoic stratigraphic sequence and faunal succession in southwestern Kansas-northwestern Oklahoma.

mollusks have usually been among the most abundant fossils recovered from these assemblages. The shells of fossil mollusks often provide the characteristics upon which specific diagnoses are based. Interpretations of the Illinoian assemblages considered in this report are predicated upon the uniformitarian assumption that fossil shells similar to those of living species represent the same species and were subject to the same limiting factors. Conclusions based on the molluscan elements of the faunas in all cases are consistent with the interpretations reached from study of the pollen and other animal groups.

This paper is concerned primarily with the description and interpretation of the hitherto incompletely reported late Illinoian molluscan assemblages from the Mt. Scott and Doby Springs local faunas. A map and description of the surficial geology of the portion of the Big Springs Ranch, Meade County, Kansas, from which the Mt. Scott local fauna was collected, is also included. New materials from the other Illinoian assemblages of this area, the Berends, Adams and Butler Spring local faunas, which have become available since these local faunas were reported on by Hibbard & Taylor (1960), have required certain emendations which are presented herein.

The interpretation of the paleoecology of these faunas is based on a synthesis of evidence from fossil pollen, vertebrate and invertebrate faunas and sedimentary characters.

FAUNAL DISCUSSION

Introduction

The climatic and stratigraphic significance of the Mount Scott and Doby Springs local faunas is perhaps most readily shown by comparison with other Illinoian faunas from the southwest-Kansas northwest-Oklahoma area. This section of the report, therefore, also includes discussion of the Berends, Adams and Butler Spring local faunas. These five assemblages show compositional changes which seem best explained by assuming climatic change. Evidence presented below suggests that the Doby Springs and Mount Scott local faunas represent the coolest and warmest climatic conditions in this sequence of faunas, respectively. Although several stadial-interstadial intervals probably occurred during the Illinoian, there is no evidence in this area indicating that these assemblages lived during more than one substage. The Doby Springs local fauna probably lived earlier in this interval, sometime near maximum glacial conditions, while the Mount Scott local fauna lived later in the Illinoian after the climate had started to change towards warmer interglacial conditions. If this transition from maximum glacial towards warmer interglacial conditions was unidirectional, then the climatic conditions implied by the Adams and Butler Spring local faunas probably occurred sometime after the Doby Springs local fauna lived, but before the time represented by the Mount Scott local fauna. This faunal sequence is also suggested by the first and last appearances of molluscan species. The mollusks of the Berends local fauna suggest slightly warmer climatic conditions than those represented by the glacial maximum Doby Springs assemblage. At the present time it is not certain whether this warmer interval occurred before or after maximum Illinoian glaciation.

Berends Local Fauna

Previous Work. The Berends local fauna is known from secs 5 and 6, T 5 N, R 28 E, Beaver County, Oklahoma. It was recovered from a dark silty interval in a sequence of sediments that accumulated as a series of late Pleistocene sink-hole deposits, after collapse of the underlying Crooked Creek formation. The fauna collected from these sediments has been summarized by Hibbard & Taylor (1960: 55-57) from previous reports (Herrington & Taylor, 1958; Hibbard, 1956b; Mengel, 1952; Rinker & Hibbard, 1952; Smith, 1954, 1958; Starrett, 1956; Taylor, 1954; Taylor & Hibbard, 1955). Kapp (1965) has recently analysed the pollen from the Berends local fauna locality. Fourteen species of mollusks, hitherto unreported from this fauna, were recovered from matrix collected during the summer of 1959 by University of Michigan Museum of Paleontology field parties.

Faunal List, Berends Local Fauna:

CLASS PELECYPODA

Order Teleodesmacea

Sphaerium lacustre (Müller)
**S. securis* Prime
S. sulcatum (Lamarck)
**S. transversum* (Say)
Pisidium casertanum (Poli)
P. compressum Prime
P. nitidum Jenyns
P. obtusale (Lamarck)
**P. variabile* Prime

CLASS GASTROPODA

Order Mesogastropoda

Valvata tricarinata (Say)

Order Basommatophora

**Carychium exiguum* (Say)
Stagnicola caperata (Say)
S. exilis (Lea)
**S. reflexa* (Say)
Fossaria dalli (Baker)
F. obrussa (Say)
Gyraulus circumstriatus (Tryon)
G. parvus (Say)
Armiger crista (Linnaeus)
**Helisoma anceps* (Menke)
H. trivolvis (Say)
Planorbula armigera (Say)

Promenetus exacuous form *kansasensis* (Baker)
**Physa anatina* Lea
P. gyrina Say
P. skinneri Taylor
Aplexa hypnorum (Linnaeus)

Order Stylommatophora

**Strobilops labyrinthica* (Say)
Gastrocopta armifera (Say)
**G. cristata* (Pilsbry & Vanatta)
G. procera (Gould)
G. tappaniana (Adams)
**G. holzingeri* (Sterki)
Pupoides albilabris (Adams)
**Vertigo milium* (Gould)
V. ovata (Say)
**Vallonia gracilicosta* Reinhardt
**V. parvula* Sterki
cf *Succinea*
Oxyloma sp.
Helicodiscus parallelus (Say)
**Deroceras aenigma* (Leonard)
**Euconulus fulvus* (Müller)
Hawaiia minuscula (Binney)
Stenotrema leai (Binney)

CLASS OSTEICHTHYES

Lepisosteus sp., gar
Esox masquinongy Mitchill, muskellunge
Catostomus commersoni (Lacépède), white sucker
Notemigonus crysoleucus (Mitchill), golden shiner
Semotilus cf *S. atromaculatus* (Mitchill), creek chub
Semotilus sp., minnow
Cyprinidae, indeterminate
Ictalurus melas (Rafinesque), black bullhead
I. punctatus (Rafinesque), channel catfish
Lepomis cf *L. cyanellus* Rafinesque, green sunfish
Perca flavescens (Mitchill), yellow perch
Fundulus sp.

CLASS REPTILIA
Order Chelonia

Unidentifiable turtle remains

CLASS AVES
Order Pelicaniformes

Pelicanus erythrorhynchus Gmelin, white pelican

CLASS MAMMALIA
Order Insectivora

Sorex cf *S. cinereus* Kerr, masked shrew
Blarina cf *B. brevicauda* (Say), short-tailed shrew

Order Rodentia

Castoroides sp., giant beaver
Paradipoides stovalli Rinker & Hibbard, Stovall's beaver
Geomys sp., eastern pocket gopher
Perognathus cf *P. hispidus* Baird, hispid pocket mouse
Peromyscus berendsensis Starrett, deer mouse
Ondatra triradicatus Starrett, muskrat,
Microtus pennsylvanicus (Ord), meadow vole
Pedomys cf *P. ochrogaster* (Wagner), prairie vole

Order Carnivora

Canis latrans Say, coyote

Order Proboscidea.

Mammuthus cf *M. columbi* (Falconer), Columbian mammoth

Order Lagomorpha

Leporidae, indeterminate, rabbit

Order Perissodactyla

Equus sp., horse

Rejected records

Deroceras laeve = *Deroceras aenigma;*
Aplodinotus grunniens = *Fundulus* sp.

*Species not previously reported.

Age and Correlation. The sediments containing the Berends local fauna overlay the Pearlette ash, and are therefore post-Kansas in age. Climatic implications of the pollen (Kapp, 1965) and fauna (Hibbard & Taylor, 1960; Miller, this report), indicate that the assemblage lived

TABLE 1. Summary of local habitats represented by the mollusks of the Berends Local Fauna.*

Habitat	Species	Number of Individuals
Semiaquatic: among vegetation and debris near water's edge.	*Oxyloma* sp.	241
Hygrophilic: moist situations in leaf mold, under sticks and debris; shaded areas not far from water.	*Carychium exiguum* *Vertigo ovata* *V. milium* *Gastrocopta tappaniana* *Deroceras aenigma*	188 1122 21 738 30
Woodland: moist areas under leaf mold litter, down timber, among tall marsh grass.	*Stenotrema leai* *Euconulus fulvus* *Strobilops labyrinthica* *Helicodiscus parallelus*	84 1 1 8
Sheltered areas: among rocks, shrubs, grass or in timbered situations.	*Gastrocopta armifera* *G. holzingeri*	30 29
Sheltered situations: these species are not restricted to a woodland habitat and can tolerate drier conditions.	*Gastrocopta cristata* *G. procera* *Pupoides albilabris* *Hawaiia minuscula* *Vallonia parvula* *V. gracilicosta*	67 8 12 581 23 7
Marginal situations: wet mud, sticks, stones or any other debris along water's edge: shallow ponds and protected spots.	*Fossaria obrussa* *F. dalli*	62 97
Shallow quiet water: small stream, pond, slough or marsh that may become dry during part of the year.	*Pisidium casertanum* *Stagnicola reflexa* *S. caperata* *S. exilis* *Armiger crista* *Gyraulus circumstriatus* *Physa gyrina* *Aplexa hypnorum*	4+4/2** 25 50 63 26 399 135 52
Shallow quiet water: small pond, stream, slough, or marsh with no current or areas of rooted vegetation with little current; soft sand or mud bottom; not subjected to significant seasonal drying.	*Sphaerium securis* *S. sulcatum* *S. transversum* *Pisidium obtusale* *Gyraulus parvus* *Helisoma trivolvis* *Planorbula armigera* (cont.)	7/2 65/2 1/2 10/2 76 51 851

*Based on material published in Taylor, 1954; Herrington & Taylor, 1958; Hibbard & Taylor, 1960; this report.

**Fractions refer to the number of isolated single valves.

Table 1 (cont.)

Habitat	Species	Number of Individuals
(cont.)	*Promenetus exacuous* form *kansasensis*	513
	Physa anatina	58
	P. skinneri	208
Perennial water: stream or lake with slow to moderate current; areas of still water; shallow spots with soft sand or mud substrate not affected by seasonal drying.	*Sphaerium lacustre*	4/2
	Pisidium compressum	322/2
	P. nitidum	65/2
	P. variabile	4/2
	Valvata tricarinata	337
	Helisoma anceps	17

during a cool, moist, glacial interval. The relatively large number of extinct species of rodents suggests that this interval was pre-Wisconsin (probably Illinoian).

Stephens (1960) correlated the Berends and Doby Springs local faunas on the basis of the mammals shared in common. Kapp (1965) has interpreted the pollen spectrum associated with the Berends fauna as representing maximum Illinoian glaciation and considered it equivalent both to locality 5 of the Doby Springs (p 181) and to the Adams (p 186) local faunas. The mollusks, however, suggest that the Berends lived under slightly warmer climatic conditions than those represented by the Doby Springs assemblage. At the present time it is not certain whether this warmer interval occurred before or after maximum Illinoian glaciation.

Habitat. A summary of the local habitats represented by the mollusks is given in Table 1. This arrangement is somewhat arbitrary since many species are not necessarily restricted to the one habitat to which they may have been assigned. However, it is believed that these habitat groups probably reflect the fact that each species does have a certain "preferred" habitat in which it is most abundant and where it most commonly occurs. Taylor (1954: 7) has interpreted the aquatic gastropods of this fauna as representing ". . . a habitat which had shallow permanent and temporary water near the shore of a lake, with little or no rough water. Connection of this lake to a permanent stream at some time is indicated by *Valvata*, which must have continuity in aquatic conditions." This interpretation is supported by the fishes (Smith, 1954), the sphaeriids (Herrington & Taylor, 1958), and by the additional aquatic mollusks reported herein.

The pollen spectrum (Kapp, 1965) shows large percentages of conifers, grasses and composites, with only small quantities of deciduous tree pollen. The relative paucity of terrestrial snails usually associated with deciduous woodlands can probably be accounted for by assuming a vegetation cover such as is indicated by the pollen. The better represented of the terrestrial species (*Carychium exiguum*, *Vertigo ovata*, *V. milium*, *Gastrocopta tappaniana* and *Hawaiia minuscula*) probably lived among the moss-covered down timber near the lake margin. The remainder of the terrestrial mollusks were probably distributed among scattered patches of deciduous trees further back from the lake, under accumulations of leaf mold and rotting timber.

Climate. The area of sympatry for most of the species of mammals, fishes and mollusks found in the Berends local fauna is the northeastern Nebraska-northwestern Iowa region of the Great Plains. This area is now characterized by a climate with normal annual temperatures of about 45° F; normal summer temperatures averages of about 70° F; normal winter temperatures of 20° F; and a precipitation rate of between 20-30 in. a year, (Visher, 1954). Most of this precipitation comes during the hot part of the year when it is most needed. The Berends local fauna appears to have lived under climatic conditions similar to those now existing in the area of sympatry.

Doby Springs Local Fauna

Previous Work. Smith (1958) proposed the name Doby Springs local fauna for the fishes and associated organic remains occurring in late Pleistocene deposits in the N 1/2 SW 1/2 sec 10, T 27 N, R 24 W, Harper County, Oklahoma. Meyers (1959) tentatively assigned these beds to the Illinoian stage on the basis of sedimentary and molluscan faunal similarities with other sink hole deposits of this age in the area. Hibbard & Taylor (1960) recorded one species of mollusk (*Probythinella lacustris*) from the Doby Springs fauna. Stephens (1960) mapped and studied the geology of the area and described the mammalian fauna. More recently, additional materials from this fauna have been reported in papers by Klingener (1963, on the jumping mouse, *Zapus*); Etheridge (1960; 1961, on the lizard *Ophisaurus*); Tihen (1962, on the bufonid toads); and Gutentag & Benson (1962, on the *ostracods*). Kapp (1965) has recorded the pollen found associated with the Doby Springs local fauna. The Doby Springs local fauna is known from 5 localities, only 4 of which contain mollusks. The locality numbers referred to below are the same as those used by Stephens (1960).

Age and Correlation. The Doby Springs

Faunal List, Doby Springs Local Fauna:

CLASS OSTRACODA

Candona nyensis Gutentag & Benson

CLASS PELECYPODA

Order Prionodesmacea

Uniomerus tetralasmus (Say)
Anodonta grandis Say

Order Teleodesmacea

Sphaerium occidentale Prime
S. rhomboideum (Say)
S. striatinum (Lamarck)
S. sulcatum (Lamarck)
Pisidium casertanum (Poli)
P. compressum Prime
P. nitidum Jenyns
P. obtusale (Lamarck)
P. variabile Prime

CLASS GASTROPODA

Order Mesogastropoda

Valvata tricarinata (Say)
**Probythinella lacustris* (Baker)

Order Basommatophora

Carychium exiguum (Say)
Lymnaea stagnalis jugularis Say
Stagnicola caperata (Say)
S. reflexa (Say)
Fossaria dalli (Baker)
F. obrussa (Say)
Armiger crista (Linnaeus)
Gyraulus circumstriatus (Tryon)
G. deflectus (Say)
G. parvus (Say)
Helisoma anceps (Menke)
H. trivolvis (Say)
Promenetus exacuous form *kansasensis* (Baker)
P. umbilicatellus (Cockerell)
Ferrissia fragilis (Tryon)
Laevapex fuscus (Adams)
Physa anatina Lea
P. gyrina Say
P. skinneri Taylor
Aplexa hypnorum (Linnaeus)

Order Stylommatophora

Cionella lubrica (Müller)

*Species reported previously in Hibbard & Taylor (1960).

Strobilops labyrinthica (Say)
Gastrocopta armifera (Say)
G. contracta (Say)
G. cristata (Pilsbry & Vanatta)
G. holzingeri (Sterki)
G. procera (Gould)
G. tappaniana (Adams)
Pupoides albilabris (Adams)
Pupilla blandi Morse
P. muscorum (Linnaeus)
Vertigo elatior (Sterki)
V. milium (Gould)
V. ovata (Say)
Vallonia gracilicosta Reinhardt
V. parvula Sterki
cf *Succinea*
Oxyloma sp.
Discus cronkhitei (Newcomb)
Helicodiscus parallelus (Say)
Deroceras aenigma Leonard
Euconulus fulvus (Müller)
Nesovitrea electrina (Gould)
Hawaiia minuscula (Binney)
Zonitoides arboreus (Say)
Stenotrema leai (Binney)

CLASS OSTEICHTHYES

Catostomus commersoni (Lacépède), white sucker
Semotilus cf *S. atromaculatus* (Mitchill), creek chub
cf *Hybopsis gracilis* (Richardson), flathead chub
Pimephales promelas Rafinesque, flathead minnow
Cyprinidae sp.
Ictalurus melas (Rafinesque), black bullhead
Lepomis cf *L. cyanellus* Rafinesque, green sunfish
Perca flavescens (Mitchill), yellow perch

CLASS AMPHIBIA
Order Salienta

Bufo "Americanus group", toad

CLASS REPTILIA
Order Squamata

Ophisaurus attenuatus Baird, glass lizard

CLASS MAMMALIA
Order Insectivora

Sorex arcticus Kerr, arctic shrew
S. cinereus Kerr, masked shrew
Sorex palustris Richardson, northern water shrew
Blarina brevicauda brevicauda (Say), short-tail shrew

Order Rodentia

Citellus cf *C. richardsonii* (Sabine), Richardson ground squirrel
Citellus tridecemlineatus (Mitchill), thirteen lined ground squirrel
Thomomys sp., western pocket gopher
Geomys bursarius (Shaw), Plains pocket gopher
Castorid, genus and species indeterminate, large beaver
Peromyscus cf *P. cochrani* Hibbard, mouse
P. oklahomensis Stephens, mouse
Onychomys cf *O. leucogaster* (Wied-Neuwied), northern grasshopper mouse
Ondatra zibethica (Linnaeus), muskrat
Microtus pennsylvanicus (Ord), meadow vole
Zapus hudsonius transitionalis Klingener, meadow jumping mouse

Order Carnivora

a large form, family indeterminate
a small form, family indeterminate

Order Proboscidea

Mammuthus sp., mammoth

Order Lagomorpha

Lepus sp., hare

Order Artiodactyla

Camelops sp., camel
Antilocaprid sp., pronghorn
Bison cf *B. latifrons* (Harlan), giant bison

Order Perissodactyla

Equus cf *E. niobrarensis* Hay, horse
Equus sp., horse

TABLE 2. Summary of local habitats represented by the mollusks of the Doby Springs Local Fauna.

Habitat	Species	Locality and Abundance*			
		1	2	4	5
Semiaquatic: among vegetation and debris near water's edge.	*Oxyloma* sp.	R	-	R	-
Hygrophilic: moist situations in leaf mold, under sticks and debris; shaded areas, not far from water.	*Carychium exiguum*	-	R	A	A
	Vertigo ovata	A	R	A	A
	V. milium	-	-	C	A
	V. elatior	S	-	A	A
	Gastrocopta tappaniana	C	R	A	A
	Deroceras aenigma	R	-	S	C
Woodland: moist areas under leaf litter, down timber, among tall marsh grass.	*Cionella lubrica*	-	-	R	R
	Stenotrema leai	-	-	R	R
	Discus cronkhitei	A	R	A	-
	Zonitoides arboreus	R	R	A	-
	Nesovitrea electrina	R	-	R	S
	Euconulus fulvus	R	-	R	S
	Strobilops labyrinthica	R	-	R	-
	Helicodiscus parallelus	S	-	A	A
Sheltered areas: among rocks, shrubs, grass, or in timbered situations.	*Gastrocopta armifera*	R	R	S	C
	G. contracta	-	-	R	-
	G. holzingeri	-	-	R	R
Sheltered situations: These species are not restricted to a woodland habitat and can tolerate drier conditions.	*Gastrocopta cristata*	R	-	A	R
	G. procera	-	R	A	-
	Pupilla blandi	-	-	-	R
	P. muscorum	A	-	C	A
	Pupoides albilabris	-	-	R	R
	Hawaiia minuscula	R	-	A	A
	Vallonia parvula	-	-	R	-
	V. gracilicosta	A	R	A	A
Marginal situations: wet mud, sticks, stones, or any other debris along water's edge; shallow pools and other protected spots.	*Fossaria obrussa*	-	-	C	-
	F. dalli	A	R	A	S**
Shallow quiet water: small streams, ponds, sloughs or marsh, that may become dry during part of the year.	*Pisidium casertanum*	C	-	C	A
	Sphaerium occidentale	-	-	R	-
	Stagnicola reflexa	R**	-	A	R
	S. caperata	R	R	A	S
	Armiger crista	R	-	S	A
	Gyraulus circumstriatus	C	R	A	S
	G. deflectus	A	R	A	-
	Promenetus umbilicatellus	R	R	-	R
	Physa gyrina	-	-	A	-
	Aplexa hypnorum	-	-	R	R**
	Ferrissia fragilis	-	-	R	R

Table 2 (cont.)

Habitat	Species	Locality and Abundance*			
		1	2	4	5
Shallow quiet water: small ponds, streams, sloughs, or marsh, with no current or areas of rooted vegetation with little current; soft sand or mud bottoms; not subject of significant seasonal drying.	*Uniomerus tetralasmus*	-	-	R	-
	Lymnaea stagnalis jugularis	R	-	R	R
	Sphaerium rhomboideum	R	-	R	-
	S. sulcatum	S	-	A	R
	Pisidium obtusale	R	-	R	R
	Gyraulus parvus	A	C	A	A
	Helisoma trivolvis	-	-	R	R
	Promenetus exacuous form *kansasensis*	A	-	A	A
	Physa anatina	R	-	A	-
	P. skinneri	R	-	A	-
	Laevapex fuscus	-	-	S	-
Perennial water: Stream or lake with slow to moderate current; areas of still water; shallow spots with soft sand or mud substrate; not affected by seasonal drying.	*Sphaerium striatinum*	-	-	C	-
	Pisidium compressum	A	R	A	A
	P. nitidum	C	-	A	A
	P. variabile	A	-	C	A
	Valvata tricarinata	A	S	A	A
	Helisoma anceps	S	R	A	A
	Probythinella lacustris	-	-	A	-
	Anodonta cf *A. grandis*	-	-	R	-

*R=<25; S= 26-49; C= 50-100; A=>100 shells.
**These specimens were questionably referred to species.

local fauna is considered Illinoian in age on the basis of both stratigraphic position and vertebrate fossils and has been correlated with the Berends and Butler Spring local faunas (Smith, 1958; Stephens, 1960; Hibbard & Taylor, 1960). However, studies of the pollen, collected from samples of sediments associated with these assemblages (Kapp, 1965), indicate that only locality 5 of the Doby Springs local fauna is equivalent to the Berends and the lower part of the section from which the Butler Spring local fauna was recovered. This lower portion of the Butler Spring local fauna (localities 2, 3, 4 and 5 of Hibbard & Taylor, 1960), has been designated the Adams local fauna by Kapp (1965).

The predominantly northern and northeastern aspect of the Doby Spring molluscan fauna indicates cool, moist, glacial conditions, and is compatible with the interpretations based on the pollen, and vertebrates.

Habitat. Stephens (1960) recognized 4 habitat associations in the vertebrate fauna: a lake and marsh border community; a lowland meadow community; a shrub and tree community; and an upland prairie community.

Table 2 summarizes the habitat associations indicated by the Doby Springs molluscan fauna. The abundant representation of *Probythinella lacustris* is interpreted as indicating that the lake in which the sediments containing the Doby Springs local fauna were deposited probably had a depth of at least five ft. The carbonaceous dark-gray to black silty clay and silt from which *P. lacustris* (Hibbard & Taylor, 1960: 81) was recovered, considered together with the occurrence of *Pisidium variabile* which prefers a bottom on which soft sediments are accumulating, suggests that the substrate, in part, consisted of a soft organic mud. Firmer patches of bottom, composed of sand and silt are indicated by

Sphaerium striatinum.

The shallower portions of the lake near shore contained dense patches of immersed aquatic vegetation which probably included such species as *Sagittaria, Myriophyllum* and *Pediastrum* (Kapp, 1965). These plants provided suitable habitats for *Sphaerium sulcatum, S. rhomboideum, Valvata tricarinata, Gyraulus parvus, Promenetus exacuous* form *kansasensis* and *Physa anatina.*

Temporary bodies of water in the marsh area along the margin of the lake contained *Pisidium casertanum, Sphaerium occidentale, Stagnicola caperata, S. reflexa, Lymnaea stagnalis jugularis, Armiger crista, Gyraulus circumstriatus, G. deflectus, Promenetus umbilicatellus, Physa gyrina, Aplexa hypnorum* and *Ferrissia fragilis.* Rest marks on some of the *P. casertanum* and the presence of some septate shells amongst the *Ferrissia,* indicate that some of the water situations were subjected to periodic drying.

The terrestrial element in the molluscan fauna is dominated by hygrophilic species, which also lived in the marsh near the lake margin. The vegetational cover postulated for this area by Kapp (1965), would have provided suitable habitats for most of the terrestrial mollusks listed.

Gastrocopta cristata, G. procera, Pupilla blandi, P. muscorum, Pupoides albilabris, Hawaiia minuscula, Vallonia parvula and *V. gracilicosta* are terrestrial species that can tolerate drier situations and probably in part lived amonst the better drained shrub and tree community further back from the lake.

Climate. Fifty-six of the 59 molluscan forms present in the Doby Springs local are identifiable to species that are now extant. Fourty-six of these species have been reported from the Lake Okoboji region of Iowa. There is, however, no one geographic locality known to me at which all the species associated in the Doby Springs assemblage occur.

The Doby Springs local fauna probably lived at a time when summer conditions were no hotter or drier than those presently occuring in northern North Dakota and Minnesota, near the southern limit of range for *Pupilla muscorum.* The winters were most likely similar to those in northeastern Nebraska-northwestern Iowa, the area in which the majority of the Doby Springs molluscan species presently occur. Some of the more easterly (e.g., *Laevapex fuscus*), and southerly (e.g., *Gastrocopta cristata, G. procera*) distributed species, are at or near the periphery of their ranges in this region. Summers in the northeastern portion of North Dakota are characterized by normal temperatures of between 65° - 70° F (Vischer, 1954: map 5). The normal annual precipitation in this area is about 18-20 in. (Visher, 1954: map 492), slightly less than in Harper County, Oklahoma (Stephens, 1960). The greater part of this precipitation in North Dakota, however, occurs during the summer months, when it is most needed. Cooler summers and lower evaporation rates, in the North Dakota region, make the smaller amount of rainfall more effective and have made it possible for a relatively large molluscan fauna to maintain itself. The normal winter temperature in the northeastern Nebraska-northwestern Iowa area, is between 15°-20° F (Visher, 1954: map 4).

The inferred climate in Harper County, Oklahoma, at the time the Doby Springs local fauna lived, combined shorter, cooler summers, with winters that were slightly cooler and longer than those presently prevailing in this area. The normal summer temperature was probably between 65° - 70° F. The normal annual precipitation was about 18-20 in., 8-10 in. of which fell during the summer months. The normal evaporation during the warmer part of the year was between 30-35 in., compared with today's 50-60 in. in Harper County (Visher, 1954: map 483). The normal winter temperatures were probably between 15° - 20° F.

Adams Local Fauna

Previous work. The term Adams local fauna was proposed by Kapp (1965) for the fossils recovered from the sequence of medium to coarse, limonitic, cross-bedded sands which occur stratigraphically below the Butler Spring local fauna (Hibbard & Taylor, 1960), in the SE 1/4 sec 32, T 34 S, R 29 W, Meade County, Kansas. Kapp found that there was a sharp change in the frequency of pine, grass and composite pollen, between the top and bottom of unit 1, measured section 2 of Hibbard & Taylor (1960: 43). Within this interval a trend towards increasing pine and decreasing grass and composites is reversed, and there is a sharp rise in the frequency of the grass pollen with a concomitant decline in pine pollen. Kapp suggests that this striking reversal may represent an unconformity between a cool, moist and a drier and/or warmer interval. This sharp transformation in the composition of the pollen spectrum occurs at a point in the section that is stratigraphically between locality 1 and localities 2, 3, 4 and 5 of the Butler Spring local fauna (as used in Hibbard & Taylor, 1960), and forms the basis for the separation of the Adams and Butler Spring local faunas. In this report the Butler Spring local fauna is restricted to locality 1 and the Adams local fauna to localities 2, 3, 4 and 5.

Faunal List; Adams Local Fauna:

CLASS PELECYPODA
Order Prionodesmacea

Lasmigona complanata (Barnes)*
Quadrula quadrula (Rafinesque)

CLASS GASTROPODA
Order Mesogastropoda

Valvata tricarinata (Say)

Order Basommatophora

Stagnicola caperata (Say)
Fossaria dalli (Baker)
Gyraulus parvus (Say)
Promenetus exacuous form *kansasensis* (Baker)
Physa anatina Lea

Order Stylommatophora

Gastrocopta cristata (Pilsbry & Vanatta)
G. procera (Gould)
G. tappaniana (Adams)
Pupilla blandi Morse
P. muscorum (Linnaeus)
P. sinistra Franzen
Vertigo milium (Gould)
V. ovata (Say)
Vallonia cyclophorella Sterki
V. gracilicosta Reinhardt
cf *Succinea*
Discus cronkhitei (Newcomb)
Helicodiscus singleyanus (Pilsbry)
Hawaiia minuscula (Binney)

CLASS AMPHIBIA
Order Caudata

Ambystoma tigrinum (Green), tiger salamander

CLASS REPTILIA
Order Chelonia

Emydoidea twentei (Taylor), Plains semibox turtle

CLASS MAMMALIA
Order Edentata

Megalonyx sp., ground sloth

Order Rodentia

Citellus sp., ground squirrel
cf *Geomys*, eastern pocket gopher
Castoroides cf *C. ohioensis* Foster, Ohio giant beaver
Microtus pennsylvanicus (Ord), meadow vole

Order Proboscidea

Mammuthus sp., mammoth

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*Species not previously reported

Order Artiodactyla

Camelops sp., camel

Order Perissodactyla

Equus scotti Gidley, horse
Equus sp., horse

Age and Correlation. Kapp (1965) tentatively correlated the Adams local fauna with locality 5 of the Doby Springs and with the Berends local faunas on the occurrence of spruce pollen. The occurrences of spruce at these 3 sites are the only unequivocal records of this pollen entity in the Meade County area. The Adams and Butler Spring molluscan faunas, however, are more closely related to each other, than is either one to the Doby Springs. All of the species found in the Adams local fauna, with the exception of the unionid clams, also occur in the Butler Spring assemblage. Three species, *Vallonia cyclophorella*, *Pupilla sinistra* and *Helicodiscus singleyanus* are present in the Adams and Butler Spring local faunas, but are absent from the Doby Springs local fauna. This has been interpreted to mean that the Doby Springs mollusks probably lived in the area earlier in the Illinoian, before these species reached this part of the Plains.

The mammals (Hibbard, 1963), the pollen (Kapp, 1965) and the mollusks (Miller, this report) indicate a trend towards a warmer climate between the time the Doby Springs fauna and the Mount Scott fauna lived. This trend was characterized by a decrease in spruce and pine pollen and an increase in the number of southern species in the faunas of the area. The first Illinoian appearance in this region of *Helicodiscus singleyanus*, a species with a relatively southern distribution, is in the Adams local fauna and suggests that this assemblage lived in the area sometime after this warming trend began. The stratigraphic position of the Adams local fauna indicates that it lived before the Butler Spring local fauna, probably sometime after the Illinoian glacial maximum represented by Doby Springs local fauna locality 5.

Habitat. The medium to coarse, cross-bedded sands from which the fauna was recovered (Hibbard & Taylor, 1960), together with the occurrence of *Valvata tricarinata*, *Gyraulus parvus*, *Quadrula quadrula* and *Lasmigona complanata*, species requiring continuity of aquatic habitat, are interpreted as indicating the existence of a stream. The presence of only one wood-land species among the terrestrial gastropods suggests that there was only a thin covering of trees and shrubs, rather than a continuous forest belt along the stream.

Climate. The Adams local fauna contains many species presently living in the northern Great Plains. *Valvata tricarinata*, *Pupilla blandi*, *P. muscorum*, *P. sinistra* and *Vallonia cyclophorella*, occur in the Great Plains only in the northernmost states, in the Rocky Mountains, or in the more humid Central Lowland where they may range farther south, but are still of obviously northern distribution (Hibbard & Taylor, 1960). A relatively southern element represented by *Gastrocopta procera*, *G. cristata*, *Physa anatina* and *Helicodiscus singleyanus*, reaches as far north as South Dakota or Nebraska in the Great Plains, but is more common farther south. Many of these northern and southern species are not now found together in the same area and it is assumed that they are presently being kept apart primarily by climatic extremes. The climate during that part of the Illinoian when the Adams local fauna lived probably combined winters which were perhaps no more severe than those presently occurring in northeastern Nebraska, with cooler, more moist summers, similar to those in eastern Montana and the Dakotas.

The normal winter temperatures were probably between 15^{o} - 20^{o} F, with normal summer temperatures of 65^{o} - 70^{o} F (Visher, 1954). The precipitation was perhaps similar to that now occurring in Meade County, about 18.43

in. per year (Frye, 1942), but because of the lower evapotranspiration rates during the warm months (Visher, 1954), it was more effective.

Butler Spring Local Fauna

Previous Work. The name Butler Spring local fauna was first used by Herrington & Taylor (1958: 4) for the fossils recovered from one locality in the SE 1/4 sec 32, T 34 S, R 29 W, Meade County, Kansas. Smith (1958) reported on the fishes from this locality. Hibbard & Taylor (1960) discussed the stratigraphy of the area and described additional mollusks and vertebrates from this locality and from 4 additional sites which were included as part of the Butler Spring local fauna. Analysis of the pollen from the sequence of sediments containing the Butler Spring assemblage (Kapp, 1965) indicates that there are significant differences between locality 1 and localities 2, 3, 4 and 5 of Hibbard & Taylor (1960). In this report the Butler Spring local fauna is restricted to include only the fossils reported from locality 1 (U. S. Geological Survey Cenozoic locality 21042) of Hibbard & Taylor (1960).

Faunal List, Butler Spring Local Fauna:

CLASS PELECYPODA

Order Prionodesmacea

Anodonta grandis (Say)
**Ligumia* cf *L. recta* (Lamarck)

Order Teleodesmacea

Sphaerium striatinum (Lamarck)
S. transversum Say
Sphaerium, indeterminate
Pisidium casertanum (Poli)
P. compressum Prime
P. nitidum Jenyns
P. walkeri Sterki ?

CLASS GASTROPODA

Order Mesogastropoda

Valvata tricarinata (Say)
Probythinella lacustris (Baker)

Order Basommatophora

Carychium exiguum (Say)
Lymnaea stagnalis jugularis Say
Stagnicola caperata (Say)
S. reflexa (Say)
Fossaria obrussa (Say)
F. dalli (Baker)
Anisus pattersoni (Baker)
Gyraulus circumstriatus (Tryon)
G. parvus (Say)
Helisoma anceps (Menke)
H. trivolvis (Say)
Promenetus exacuous form *kansasensis* (Baker)
P. umbilicatellus (Cockerell)
Ferrissia fragilis (Tryon)
Laevapex fuscus (Adams)
Physa anatina Lea
P. gyrina Say
P. skinneri Taylor
Aplexa hypnorum (Linnaeus)

Order Stylommatophora

Gastrocopta armifera (Say)
G. contracta (Say)
G. cristata (Pilsbry & Vanatta)
G. holzingeri (Sterki)
G. procera (Gould)
G. tappaniana (Adams)
Pupoides albilabris (Adams)
P. inornatus Vanatta
Pupilla muscorum (Linnaeus)
P. blandi (Morse)
P. sinistra Franzen
**Vertigo elatior* (Sterki)
V. milium (Gould)
V. ovata (Say)
Vallonia cyclophorella Sterki
V. gracilicosta Reinhardt
V. parvula Sterki
cf *Succinea*
Oxyloma sp.
Discus cronkhitei (Newcomb)
Helicodiscus singleyanus (Pilsbry)
Hawaiia minuscula (Binney)
Zonitoides arboreus (Say)
Stenotrema leai (Binney)

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*Species not previously reported

CLASS OSTEICHTHYES

Lepisosteus sp., gar
Catostomus commersoni (Lacépède), white sucker
Ictalurus cf *I. punctatus* (Rafinesque), channel catfish
I. melas (Rafinesque), black bullhead
Perca flavescens (Mitchill), yellow perch

CLASS REPTILIA
Order Chelonia

Chelydra serpentina (Linnaeus), snapping turtle

CLASS MAMMALIA
Order Rodentia

Microtus pennsylvanicus (Ord), meadow vole

Rejected Records

Vertigo elatior = *Vertigo gouldi; Oxyloma* sp. = *Oxyloma retusa.*

Age and Correlation. Examination of the mollusks from the Mount Scott (p 189 et seq.), Butler Spring and Doby Springs local faunas, suggests that the Butler Spring is intermediate between the other 2 in terms of first and last occurrences of species. The first Illinoian occurrences of the 4 northern species *Probythinella lacustris, Lymnaea stagnalis jugularis, Vertigo elatior* and *Pupilla muscorum*, in this region, is in the Doby Springs local fauna. These species continue in the area through the time represented by the Butler Spring local fauna but in greatly reduced relative numbers. The absence of the first 3 of these species from the Adams local fauna is possibly due to the smaller size of the sample from which this assemblage was recovered. (The Adams local fauna was sorted from approximately 10 pounds of of matrix, whereas the Butler Spring local fauna was picked from about 750 pounds of matrix [Hibbard & Taylor, 1960]). The Adams assemblage also includes the first Illinoian occurrence of *Helicodiscus singleyanus*, a relatively southern species which persists locally through that portion of the Illinoian during which the Mount Scott local fauna lived. These data suggest a trend toward a slightly warmer climate between the time the Doby Springs and Mount Scott local faunas lived. The climatic change produced a diminution in the abundance of certain of the dominant northern elements present in the Doby Springs local fauna and permitted *Helicodiscus singleyanus* to enter the area by the time the Adams and Butler Spring local faunas lived. The increase in southern faunal elements within the Mount Scott local fauna is interpreted as a continuation of this climatic change toward slightly warmer conditions. In this context the Butler Spring and Adams assemblages appear to have lived after the Doby Springs and before the Mount Scott local faunas.

Habitat. The Butler Spring fauna lived in or near a medium sized river, probably the ancestral Cimarron River (Hibbard & Taylor, 1960). This river had a slow to moderate current, with a probable depth of several feet. Protected areas of the river, with less current, contained dense beds of submergent aquatic vegetation. The terrestrial gastropods lived among scattered groups of trees along the river, but the predominant vegetation consisted mostly of grasses and shrubs.

Climate. The climate suggested by the Butler Spring local fauna (Hibbard & Taylor, 1960) consisted of cooler summers than now occur in Meade County. These conditions are similar to those now occuring in the eastern North Dakota region. Winters were probably no more severe than those in north-central Nebraska.

Mount Scott Local Fauna

Previous work. In the summer of 1953, Claude W. Hibbard and members of the University of Michigan Museum of Paleontology field party opened a quarry (UM-K4-53) on the north side of Spring Creek, a little over 2 miles upstream from Mount Scott, Big Springs Ranch, Meade County, Kansas. A total of 5 tons of matrix was removed from this quarry during the summers of 1953, 1957 and 1960, and has yielded a large biota containing pollen, ostracods, mollusks, fishes, amphibians, reptiles, birds and mammals. A second locality (UM-K2-59) opened near the base of Mount Scott, was worked during the 1959 and 1960 field seasons. Two additional localities (UM-K1-60 and UM-K3-60), were discovered along Spring Creek and Hart Draw, during the summer of 1960.

The ostracods from localities UM-K1-60 and UM-K2-59 (Gutentag, written communication); the mollusks from locality UM-K4-53 (Miller, 1961); some of the reptiles from locality UM-K2-59 (Etheridge, 1961); the fishes (Smith, 1963) and mammals (Klingener, 1963; Hibbard, 1963) from localities UM-K4-53, UM-K1-60 and UM-K2-59; and the pollen (Kapp, 1965) from UM-K4-53, UM-K1-60, UM-K2-59 and UM-K3-60, represent all the fossil remains recovered from these collections that have thus far been studied. The name Mount Scott local fauna was first used by Etheridge (1961: 181) for the fossil material recovered from locality UM-K2-59, near the base of Mount Scott.

The following faunal list summarizes the above and includes all the mollusks from localities UM-K1-60, UM-K2-59 and UM-K3-60, none of which have been previously reported.

Faunal List; Mount Scott Local Fauna:

Species	Locality			
	UM-K4-53	UM-K1-60	UM-K2-59	UM-K3-60
CLASS OSTRACODA				
Candona reonensis Gutentag & Benson		x	x	
Cypridopsis vidua (O. F. Müller)		x	x	
Candona sp. "a"			x	
CLASS PELECYPODA				
Order Prionodesmacea				
Uniomerus tetralasmus (Say)	x*	x		x
Order Teleodesmacea				
Sphaerium lacustre (Müller)	x			
S. occidentale Prime	x		x	
S. partumeium (Say)			x	
S. rhomboideum (Say)	x			
S. striatinum (Lamarck)	x		x	
S. sulcatum (Lamarck)	x	x	x	
S. transversum (Say)			x*	
Pisidium casertanum (Poli)	x	x	x	x
P. compressum Prime	x	x	x	x
P. nitidum Jenyns	x	x	x	
P. obtusale (Lamarck)	x	x	x	
P. subtruncatum Malm	x			
P. variabile Prime	x	x	x	
P. walkeri Sterki	x	x		
CLASS GASTROPODA				
Order Mesogastropoda				
Valvata tricarinata (Say)	x	x	x	
Order Basommatophora				
Carychium exiguum (Say)	x		x	
Stagnicola caperata (Say)	x	x	x	
S. exilis (Lea)			x	
S. reflexa (Say)	x*	x	x	
Fossaria dalli (Baker)	x	x	x	
F. obrussa (Say)	x	x	x	
Armiger crista (Linnaeus)	x	x	x	
Gyraulus circumstriatus (Tryon)	x	x	x	
G. parvus (Say)	x	x	x	
Helisoma anceps (Menke)	x	x		
H. trivolvis (Say)	x		x	
Promenetus exacuous form *exacuous* (Say)	x	x	x	
P. umbilicatellus (Cockerell)			x	
Ferrissia fragilis (Tryon)	x	x	x	
Laevapex fuscus (Adams)	x	x	x	x
Physa anatina Lea	x	x	x	
P. gyrina Say	x	x	x	
P. skinneri Taylor	x		x	
Aplexa hypnorum (Linnaeus)	x		x	
Order Stylommatophora				
Cionella lubrica (Müller)				x
Strobilops labyrinthica (Say)	x	x	x	
Gastrocopta armifera (Say)	x	x	x	x
G. contracta (Say)	x	x	x	
G. cristata (Pilsbry & Vanatta)	x	x	x	x
G. holzingeri (Sterki)	x	x	x	x
G. pellucida hordeacella (Pilsbry)			x	
G. procera (Gould)	x	x	x	x
G. tappaniana (Adams)	x	x	x	
Pupoides albilabris (Adams)	x	x	x	x

Species	UM-K4-53	UM-K1-60	UM-K2-59	UM-K3-60
	Locality			
Pupilla blandi Morse	x		x	
Vertigo milium (Gould)	x	x	x	
V. ovata (Say)	x	x	x	x
Vallonia gracilicosta Reinhardt	x	x	x	x
V. parvula Sterki	x	x	x	x
cf *Succinea*	x	x	x	x
Oxyloma sp.	x		x	
Discus cronkhitei (Newcomb)	x	x	x	x
Helicodiscus parallelus (Say)	x	x	x	x
H. singleyanus (Pilsbry)		x		
Punctum minutissimum Lea	x			
Deroceras aenigma Leonard	x	x	x	
Euconulus fulvus (Müller)	x	x	x	
Nesovitrea electrina (Gould)	x		x	
Hawaiia minuscula (Binney)	x	x	x	x
Zonitoides arboreus (Say)	x	x	x	x
Z. nitidus (Müller)	x		x	
Stenotrema leai (Binney)		x	x	
CLASS OSTEICHTHYES				
Lepisosteus platostomus Rafinesque, Shortnose gar		x	x	
Esox masquinongy Mitchill, muskellunge		x		
Hybognathus hankinsoni Hubbs, brassy minnow		x		
Campostoma anomalum (Rafinesque), stoneroller	x	x		
Semotilus atromaculatus (Mitchill), creek chub	x	x	x	
Dionda nubila (Forbes), ozark minnow		x		
Cyprinidae, indeterminate	x	x		
Ictiobus, sp. Rafinesque, buffalo fish		x		
Catostomus commersoni (Lacépède), white sucker		x	x	
Moxostoma duquesnei (LeSueur), black redhorse		x		
Ictalurus punctatus (Rafinesque), channel catfish			x	
I. melas (Rafinesque), black bullhead	x	x		
Micropterus salmoides (Lacépède), largemouth bass	x	x		
Lepomis cyanellus Rafinesque, green sunfish	x			
L. humilis? (Giarard), orange-spotted sunfish		x		
Perca cf *P. flavescens* (Mitchill), yellow perch	x	x		
CLASS AMPHIBIA				
Order Salienta				
Bufo sp., toad			x	
?*Acris* sp., frog		x	x	
Rana pipiens Schreber, leopard frog		x	x	
CLASS REPTILIA				
Order Chelonia				
Terrapene llanensis Oelrich, plains box turtle			x	
Order Squamata				
Ophisaurus attenuatus Baird, glass lizard	x	x	x	
CLASS AVES				
Unstudied				
CLASS MAMMALIA				
Order Insectivora				
Sorex cinereus Kerr, masked shrew	x		x	
S. arcticus Kerr, arctic shrew			x	
S. palustris Richardson, northern water shrew			x	
Blarina brevicauda carolinensis (Bachman), southern shorttail shrew	x	x	x	
Cryptotis parva (Say), least shrew	x	x		
Order Chiroptera				
Lasiurus cinereus (Beauvois), hoary bat			x	
Order Rodentia				
Cynomys sp., prairie dog			x	
Citellus cf *C. tridecemlineatus* (Mitchill), ground squirrel			x	
Citellus sp., ground squirrel		x	x	
Geomys sp., pocket gopher	x		x	
Paradipoides or *Castor* sp., beaver		x		
Reithrodontomys sp., harvest mouse		x	x	
Peromyscus berendsensis Starrett, deer mouse	x		x	
P. progressus Hibbard, plains deer mouse	x		x	
Peromyscus sp., mouse			x	

Species	UM-K4-53	UM-K1-60	UM-K2-59	UM-K3-60
Neotoma cf *N. floridana* (Ord), packrat			x	
Oryzomys fossilis Hibbard, fossil rice rat		x	x	
Synaptomys australis Simpson, Simpson's bog lemming	x	x	x	
Ondatra zibethica Linnaeus, muskrat,	x	x	x	
Microtus pennsylvanicus (Ord), meadow vole	x	x	x	
Pedomys ochrogaster (Wagner), prairie vole	x	x	x	
Zapus hudsonius transitionalis Klingener, meadow jumping mouse		x	x	
Order Carnivora				
Mustela vison Schreber, mink			x	
Order Lagomorpha				
Sylvilagus sp., cottontail rabbit		x	x	
Lepus sp., hare	x	x		
Order Artiodactyla				
Bison cf *B. latifrons* (Harlan), giant bison			x	

*cf.

Localities. The Mount Scott local fauna is known from the following 4 localities, situated on the Big Springs ranch, Meade County, Kansas (Figs. 2 and 3):

Locality UM-K4-53. SE 1/4 sec 14, T 32 S, R 29 W, approximately 1914 ft north and 1254 ft west, of the southeastern section corner. The fossils were recovered from a greenish-brown silty clay (unit 3 in. Measured Section 1, see p 200), 2-3 ft above the stream bed of Spring Creek (Miller, 1961: 104). Five tons of matrix have been removed from this locality since it was first worked in 1953. About 10% of the concentrate from these collections has been sorted for mollusks.

Locality UM-K1-60. SW 1/4 sec 13, T 32 S, R 29 W, approximately 528 ft north and 396 ft east of the southwestern section corner, about 1/2 mile downstream from locality UM-K4-53. The faunule from this locality was removed from the sand, silt and marl, represented by units 1-3, in Measured Section 4 (see p 202). Seven tons of matrix were washed from this site during the 1960-1961 field seasons. Only about 12% of this concentrate has been sorted for mollusks.

Locality UM-K2-59. SE 1/4 sec 18, T 32 S, R 28 W, 396 ft north and 1386 ft west of the southeastern section corner, a little over 2 miles downstream on Spring Creek, from locality UM-K4-53. The fossils were collected from a coarse, greenish brown silt (unit 8 of Measured Section 3, see p 202), exposed in a quarry excavated on the lower slope of Mount Scott, approximately 23 ft above the bed of Spring Creek. Twenty-seven tons of matrix have been removed from this locality, less than 5% of which has been sorted for mollusks.

Locality UM-K3-60. NE 1/4 SW 1/4 sec 17, T 32 S., R 28 W, about 1980 ft north and 924 ft east of the southwestern section corner. The fossils occur in dark brown, silty clay, near the base of Hart Draw, downstream from and approximately 40 ft below locality 1 of the Cragin Quarry local fauna (Hibbard & Taylor, 1960). The mollusks represent all the fossils recovered from about 10 pounds of matrix.

Local Stratigraphy. A sequence of sediments ranging in age from upper Pliocene to Recent is exposed in the Big Springs Ranch area (Fig. 1). The Rexroad, Ballard and Crooked Creek formations represent cycles of widespread sheet deposition, in which aggrading streams filled their valleys, spreading sands, silts and clays across the interstream divides. The Kingsdown

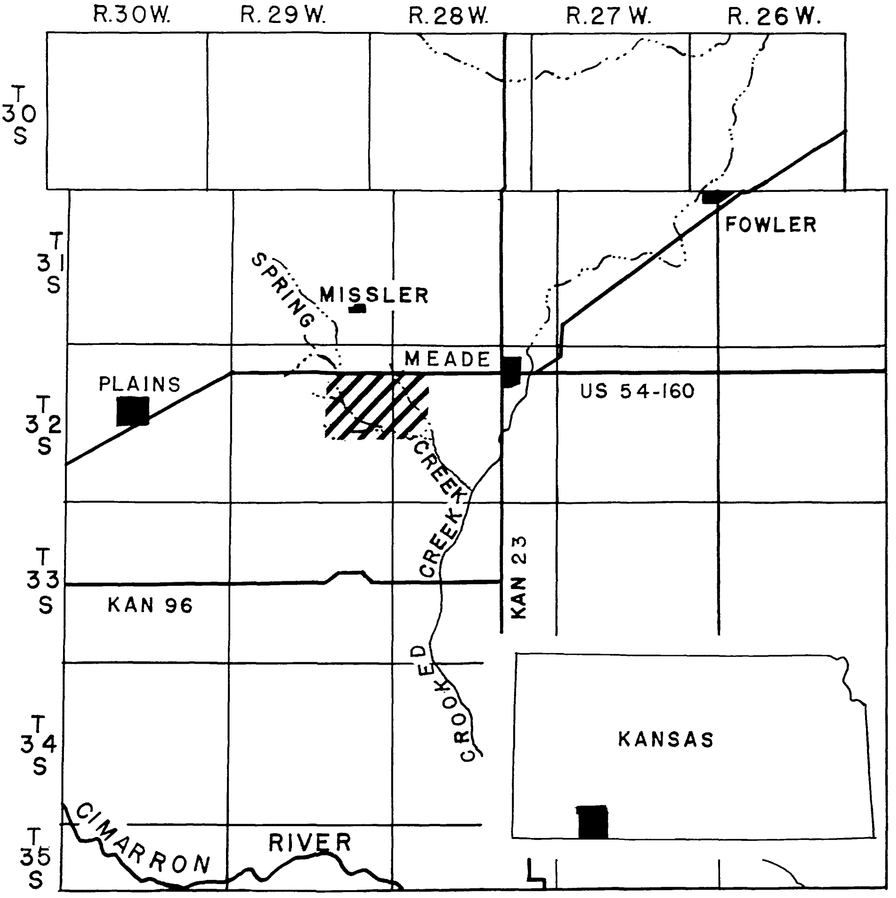


FIG. 2. Map of Meade County, Kansas showing location of Big Springs Ranch area (diagonal lines).

and Vanhem formations in this area, by contrast, occur as valley fills or terrace deposits that are usually situated topographically below the older beds.

At many localities, the beds are obscured by slopewash and wind blown sand, and good exposures are usually restricted to the relatively few steep bluffs occurring on the outside of meanders. Where the bedding of the sediments could be observed, it showed a very low apparent dip, the greatest angle measured not exceeding 4^{O}. All these difficulties made mapping difficult and accurate measurement of strike and dip impossible.

Rexroad Formation. The upper Pliocene in this area is represented by the Rexroad Formation, exposed along the south bank of Spring Creek and the north and south sides of Hart Draw, in portions of sections 13, 14, 24, T 32 S, R 29 W, and sections 7, 18, 19, T 32 S, R 28 W. Good outcrops of the Rexroad are comparatively rare, and are usually restricted to the base of bluffs along the main stream valleys where erosion has been deep enough to expose the upper portion of the formation. There are 2 exceptions to this usual mode of occurrence: the first is an outcrop, composed of approximately 3 1/2 ft of

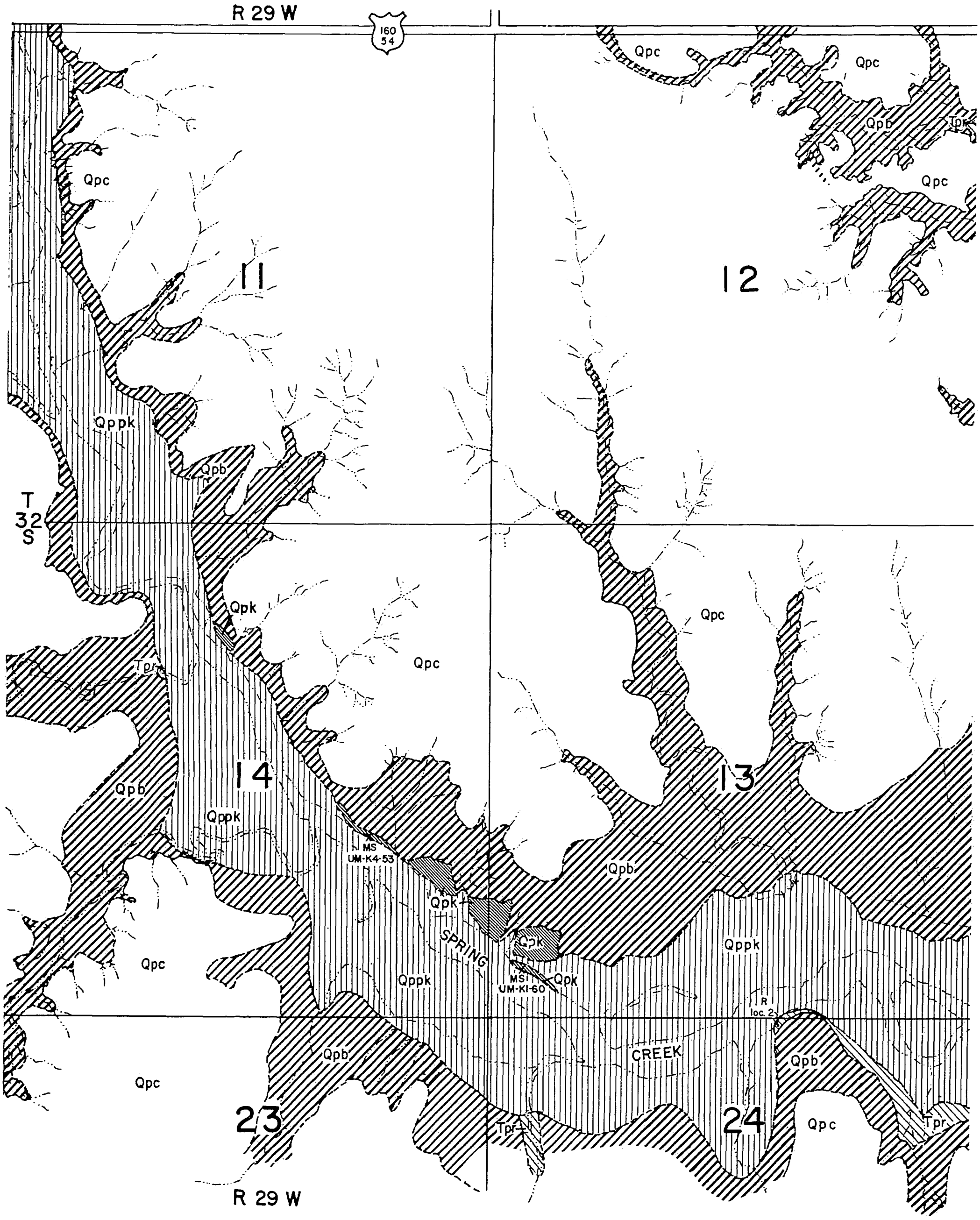
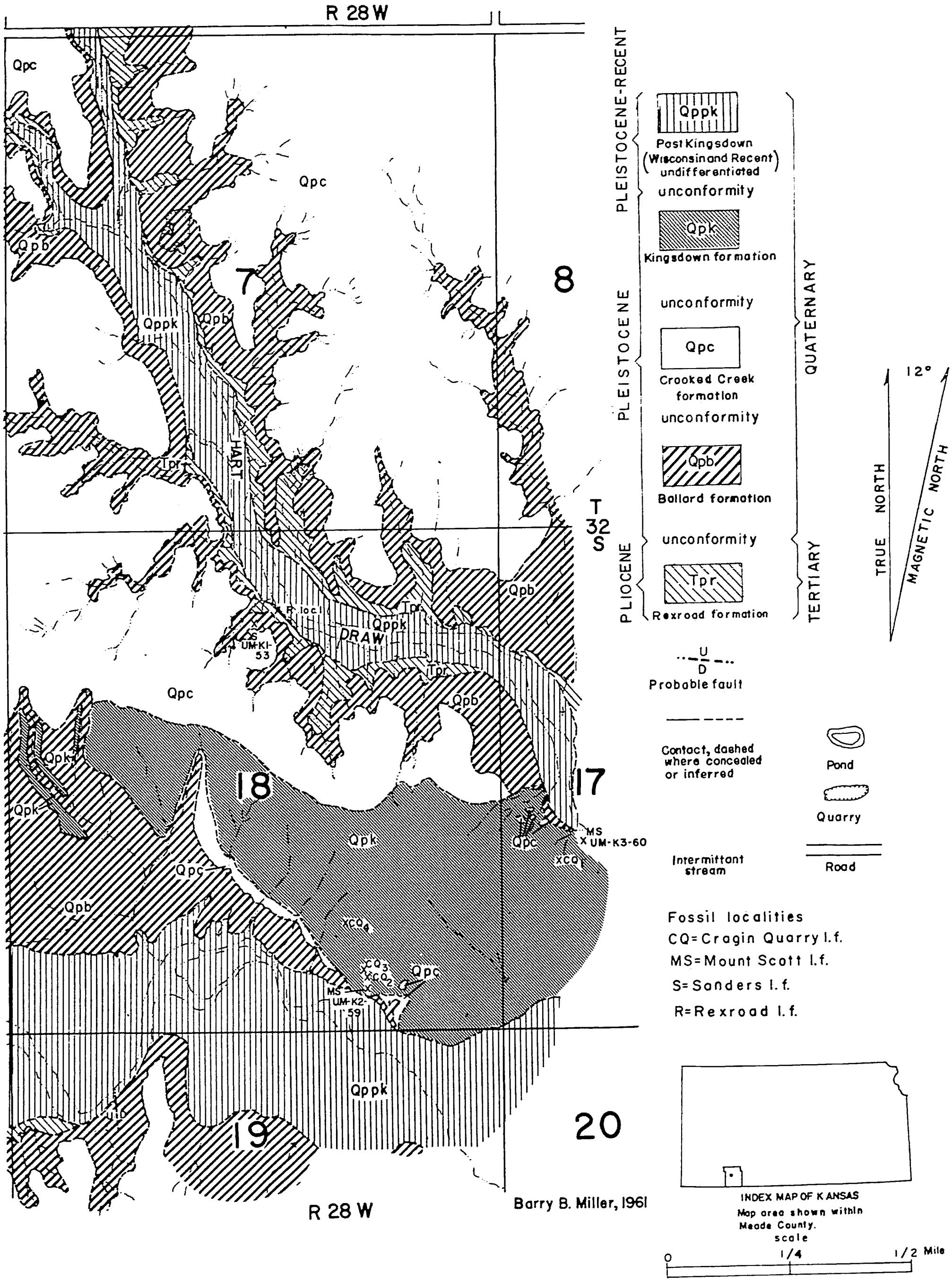


FIG. 3. Geologic map of the Big Springs Ranch area, Meade County, Kansas.


R 28 W
Qpc
Qpb
Qppk
7
8
HART
DRAW
Tpr
T
32
S
R loc I
S
UM-KI-53
17
18
Qpk
MS
UM-K3-60
XCQ1
XCQ4
CQ3
XCQ2
MS
UM-K2-59
19
20
R 28 W
Barry B. Miller, 1961
PLEISTOCENE-RECENT
Qppk
Post Kingsdown (Wisconsin and Recent) undifferentiated
unconformity
Qpk
Kingsdown formation
PLEISTOCENE
unconformity
Qpc
Crooked Creek formation
unconformity
Qpb
Ballard formation
QUATERNARY
PLIOCENE
unconformity
Tpr
Rexroad formation
TERTIARY
U
D
Probable fault
Contact, dashed where concealed or inferred
Pond
Quarry
Intermittant stream
Road
Fossil localities
CQ=Cragin Quarry l.f.
MS=Mount Scott l.f.
S=Sanders l. f.
R=Rexroad l. f.
12°
TRUE NORTH
MAGNETIC NORTH
INDEX MAP OF KANSAS
Map area shown within Meade County.
scale
0
1/4
1/2 Mile

orange, yellow and green sands and clays, exposed in a low bank along a tributary of Spring Creek in the SW 1/4 NW 1/4 sec 24, T 32 S, R 29 W; the second is an exposure in the floor of the Sanders Gravel pit, SE 1/4 NW 1/4 sec 7, T 32 S, R 28 W.

The thickest section of Rexroad examined in the area outcrops on the south side of Hart Draw, in the NW 1/4 NE 1/4 sec 18, T 32 S, R 28 W. It is composed of 23 ft of reddish-gray to gray sandy silt and fine sand, capped by one foot of caliche. This exposure yielded the mollusks reported by Taylor (1960), from locality 1 of the Rexroad local fauna. A second occurrence of mollusks in the Rexroad has been recorded by Taylor (1960) from deposits exposed along the south side of Spring Creek in the NW 1/4 NE 1/4 sec 24, T 32 S, R 29 W.

Ballard Formation. The name Ballard Formation was proposed by Hibbard (1958) as a replacement for Meade Formation, which had undergone a variety of usages (see summaries in Hibbard, 1955, Chart I; and Hibbard & Taylor, 1960, fig. 2). The type locality of the Ballard Formation is situated on the Big Springs Ranch, on the south side of Hart Draw, in Sections 7 and 18, T 32 S, R 28 W (Hibbard, 1958). At the type locality, the Ballard rests unconformably on the Rexroad. It is relatively thin, consisting of about 8 ft of cemented basal sand and gravel, overlain by 12 ft of buff-gray silt and clay. The upper 3 ft of the Ballard at this exposure yielded the mollusks and mammals comprising locality 1 (UM-K1-53) of the Sanders local fauna (Hibbard, 1956a; Taylor, 1960).

The Ballard Formation occurs along the valleys of Spring Creek and Hart Draw in portions of all the mapped sections of the Big Springs area. Wherever the base of the Ballard is clearly exposed, it rests unconformably on the Rexroad. The maximum thickness of the Ballard measured in the area is in a bluff along the south side of Spring Creek, in SE 1/4 NW 1/4 sec 19, T 32 S, R 28 W. At this locality, the Ballard is 42.5 ft thick and has an apparent dip of about 4^{o} east (see Measured Section 5, p 203).

Hibbard (1958) introduced the name Angell member, for the basal portion of the Ballard Formation, designating the 13.7 ft of cross-bedded, partly cemented, sand, gravel and cobbles, exposed near the base of the Sanders Gravel pit in SE 1/4 NW 1/4 sec 7, T 32 S, R 28 W, as the type section.

Differences in amount of cementation have produced some lateral variation in the appearances of the Angell member. Three different modes of occurrence have been recognized. In its most common form, it is a well indurated, cross-bedded, dark gray sand and gravel, stained with manganese and iron, best displayed in outcrops along Spring Creek and its tributaries, in sections 11, 12 and 24, T 32 S, R 29 W, and in sections 7 and 8, T 32 S, R 28 W. Less frequently, the Angell occurs as a partially cemented, cross-bedded, yellow-buff sand and gravel, exemplified by exposures in the NE 1/4 SE 1/4 sec 14, T 32 S, R 29 W, and NW 1/4 SE 1/4 sec 19, T 32 S, R 28 W. A third type of occurrence, in which the deposit is a yellowish-tan, unconsolidated sand and gravel, was observed in the SW 1/4 NW 1/4 sec 24, T 32 S, R 29 W.

Fossils are not abundant in the Angell member although some vertebrate remains have been collected from exposures at the Sanders Gravel pit (Hibbard, 1956a).

The Missler member of the Ballard Formation (Hibbard, 1949a) is the reddish-buff sand and silt overlying the Angell sand and gravel sections in 6 and 7, T 32 S, R 28 W. Good outcrops, where the member is as much as 35 ft thick, occur along Spring Creek and its tributaries in sections 12, 14 and 23, T 32 S, R 29 W, and in sections 7, 8 and 19, T 32 S, R 28 W. The Missler, where it is well exposed because of the steepness of slope, usually appears as reddish-brown and green sands, silts and clays, interbedded with zones of caliche nodules and stringers. A well indurated, dense, white caliche, about 6 in. thick, often occurs near the top of this member.

Crooked Creek Formation. The Crooked Creek Formation as defined by Hibbard (1949a), includes those sediments which were laid down during the cycle of deposition which followed the Ballard Formation. It is by far the most widespread formation exposed in the study area, and reaches a thickness locally of at least 61.5 ft.

The basal Stump Arroyo sand and gravel member of the Crooked Creek Formation is extensively exposed in portions of all sections of the map area, reaching a thickness of up to 31.5 ft. It occurs most frequently as an unconsolidated, reddish-tan sand and pebble rubble. The gravel contains a distinctive milky white quartz component, which in overall aspect makes the Stump Arroyo appear lighter in color than the Angell sand and gravel. The sands and gravels are generally not well sorted and cross-bedding is poorly preserved. Locally the Stump Arroyo occurs as a lime cemented, cross-bedded, sand and gravel which grades upward to a massive greenish-gray sand. The surface of the entire unit usually is stained a dark gray.

The gray color of the Stump Arroyo is possibly imparted by finely disseminated particles of manganese and iron which have been reworked from weathered portions of the Angell member of the Ballard. No pieces of reworked Angell were observed at the localities examined, although such an occurrence has been reported by Hibbard (1951), in unconsolidated Stump Arroyo in the Seger Gravel pit. The sand presently being deposited in the beds of Hart Draw and Spring Creek contains local concentrations of this black manganese and iron stain; here, too, the color is apparently derived from reworked older beds.

Vestiges of what seem to be the channel or channels, in which the Stump Arroyo member was deposited, crop out along the tributaries of Spring Creek in sections 10, 11, 14 and 15, T 32 S, R 29 W. Some of the exposures reveal channels at least 12 ft deep, as evidenced by the relief on the Stump Arroyo-Missler contact.

The only fossils collected from the Stump Arroyo member in the Big Springs Ranch area are a lower molar (UMMP 31352*) and astragalus (UMMP 31353) of *Nannippus* sp., from the N 1/2 sec 14, T 32 S, R 29 W.

Exposures of the Atwater member of the Crooked Creek Formation occur in all sections of the mapped area. With the exception of the Kingsdown Formation exposed in the S 1/2 sec 17, T 32 S, R 28 W, this member forms most of the upland surface. The thickest section of Atwater measured consists of 31.25 ft of reddish-brown sand and silt, intermixed with stringers and nodules of caliche and ash. It is exposed in the E 1/2 of sec 14, T 32 S, R 29 W (see Measured Section 2, p 200). The Pearlette ash, the most distinctive unit in the Atwater when present, is well exposed in the NW 1/4 sec 18; SW 1/4 and NW 1/4 SE 1/4 sec 7, T 32 S, R 29 W, and in the NE 1/4 sec 14, T 32 S, R 28 W. The greatest thickness of ash measured was a 160 in. section exposed in the NW 1/4 SE 1/4 sec 7, T 32 S, R 28 W. The fossiliferous base of this sequence is listed as locality 11, of the Cudahy fauna, in Hibbard (1949a, map 2). Getz (1960) has reported an astragalus of *Canis* sp. (UMMP 38406) from below a lentil of Pearlette ash exposed in the NW 1/4 sec 18, T 32 S, R 28 W.

Kingsdown Formation. The Kingsdown is represented in the vicinity of the Big Springs Ranch by scattered, discontinuous remnants of stream channel and floodplain deposits. It reaches its

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*University of Michigan Museum of Paleontology catalogue number.

greatest development in the SE 1/4 sec 18, T 32 S, R 28 W, at Mount Scott, on the north side of Spring Creek, where a thick sequence of at least 61 ft of gravel, sand, silt, clay and caliche are exposed (see Measured Section 3, p 202). Other outcrops of the Kingsdown occur in the SW 1/4 sec 17, T 32 S, R 28 W, on the south side of Hart Draw; in the SW 1/4 sec 13, the SE 1/4 sec 14, T 32 S, R 29 W, and the S 1/2 sec 18, T 32 S, R 28 W, on the north side of Spring Creek.

The absence of the Kingsdown Formation from the south side of Spring Creek in section 19, to the southwest of Mount Scott, may in part be the result of local sinkhole collapse. There is some evidence for at least one episode of late Pleistocene collapse that involved the Rexroad, Ballard and Crooked Creek formations in this area. Unit 11 of the Ballard Formation (see Measured Section 5, p 203) is exposed some 42 ft above the base of a high bluff on the south side of Spring Creek, in the NW 1/4 sec 19. A green clay which appears to be the same as unit 11, is exposed about 1/8 mile downstream near the base of the stream. If the bed at these 2 exposures is the same there must have been approximately 42 ft of displacement.

The Kingsdown and Crooked Creek formations in section 18, are both capped by a caliche, which underlies the upland surface. The contact between these 2 formations is uncertain probably because of the continued caliche accumulation on the Crooked Creek during the Sangamon. The boundary has been questionably mapped along the outermost occurrence of several caliche-capped hummocks which rise a short distance above the adjoining Crooked Creek caliche. The tops of these hummocks, approximately at the same elevation as the caprock at Mount Scott, have been interpreted as erosional remnants of what was formerly a more extensive Sangamon caliche bed.

Kingsdown sediments, composed of red-brown silts capped in places by caliche, are exposed along the valleys of the north-south tributaries of Spring Creek, in the S 1/2 sec 18. Lithology and stratigraphic and topographic position suggest that these deposits are equivalent to the upper part of the Kingsdown exposed at Mount Scott (see Measured Section 3, p 202).

The lower portions of the Kingsdown, exposed along the north side of Spring Creek and the southwest side of Hart Draw, include sediments which contain the Mount Scott local fauna and its stratigraphic equivalents. These sediments consist primarily of sands, silts, silty clays and marls, deposited on the floodplain of ancestral Spring Creek.

The Kingsdown exposed in a quarry at locality UM-K2-59, near the base of Mount Scott, contains at its base a 2 ft fossiliferous, greenish-brown to green silt, representing a floodplain phase of deposition. Overlying these sediments, is a 6.5 ft channel phase sequence of cut and fill structures, composed of lenses of sand and gravel containing cobbles up to 10 in. in length. The gravels appear to be composed of reworked Stump Arroyo gravel and pieces of Ballard caliche. The close proximity of the Kingsdown at this locality to known exposures of the Stump Arroyo-Ballard contact (see Measured Section 3, p 202), together with the size and high degree of angularity of the caliche cobbles, all indicate a local origin for these coarser clastics, and by implication, that ancestral Spring Creek had become entrenched in the Crooked Creek Formation, and had cut downward, at least locally, to the Ballard caliche.

A similar succession occurs on the southwest side of Hart Draw (Hibbard & Taylor, 1960: 29). A dark brown silt containing mollusks and pollen (Kapp, 1965) is exposed at locality UM-K3-60, near the base of Hart Draw, several hundred feet downstream from the section measured by Taylor (Hibbard & Taylor, 1960: 29-30). These sediments are considered correlatives of those at UM-K2-59 on the basis of lithology and stratigraphic position, even though this relationship has not clearly been established by paleontologic evidence.

The remaining outcrops of Kingsdown exposed along Spring Creek, upstream from UM-K2-59, are floodplain deposits similar to those at the base of Mount Scott. The fossil-bearing units at locality UM-K1-60, however, are marls and sands which apparently represent a small lake or impoundment of the stream (Hibbard, 1963).

Post-Kingsdown Sediments. At least 2 cycles of post-Kingsdown incision and deposition are recognizeable in the Big Springs Ranch area. Evidence for the older channel cutting phase is recorded along the north bank of Spring Creek, in sections 13 and 14, T 32 S, R 29 W. Here the Kingsdown Formation has been channeled into, at places, to a depth of at least 12 ft, and filled with fine gravel and light brown-buff sand and silt (Fig. 4). These sediments were previously interpreted as Wisconsin in age (Miller, 1961: 105), and placed in the Vanhem Formation, even though, at the time, there was no way of excluding the possibility of their Recent origin. Fossil mollusks since recovered from the upper part of these deposits (UM-K2-60 located in the SE 1/4 sec 14, T 32 S, R 29 W), include 6 species no longer living in the Meade County area, thus supporting the original assignment of the beds to the Wisconsin Vanhem Formation.

A thicker succession of sediments, with similar lithology, is exposed in bluffs along the south side of Spring Creek and along some of its tributaries. At some localities these deposits reach 51 ft in thickness, filling channels that have been cut through the Crooked Creek, Ballard and Rexroad formations to at least the present stream floor. These channel fills are believed to be equivalent to the Vanhem exposed on the north side of Spring Creek, and probably represent the position of ancestral Spring Creek during a portion of the Wisconsin.

A younger cycle of post-Kingsdown cutting is represented by the present stream system. This valley cutting episode was discontinuous, as evidenced locally by at least one terrace level approximately 6 ft above the present stream floor of Spring Creek and Hart Draw and by the series of terrace deposits of Late Wisconsin age located along the north side of the Cimarron River (Hibbard & Taylor, 1960: 22, McLaughlin, 1946: 36; Byrne & McLaughlin, 1948: 84).

The entrenchment of the Recent streams has not proceeded to the depth of the earlier Illinoian and Wisconsin erosional phases, for the base of the Kingsdown and Vanhem formations are not exposed. The valley walls along most of the major stream valleys are usually not steep, and the light brown sands, silts and gravels of Recent alluvium, exposed in the beds of these streams, often grade imperceptibly into the slope wash and wind blown sand obscuring the older deposits. These sediments mask the Vanhem Formation over much of the area. The relatively few good exposures of the Vanhem occur in steep bluffs and are not frequent enough to permit determination of the aerial extent of this formation. These difficulties made it impractical to separate the Vanhem from the younger Recent sediments, and the entire sequence of post-Kingsdown deposits has consequently been mapped as one unit.

Measured Sections

Measured Section 1. Section measured in SW 1/4 NE 1/4 SE 1/4 sec 14, T 32 S, R 29 W, on north bank of Spring Creek. The section is a composite, with the upper 7.15 ft measured about 85 ft upstream from the lower 6.33 ft.

Top of bank	Thickness of unit (in feet)	Total thickness (in feet)
Vanhem Formation		
8. Gravel, sand and silt, light brown-buff; channeled into gray clay below.	2.25	2.25
Kingsdown Formation		
7. Clay, light gray, with joints apparently dipping 43° W, 75° N and 80° E	2.30	4.55
6. Clay, "varved", with light and dark gray laminae.	2.60	7.15
Measured section continued 85 ft upstream.		
5. Clay, gray-black, with sandy limonitic nodules.	2.20	9.35
4. Clay black, with caliche nodules.	0.75	10.10
3. Clay, silty, greenish-brown, grading upward into black clay (loc. UM-K4-53).	1.33	11.43
2. Clay, black, streaked with white flecks.	0.25	11.68
1. Silty clay, greenish-brown on fresh exposures, gray-black when dry; limonite stains; shell zone in upper 15" (base not exposed).	1.80	13.48
Floor of Spring Creek		

Measured Section 2. Started in the floor of Spring Creek, NW 1/4 SE 1/4 sec 14, T 32 S, R 29 W, Meade County, Kansas and measured along a northward traverse that ascends to the High Plains surface.

Crooked Creek Formation	Thickness of unit (in feet)	Total thickness (in feet)
Atwater member		
11. Silts and caliche, gray-brown, containing caliche nodules and stringers.	28.75	28.75
10. Volcanic ash (Pearlette ash), white, impure, containing reworked fragments of jasper, feldspar; contact above and below very irregular	2.50	31.25
9. Sandy silt, thin-bedded, thin clay layer on top, olive color with orange mottling.	1.00	32.25
Stump Arroyo member		
8. Gravel, with milky white quartz most distinctive component, gravel imbedded in gray-green sandy silt matrix, bed cemented in places.	29.50	61.75
Ballard Formation		
Missler member		
7. Silt, brown.	1.50	63.25
6. Clay, green.	0.80	64.05
5. Caliche, fine grained, well indurated.	0.50	64.55

	Thickness of unit (in feet)	Total thickness (in feet)
4. Clay, thinly laminated, light brown, high in organic content . . .	1.20	65.75
3. Silts, red, interbedded with caliche nodules.	3.20	68.95
2. Sand, yellow-brown, with lime cement, grades upward into red-brown to red-buff silt, with zones of caliche nodules. Sand stained orange with limonite streaks.	6.00	74.95
Angell member		
1. Sand and gravel, medium to coarse yellow-buff, indurated in places. Light buff color on dry surface. Top 18" cross bedded (base not exposed).	4.00	78.95

Measured Section 3. Section measured on the north side of Spring Creek, in the SE 1/4 sec 18, T 32 S, R 28 W, Meade County, Kansas. The section was started at a willow grove in the bed of Spring Creek and measured along a north northwest traverse which ascends to the top of Mount Scott. The description of sediments is based on fresh exposures. The stratigraphic section is approximately 3 ft greater than the usual topographic thickness because of Kingsdown deposits in channels cut into the Crooked Creek and Ballard Formations. Units 15 and 18 contain respectively, localities 2 and 3 of the Cragin Quarry local fauna (Hibbard & Taylor, 1960) of Sangamon age.

Topsoil	Thickness of unit (in feet)	Total thickness (in feet)
Kingsdown Formation		
19. Caliche, white, indurated, porous, with irregular cavities. Surface covered with a black lichen	2.00	2.00
18. Sand and silt, red-brown, with zones of lime enrichment; some caliche nodules; orange-yellow limonite stringers; coarser at base, grading upward into finer sand and silt (Cragin Quarry local fauna, locality 3, comes from red-brown silt near top of unit).	11.40	13.40
17. Silt, gray-green, with limonite blotches and stringers; shell at base.	0.80	14.20
16. Sand, medium to fine, light brown, grading upward to fine sand with orange limonite blotches and stringers.	7.40	21.60
15. Silt, brown, with some limonite stringers. Contains *Sphaerium* and other mollusks. (Cragin Quarry local fauna, locality 2).	6.70	28.30
14. Clay, gray-green, with some fine silt; silt component increases towards top; with manganese dioxide and limonite strains; contains shells.	7.30	35.60
13. Clay, brown, with some silt; grades upward to light brown-buff clay.	11.00	46.60
12. Silty clay, light brown.	1.60	48.20
11. Sandy clay, red-brown.	5.00	53.20
Top of west wall of quarry		
10. Sand and gravel, yellow and buff, occur in cut and fill type deposition, with lenses of sand and gravel that pinch out laterally; sands containing some shells and clay balls.	5.50	58.70
9. Gravel, over 2 in. in diameter (reworked Stump Arroyo gravel) in yellow sand; cobbles of caliche (reworked Ballard caliche) up to 10 in. long; base irregular, channeled into lower unit.	0.80	59.50

	Thickness of unit (in feet)	Total thickness (in feet)
8. Silt, coarse, greenish-brown, with mollusks (Mount Scott local fauna, locality UM-K2-59) grading upward into green silt and olive green clay with orange limonite clay.	2.00	61.50
Quarry floor. Base of Kingsdown is not exposed		
Crooked Creek Formation		
Stump Arroyo member (exposed approximately 75 ft east southeast of quarry).		
7. Gravel and sand; sand colored yellow-orange.	2.50	64.00
Ballard Formation		
Missler member		
6. Silt, green; indurated, dense, white caliche at top forms small ridge.	1.90	65.90
5. Sand, fine, orange-brown.	0.90	66.80
4. Clay, green, with lime enriched zone near top.	1.20	68.00
3. Silt, red-brown.	1.20	69.20
2. Clay, silty, green, with caliche nodules.	2.30	71.50
1. Covered interval.	11.30	82.80
Floor of Spring Creek		

Measured Section 4. Section measured in the SW 1/4 SW 1/4 sec 13, T 32 S, R 29 W, on the north side of Spring Creek. The Vanhem formation at this locality is channeled into the Kingsdown and is topographically lower than the upper portion of that formation.

Topsoil	Thickness of unit (in feet)	Total thickness (in feet)
Kingsdown Formation		
7. Clay, gray-green, with red-brown limonite stringers; base not exposed. Top 2 ft contain mollusks.	5.66	5.66
Vanhem Formation		
6. Covered interval.	5.66	11.32
Top of bank		
5. Sands and silts, reddish-brown, with small caliche nodules; coarser at base, grading upward into finer sands and silts; contains lenses up to 6 1/2 in. thick of light gray clay. These sediments are channeled into the black clay of unit 4.	7.00	18.32
Kingsdown Formation		
4. Clay, black on fresh exposures; gray when dry; with nodules and streaks of calcium carbonate 3/4 of an inch in diameter, and red-orange limonite spots; unit containing many unionid fragments.	0.70	19.02
3. Silt, light gray, with layers 1/2 in. thick stained with limonite; white calcareous stringers interspersed throughout the unit; unit containing many mollusks (Mt. Scott local fauna, locality UM-K1-60).	1.00	20.02

	Thickness of unit (in feet)	Total thickness (in feet)
2. Marl; interbedded with very thin layers of yellow-orange sand. Contains mollusks, bone and plant impressions (Mt. Scott local fauna, locality UM-K1-60).	0.25	20.27
1. Sand, yellow on fresh exposures; gray-buff when dry; with mollusks and bones of fishes (Mt. Scott local fauna, locality UM-K1-60).	0.85	21.12
Floor of Spring Creek		

Measured Section 5. Section ascends the slope of a steep bluff, on the south side of Spring Creek, SW 1/4 NW 1/4 NW 1/4 sec 19 T 32 S, R 28 W, Big Springs Ranch, Meade County, Kansas. The beds exposed in this section have an apparent dip of 4^{o} to the east.

	Thickness of unit (in feet)	Total thickness (in feet)
Top of Bluff		
Topsoil		
Ballard Formation		
Missler member		
12. Clay, brown, grading upward into reddish-brown silt.	7.33	7.33
11. Clay, green with small nodules of caliche.	1.93	9.26
10. Silt, red, with caliche nodules.	7.25	16.51
9. Caliche, indurated	0.50	17.01
8. Clay, silty, green; grading upward to silt with layer of caliche stringers at top.	2.00	19.01
7. Silt, red; with orange limonite blotches; zone of caliche stringers near top.	3.33	22.34
6. Silts and clays, red; with local zones of lime enrichment and sand pockets.	5.66	28.00
5. Sand and silt; grading upward from poorly cemented orange sand, to reddish-brown fine silt, with limonite blotches. Contains zones of lime enrichment, with caliche nodules and stringers concentrated near top of unit.	4.17	32.17
Angell member		
4. Sand, medium, yellow, becoming orange towards top; fine gravel concentrated towards bottom of unit; cross-bedded near base. Sand is case-hardened in areas, with lime cement.	5.17	37.34
Rexroad Formation		
3. Caliche, indurated.	0.50	37.84
2. Clay, rust colored; with 2 in. caliche layer at bottom. Clay contains nodules of caliche, 1 in. and less in diameter, in top 20 in.	3.50	41.34
1. Sand, red-rust colored, with green blotches.	7.33	48.67
Floor of Spring Creek		

Summary of the Late Cenozoic Geologic History of the Big Springs Ranch area. The late Cenozoic history of southwestern Kansas and northwestern Oklahoma has been reviewed in papers by Hibbard (1949a; 1950; 1954; 1955), and Hibbard & Taylor (1960). The discussion below concerns primarily that portion of this history pertaining to the Big Springs Ranch area.

There are no known exposures of pre-Rexroad Pliocene sediments in the Big Springs Ranch area. The Rexroad Formation represents a local accumulation of sediments from a through-flowing stream, which were trapped in a basin produced by subsidence along the west side of the Crooked Creek Fault sometime during the early part of the upper Pliocene (Smith, 1940: 98). A climatic change toward conditions of increased aridity near the end of Rexroad time is implied by the caliche occurring at the top of the Rexroad Formation (Hibbard, 1954: 235).

Increased runoff and regional warping rejuvenated the through-flowing streams at the close of Rexroad time, and inaugurated a new cycle of erosion and deposition, during which the sediments of the Ballard Formation (Nebraskan-Aftonian) were laid down (Hibbard, 1948: 593). The decrease in particle size towards the top of the formation and the presence of a buried caliche seem to indicate a period of increasing drought. The climatic implications of the Sanders local fauna, which occurs above the buried caliche, suggests that this cycle terminated in a mesothermal, subhumid climate (Taylor, 1960).

The sediments represented by the Crooked Creek Formation (Kansan-Yarmouth) are the product of the episode of downcutting and deposition which followed the Ballard. Increased precipitation and uplift are implied by the channels cut into the Ballard and coarser clastics represented by the Stump Arroyo sands and gravels. During late Yarmouth time, climatic conditions were again conducive to the formation of a caliche on the upper portion of the Crooked Creek Formation.

Sometime during the late Yarmouth-early Illinoian interval, ancestral Spring Creek, flowing as a northwest-southeast stream, started to entrench its course on the Yarmouth surface formed on top of the Crooked Creek Formation, and cut downward to at least the Angell member of the Ballard Formation. The topographic occurrence of the Kingsdown, below the top of the older Crooked Creek Formation in the Big Springs Ranch area of Meade County, and in northwest Clark County, along the upper part of Bluff Creek (Hibbard & Taylor, 1960: 20), over 30 miles to the northeast, suggests that this cycle of valley cutting was related to regional, rather than local events. This erosional cycle was followed by one of deposition, which started later in the early Illinoian and continued through middle Sangamon time, nearly filling the valley to the Yarmouth surface. Sediments representing the lower portion of the Kingsdown, exposed at Mount Scott, are the result of stream aggradation; some of the units in the upper portion of this sequence, however, are probably eolian in origin. The Kingsdown sediments occuring along Spring Creek record only the late Illinoian-early Sangomon part of this sequence. An older portion of the Kingsdown, representing sediments equivalent to those containing the earlier Illinoian Butler Spring, Adams, Doby Springs and Berends local faunas, was probably deposited in the deeper main channel phase somewhere to the south of Mount Scott.

A late Sangamon-early Wisconsin erosion interval is indicated by the thick series of sediments filling the channels cut into the Kingsdown, Crooked Creek, Ballard and Rexroad formations. During this phase, ancestral Spring Creek, probably aided by local sinkhole collapse in the area to the south and southwest of Mount Scott, migrated to the south of the present valley as it became entrenched in the older formations. The apparent dip of 4° E on the Ballard For-

FIG. 4. Photograph taken near locality UM-K4-53 showing sediments of the Vanhem Formation filling channels cut into the Kingsdown Formation. The white dashed line shows the approximate contact. In the middle foreground this contact is covered by slump.

mation (see Measured Section 5), is believed to be related to this event. Those portions of the Kingsdown deposited on the south side of Spring Creek were either buried during the episode of sinkhole collapse or were removed during the subsequent cycle of stream entrenchment. This new cycle of valley cutting was perhaps in part related to a climatic change involving an increase in preciptiation and runoff, such as is implied by the late Sangamon Jinglebob local fauna (Hibbard, 1955: 204; Hibbard & Taylor, 1960: 24). Later in the Wisconsin, aggrading streams filled the valleys cut during the previous erosional cycle with sediments belonging to the Vanhem Formation.

The present stream system represents the most recent cycle of valley cutting. The entrenchment of the Recent streams has been discontinuous, as evidenced by the series of terraces along the Cimarron River (McLaughlin, 1947; Byrne & McLaughlin, 1948; Hibbard & Taylor, 1960) and at least one terrace level along

Spring Creek and Hart Draw.

Age and Correlation. The Mount Scott local fauna is considered Late Illinoian in age on the basis of the following stratigraphic and paleontologic evidence.

1) It occurs in sediments that are topographically lower, but stratigraphically younger, than the Crooked Creek Formation of Kansan and Yarmouth age. At locality UM-K2-59, the fossils occur in a coarse, greenish-brown silt of the Kingsdown Formation which is channeled into the Stump Arroyo member of the Crooked Creek Formation. The section at this locality may be followed up the slope of Mount Scott, to locality 3 of the Cragin Quarry local fauna of Sangamon age (Hibbard & Taylor, 1960). The only gap in sedimentation in this interval, occurs at the base of unit 9 (Measured Section 3); it is believed to represent only a small local unconformity produced by the migration of the main stream channel of ancestral Spring Creek northward toward Mount Scott soon after deposition of the sediments containing the UM-K2-59 faunule on the floodplain of this same stream.

2) The Kingsdown Formation at locality UM-K4-53, again is an alluvial deposit, occupying the valley of ancestral Spring Creek. This stream had become entrenched in the Crooked Creek Formation early in the Illinoian and cut downward to at least the Angell member of the Ballard Formation. The fossils at localities UM-K4-53 and UM-K1-60 are from the same stratigraphic interval of the Kingsdown Formation, which can be traced downstream about 1/2 mile (see Fig. 3) as an almost continuous bed. The stratigraphic position of the Kingsdown in this area indicates that it is post-Crooked Creek in age.

A post-Kingsdown episode of channel cutting is recorded by gravel and light brown-buff sands and silts filling valleys which have been cut into the Kingsdown Formation (Fig. 4). Mollusks recovered from this interval (locality UM-K2-60), include 6 species no longer living in Meade County area, thus eliminating the probability that these sediments are of Recent origin. The fossils are interpreted as indicating a probable Wisconsin age for these sediments. The bed containing the UM-K4-53 and UM-K1-60 faunules is thus post-Yarmouth (Crooked Creek Formation) and pre-Wisconsin (Vanhem Formation) in age.

3) The presence of many species with predominantly northern and/or northeastern distributions implies a glacial fauna, which, on the basis of the stratigraphic position of the containing beds, must be Illinoian. Miller (1961: 123) after studying the mollusks from UM-K4-53, concluded "If future work can definitely establish the age of the fossils as Illinoian, the term 'Butler Spring local fauna' should be used for this local faunule." Subsequent study however, has suggested that the Mount Scott is slightly younger than the Butler Spring local fauna. The Mount Scott local fauna appears to be the youngest of the 5 Illinoian molluscan assemblages (Mount Scott, Butler Spring, Adams, Doby Springs and Berends local faunas) considered in this report.

A climatic change from a cooler glacial maximum, represented by the Doby Springs local fauna, to slightly warmer conditions during the time the Mount Scott local fauna lived, is indicated by the mammals (Hibbard, 1963) and the pollen (Kapp, 1965). The mollusks imply a similar trend with the number of species with southern distributions increasing from 4, in the Doby Springs local fauna (*Uniomerus tetralasmus*, *Physa anatina*, *Gastrocopta procera* and *G. cristata*), to 6 in Mount Scott local fauna (which moreover includes *Gastrocopta pellucida hordeacella* and *Helicodiscus singleyanus*).

Habitat. Table 3 lists by habitat group, the species of mollusks occuring in the Mount Scott local fauna.

Miller (1961: 123), concluded that the molluscan assemblage at locality UM-K4-53 represented 3 major habitats: "(1) a small permanent stream of the same approximate size as the present Spring Creek; (2) a temporary water

TABLE 3. Summary of the local habitats represented by the mollusks of the Mount Scott Local Fauna.

Habitat	Species	Locality and Abundance*			
		UM-K4-53	UM-K1-60	UM-K2-59	UM-K3-60
Semiaquatic: among vegetation and debris near water's edge.	*Oxyloma* sp.	A	-	A	-
Hygrophilic: moist situations in leaf mold, under sticks and debris; shaded areas, not far from water.	*Carychium exiguum*	A	-	A	-
	Vertigo ovata	A	C	A	R
	V. milium	A	R	A	-
	Gastrocopta tappaniana	A	C	A	-
	Deroceras aenigma	A	R	A	-
Woodland: moist areas under leaf litter, down timber, among tall marsh grass, on the floodplain.	*Cionella lubrica*	-	-	-	R
	Stenotrema leai	-	R	S	-
	Discus cronkhitei	R	R	R	R
	Zonitoides arboreus	A	R	A	R
	Z. nitidus	C	-	R	-
	Nesovitrea electrina	A	-	R	-
	Euconulus fulvus	C	R	R	-
	Strobilops labyrinthica	A	C	C	-
	Helicodiscus parallelus	A	R	A	C
	Punctum minutissimum	S	-	-	-
Sheltered areas: among rocks, shrubs, grass, or in timbered situations.	*Gastrocopta armifera*	A	C	A	R
	G. contracta	A	A	A	-
	G. holzingeri	A	R	A	R
Sheltered situations: these species are not restricted to a woodland habitat and can tolerate drier conditions.	*G. cristata*	A	C	A	R
	G. procera	A	R	C	R
	G. pellucida hordeacella	-	-	R	-
	Pupilla blandi	R	-	R	-
	Pupoides albilabris	A	S	A	R
	Hawaiia minuscula	A	C	A	S
	Vallonia parvula	A	R	A	R
	V. gracilicosta	A	R	A	S
	Helicodiscus singleyanus	-	R	-	-
Marginal situations: wet mud, sticks, stones, or any other debris along water's edge; shallow pools and protected spots.	*Fossaria dalli*	A	R	A	-
	F. obrussa	C	R	R	-
Shallow, quiet water: small streams, ponds, or sloughs on the floodplain, that may become dry during part of the year.	*Pisidium casertanum*	A	A	A	R
	Sphaerium occidentale	R	-	C	-
	Stagnicola exilis	-	-	R	-
	S. caperata	A	R	A	-
	S. reflexa	R	R	A	-
	(cont.)				

Table 3 (cont.)

Habitat	Species	Locality and Abundance*			
		UM-K4-53	UM-K1-60	UM-K2-59	UM-K3-60
(cont.)	*Armiger crista*	R	R	C	-
	Gyraulus circumstriatus	A	A	A	-
	Promenetus umbilicatellus	-	-	A	-
	Physa gyrina	A	S	A	-
	Aplexa hypnorum	A	-	A	-
	Ferrissia fragilis	R	R	R	-
Shallow, quiet water: small pond, streams or sloughs with no current or areas of rooted vegetation with little current; soft sand or mud bottoms; not subject to significant seasonal drying.	*Uniomerus tetralasmus*	R	R	-	R
	Sphaerium partumeium	-	-	R	-
	S. rhomboideum	R	-	-	-
	S. sulcatum	C	S	R	-
	S. transversum	-	-	R	-
	Pisidium obtusale	C	R	A	-
	Gyraulus parvus	A	A	A	-
	Helisoma trivolvis	R	-	S	-
	Promenetus exacuous form *exacuous*	A	A	A	-
	Physa anatina	A	A	A	-
	P. skinneri	R	-	S	-
	Laevapex fuscus	R	A	R	R
Perennial water: stream or lake, with slow to moderate current; areas of still water; shallow spots with soft sand or mud substrate; not affected by seasonal drying.	*Sphaerium lacustre*	R	-	-	-
	S. striatinum	R	-	R	-
	Pisidium compressum	A	A	R	R
	P. nitidum	A	A	R	-
	P. subtruncatum	R	-	-	-
	P. variabile	R	C	R	-
	P. walkeri	R	R	-	-
	Valvata tricarinata	A	A	A	-
	Helisoma anceps	A	A	-	-

*R=<25; S= 26-49; C= 50-100; A=>100 shells.

situation, perhaps a slough or temporary pond, situated on the floodplain of the stream; and (3) a woodland habitat, situated near the stream." New information, based on subsequent studies of the pollen (Kapp, 1965), the fishes (Smith, 1963), the mammals (Hibbard, 1963), the remainder of the molluscan fauna and field observations, have confirmed some of these earlier conclusions and filled in certain details of the environment.

Sedimentary and paleontologic evidence indicate that the Mount Scott local fauna contains the following major habitat associations: (1) a small lake or permanent pond; (2) a perennial stream; (3) a temporary water situation; (4) a marsh-woodland; and (5) an upland meadow.

The thin bed of marl (unit 2, Measured Section 4) at locality UM-K1-60 implies slack water deposition at this site, and is interpreted as indicating the existence of a small oxbow lake or permanent pond on the floodplain of ancestral Spring Creek. Faunal evidence, based primarily on the occurrence of *Esox masquinongy*, *Ictiobus* sp., *Perca flavescens* and *Micropterus salmoides*, (Smith, 1963), an association of fish most frequently found in a lacustrine habitat (Smith, oral communication), supports this interpretation. Shallow areas near the shore of this lake probably contained dense growths of aquatic vegetation which provided suitable habitat conditions for *Promenetus exacuous* form *exacuous*, *Valvata tricarinata*, *Gyraulus parvus*, *Physa anatina*, *Sphaerium sulcatum*, *Pisidium variabile*, *P. walkeri*, *P. nitidum* and *P. compressum*. These species, which constitute the largest portion of the total number of individual mollsusks at this locality, are believed for the most part to have been autochthonous and to have lived at or near the site of deposition. Some of the shells in this group, especially those of the *Valvata*, show signs of abrasion suggesting that they have been transported. These individuals, together with the thin layers of interbedded sand associated with the marl and more obvious allochthonous faunal elements, were probably washed into the lake during periods when the nearby stream was in floodstage.

The existence of a small permanent stream near the site at which the Mount Scott assemblage lived is indicated by the following: (1) the intermittent nature of the outcrop is suggestive of a meandering stream that followed a course similar to that of the present Spring Creek. Similarities in lithology and fauna of localities UM-K4-53 and UM-K2-59 are interpreted as meaning that they were essentially contemporaneous and were once part of the floodplain of ancestral Spring Creek. (2) The sediments directly overlying the Mount Scott local fauna at locality UM-K2-59 (units 9 and 10, Measured Section 3) consist of lentils of cobbles, gravel and sand. These cut and fill structures are believed to represent a younger depositional phase when the main stream channel of ancestral Spring Creek shifted north over the older floodplain. (3) The large fish assemblage reported from the Mount Scott local fauna (Smith, 1963), as well as some of the mollusks (Miller, 1961; this paper), suggest permanently flowing water. This stream was perhaps several feet deep and in places had a slow to moderate current, a substrate of mud, soft sand and some gravel, and shallow spots with dense rooted vegetation that greatly reduced the effects of the current.

The presence of ephemeral bodies of water on the floodplain of ancestral Spring Creek is evidenced by the occurrence of prominent "rest marks" on many of the *Pisidium casertanum* and *Sphaerium occidentale*, a condition generally considered indicative of a fluctuating water level, and by the abundance of aquatic mollusks frequently associated with temporary water situations. The overwhelming predominance among the aquatic mollusks of locality UM-K2-59 of temporary water species, together with the relatively large terrestrial faunal element, suggests that it was probably part of a backwater swamp or marsh. The mollusks requiring permanent water, as well as the fish, were probably carried to this site from the nearby stream during floods.

A marshy-woodland community representing animals which probably lived on the floodplain of the stream among patches of tall grass, sedges, shrubs and some scattered stands of trees in which moist leaf mold accumulated, is implied by the pollen spectra (Kapp, 1965) and the abundance of *Strobilops labyrinthica*, *Gastrocopta contracta*, *G. tappaniana*, *Vertigo ovata*, *V. milium*, *Oxyloma* sp., *Helicodiscus parallelus*, *Deroceras aenigma*, *Carychium exiguum* and *Zonitoides nitidus*. Some of the mammals represented by *Sorex cinereus*, *S. arcticus*, *Oryzomys fossilis*, *Synaptomys australis*, *Blarina brevi-*

cauda carolinensis, *Microtus pennsylvanicus* and *Zapus hudsonius transitionalis* (Hibbard, 1963), support this conclusion.

A better drained upland, containing some trees, herbaceous composites and grasses, is indicated by the pollen (Kapp, 1965). This community included *Cryptotis parva*, *Pedomys ochrogaster*, *Lepus* and *Citellus* (Hibbard, 1963; Stephens, 1960), and some of the less numerous xerophilic terrestrial gastropods represented by *Gastrocopta pellucida hordeacella*, *G. cristata*, *Helicodiscus singleyanus* and *Pupoides albilabris*.

Climate. The climatic conditions under which the Mount Scott local fauna lived may be inferred from the elements of the fauna. Interpretation of the Mount Scott molluscan assemblage is predicated on 2 assumptions: (1) that climatic factors are the primary agents controlling the distribution of nonmarine mollusks (Taylor, 1960; Boycott, 1921; 1934; 1936). The rationale for believing that the north-south and east-west distributions of some groups of mollusks appear to be controlled essentially by temperature extremes and available moisture has been presented by Taylor (1960). (2) The area in the Great Plains containing a molluscan fauna most similar to the Mount Scott assemblage will probably most closely simulate the climatic conditions represented by the Mount Scott mollusks.

Additions to the Mount Scott molluscan fauna and new distribution data for some of the species in the Great Plains region has necessitated a slightly different climatic interpretation from that given by Miller (1961). Perhaps the most conspicuous and significant aspect of the Mount Scott molluscan fauna is the relatively large number of species it contains as compared with the depauperate Recent fauna of the Meade County area. Hibbard & Taylor (1960) listed only 29 species living in the county today, whereas the Mount Scott local fauna contains some 63 species. The contrast in size alone, between the Recent and fossil molluscan faunas, signifies a climate markedly different from that which characterizes the area today.

The majority of the fossil species are aquatic, requiring permanent or semipermanent water, and for the most part are presently distributed well to the north and/or northeast of the Mount Scott fauna locality. The variety of habitats indicated by the fauna requires a supply of water not available in the area at the present time. Hibbard (1963) suggested that incision by ancestral Spring Creek of the highly charged aquifers represented by the Stump Arroyo and Angell sands and gravels would have produced a series of springs that provided much of the water for the aquatic habitats. The amount of downcutting necessary to expose these aquifers, together with the occurrence of land snails that probably would not have been influenced by these springs, imply greater runoff due to an increase in rainfall.

Although the Mount Scott molluscan assemblage contains some associations of species that are no longer known to occur together (e.g., *Pupilla blandi* and *Stenotrema leai*) it most resembles the fauna living in the tri-state area of Nebraska, South Dakota and Iowa, far to the north. The mollusks of this area have not been intensively studied, but published records (Shimek, 1915; Over, 1915, 1928; Roscoe, 1954, 1955; Jones, 1932; and Taylor, 1960), together with materials examined in the University of Michigan Museum of Zoology and the United States National Museum collections indicate that 50 of the 63 species included in the Mount Scott local fauna occur in this general region.

Forty-seven of the species represented in the Mount Scott local fauna have been recorded from the area surrounding the Lake Okoboji region of northwest Iowa. The great similarities between the molluscan fauna of this relatively restricted area and the Mount Scott assemblage, together with the fact that many species with predominantly northern, northeastern and southern dis-

TABLE 4. Comparison of climatic data for Meade County, Kansas, and the Lake Okoboji region of Northwest Iowa*

Temperature	Meade County	Lake Okoboji
Annual temperature	55°-60° F	40°-45° F
Normal winter temperature	25°-35° F	15°-20° F
Normal summer temperature	75°-80° F	65°-70° F
Normal annual numbers of days with maximum temperature of 90° or higher	60- 80	10-20
Normal annual number of days with daily maximum temperatures above 85°	80-100	10-30
Normal daily maximum temperature in July	90°-93° F	84°-87° F
Normal annual number of days of very hot weather (day and night averaging 75° or higher)	50- 75	0
Evaporation		
Normal annual evaporation from reservoirs and shallow lakes	50-70 inches	30-40 inches
Normal annual evaporation from pans	90 inches	50-60 inches
Normal annual excess of precipitation over evaporation	0 inches	0-10 inches
Precipitation		
Normal annual precipitation	20-30 inches	20-30 inches
Percent of precipitation that occurs in summer	30-40%	40-50%
Normal summer precipitation	6-8 inches	10-12 inches

*Based on Visher, 1954

tributions, are close to or at the periphery of their respective ranges in the Great Plains region in this area, are interpreted as indicating that the climatic conditions prevaling in the Lake Okoboji region represent fairly closely those that existed in southwestern Kansas at the time the Mount Scott local fauna lived.

Twelve of the extant species not occurring in the Lake Okoboji area form part of the 3 major distribution groups mentioned above. The northern element includes *Pisidium variabile*, *P. walkeri*, *P. nitidum*, *P. subtruncatum*, *Sphaerium occidentale* and *Pupilla blandi*. The first 2 species in this group are presently known to occur in South Dakota and eastern Iowa, while *P. nitidum* has been recorded from eastern Iowa and Douglas County, Nebraska (UMMZ 110376)*. *P. subtruncatum* and *P. obtusale* reach their southern limits in the Great Plains, in South Dakota (Herrington, 1962). Two species are included in the northeastern category. *Ferrissia fragilis* and *Laevapex fuscus*

*University of Michigan Museum of Zoology catalogue number.

occur in Iowa to the south and east of Lake Okoboji (Leonard, 1959; Basch, 1963).

Three species with predominantly southern distributions, *Physa anatina*, *Gastrocopta cristata* and *Helicodiscus singleyanus*, occur in northeastern Nebraska and southeastern South Dakota, and might be expected in the Okoboji region of Iowa (Taylor, 1960; Roscoe, 1954). A fourth member of this group, *Gastrocopta pellucida hordeacella*, reaches the northern limit of its range in the Plains, in the northeastern Kansas-southeastern Nebraska region.

The occurrence in the Mount Scott local fauna of species that are now separated by several hundred miles seems most reasonably explained in terms of climatic change in which seasonal extremes were not of the same magnitude as those which presently characterize the Meade County or overlap areas.

The climatic differences between Meade County, Kansas and the Lake Okoboji region of Iowa are most pronounced in terms of summer temperatures and moisture extremes (Table 4). The normal summer temperatures in the Okoboji area are about 5° cooler than in Meade County. The latter moreover has higher maximum summer temperatures which persist for longer periods of time. Both areas are shown by Visher (1954) as having an annual rate of precipitation of between 20-30 in., but the Okoboji region receives a larger portion of this precipitation during the summer months when it is most needed. The greater summer rainfall, lower temperature, and smaller evapotranspiration rates, produce cooler, more moist summers in the Lake Okoboji area.

The low frequency of some of the southern faunal elements in the Mount Scott local fauna, represented by *Helicodiscus singleyanus* and *Gastrocopta pellucida hordeacella*, suggests that these species may have been close to the limits of their range. *G. p. hordeacella* is the most southerly mollusk in the fauna, with respect to its range, in the Great Plains; it presently extends as far north as the southeastern Nebraska-northeastern Kansas area. The association in the Mount Scott local fauna of *G. p. hordeacella* and other southern elements, with more northerly species seems best explained by assuming that the winter temperatures were not quite as cold as those now occurring in the vicinity of Lake Okoboji.

A winter temperature between 25° and 35° F, similar to that existing in the area of the Great Plains in which *G. p. hordeacella* reaches its northern limits, is believed to have prevailed during the time the Mount Scott local fauna lived. The summers during this interval were probably like those of northwestern Iowa at the present, with temperatures between 65° and 70° F, and with between 20-30 in. of rainfall, 10-12 in. of which falls during the warmer part of the year (see Table 4).

Summary of Illinoian Molluscan Faunas

The 5 molluscan assemblages considered in this report show compositional differences which seem best explained by assuming climatic change. The Doby Springs and Mount Scott local faunas appear to represent the climatic end points in a sequence of Illinoian biotic assemblages. Vertebrate and pollen evidence show that the Doby Springs local fauna represents the coolest and the Mount Scott local fauna the warmest of these faunas. The mollusks show a similar trend with the Doby Springs containing fewer southern elements than does the Mount Scott local fauna. The Doby Springs local fauna has been interpreted by Kapp (1965) and Hibbard (1963) as having probably lived during maximum Illinoian glaciation, while the Mount Scott local fauna has been considered as transitional between the Illinoian and Sangamon (Kapp, 1965). Although several stadial-interstadial intervals may have occurred, there is no evidence in this area indicating that these faunas lived during more than one substage of the Illinoian. This interval was characterized by a trend towards increasingly warmer climatic conditions which culminated in the Sangamon interglacial.

A tentative chronology based on the climatic interpretation of the faunas, first and last occurrences of molluscan species, and pollen analytical data, suggests that the Doby Springs probably represents the oldest, followed by the Adams, Butler Spring and Mount Scott local faunas.

The proper placement of the Berends local fauna in this sequence is not certain. The overlap area for most of the mollusks of the Berends local fauna is the northeastern Nebraska-northwestern Iowa region. This has been interpreted to mean that the Berends assemblage lived at a time when the climate in the panhandle of Oklahoma was similar to that now occuring in the Plains farther to the north. The winters probably average about 20° F, with average summer temperatures of 70° F. The precipitation was between 20-30 in. (Visher, 1954). This indicates a slightly warmer, more moist climate than that of the time of the Doby Springs and Adams local faunas. The last appearance in this area of the Plains of *Planorbula armigera* and *Sphaerium securis* occurs in the Berends local fauna. The absence of these 2 species from the Doby Springs, Adams, Butler Spring and Mount Scott local faunas has been interpreted to mean that the Berends assemblage probably lived earlier in the Illinoian, before these species had become locally extinct.

The Doby Springs mollusks represent the coolest of the 5 Illinoian assemblages considered in this report. The distribution pattern of the Doby Springs mollusks suggests that this assemblage probably lived in a climate that combined winters similar to those in northeastern Nebraska-northwestern Iowa (the area in which the majority of the Doby Springs species currently occur), with summers that were no more severe than those now occurring in northern North Dakota and Minnesota. The inferred climate for the Harper County, Oklahoma area at the time the Doby Springs local fauna lived probably consisted of summer temperatures of between 65°-70° F, with winter temperatures of between 15°-20° F, and an annual precipitation of about 18-20 in., 8-10 in. of which fell during the summer months.

The overlap area which encompasses most of the species present in the Adams and Butler Spring local faunas is not very different from that of the Doby Springs local fauna. The climate at the time the Adams and Butler Spring local faunas lived combined winters which were similar to those now occurring in northeastern Nebraska with summers like those that presently prevail in eastern Montana and the Dakotas. Winter temperatures were probably between 15°-20° F, with normal summer temperatures of 65°-70° F. The annual precipitation was perhaps between 18-19 in.

The Adams and Butler Spring local faunas appear to have lived during a slightly warmer phase of the Illinoian than did the Doby Springs local fauna. Some of the same northern species present in the Doby Springs local fauna continued to live in the area through the time represented by the Butler Spring local fauna, but they were greatly reduced in numbers. In addition, the Adams and Butler Spring local faunas contain the earliest Illinoian occurrences in the Meade County area of *Helicodiscus singleyanus*, a relatively southern species. These 2 lines of evidence suggest that the climate was changing towards slightly warmer conditions. This warming trend evidently brought about a reduction in many of the northern species which were present in the Doby Springs local fauna, and permitted more southerly elements to enter this area. This influx of southern species continued through at least that portion of the Illinoian repre-

PLATE I

FIGS. 1, 2. *Sphaerium sulcatum* (Lamarck), Mount Scott Locality UM-K2-59. Inner and outer view of right valve. X4, UMMZ 208885a.

FIG. 3. *Anodonta grandis* Say, Doby Springs locality 4. Outer view of right valve. X0.8, UMMZ 213832.

FIGS. 4, 5. *Pisidium obtusale* (Lamarck), Mount Scott locality UM-K2-59. Inner and outer views of left valve. X8, UMMZ 208872a.

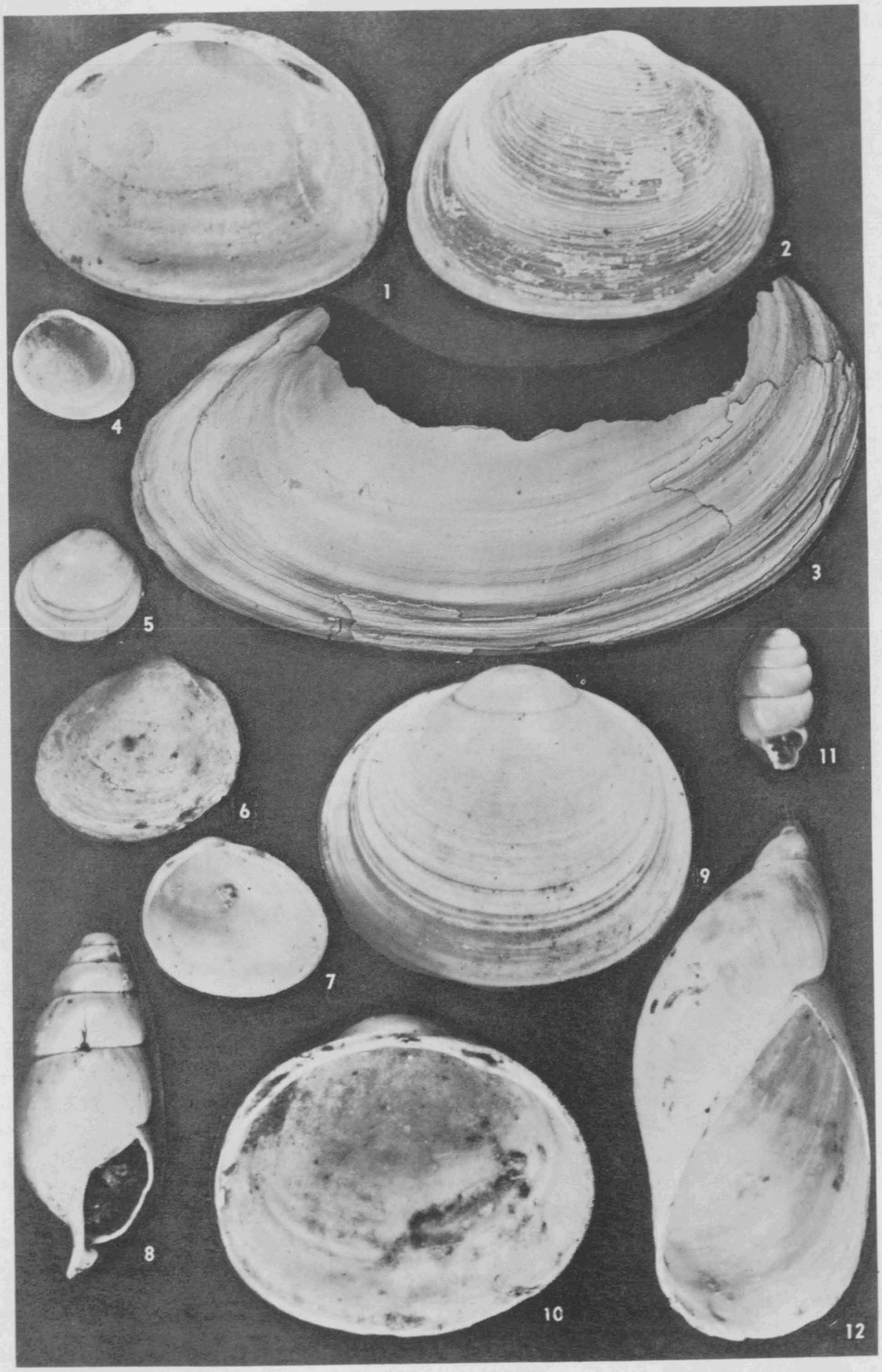
FIGS. 6, 7. *Pisidium subtruncatum* Malm. Fig. 6, Mount Scott locality UM-K4-53. Outer view of right valve. X8, UMMZ 200632. Fig. 7, Jones Sink, lower level. Inner view of right valve. X8, UMMZ 195840a.

FIG. 8. *Cionella lubrica* (Müller), Doby Springs locality 4. Apertural view. X8, UMMZ 208994.

FIGS. 9, 10. *Sphaerium occidentale* Prime. Mount Scott locality UM-K2-59. Inner and outer views of left valve. X8, UMMZ 208880a.

FIG. 11. *Vertigo elatior* Sterki, Doby Springs locality 5. Apertural view. X8, UMMZ 213770a.

FIG. 12. *Oxyloma* sp., Mount Scott locality UM-K2-59. Apertural view. X8, UMMZ 213697a.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sented by the Mount Scott local fauna. The Adams and Butler Spring local faunas, thus, appear to be intermediate between the Doby Springs and Mount Scott local faunas.

The Mount Scott local fauna is believed to be the youngest of the 5 Illinoian assemblages considered in this report. Locality UM-K2-59 of the Mount Scott local fauna occurs stratigraphically below the Cragin Quarry local fauna of Sangamon age (Hibbard & Taylor, 1960). There is no evidence in the intervening sequence of sediments of an unconformity or of any faunas equivalent to the Butler Spring, Adams, Doby Springs or Berends local faunas. It is assumed that the correlatives of these assemblages occur somewhere below the interval from which the Mount Scott local fauna was recovered.

Several different lines of evidence, the overlap area of the mollusks, the larger number of species with relatively southern distributions, the mammals (Hibbard, 1963), and the pollen (Kapp, 1965), all indicate that the Mount Scott local fauna is the warmest of the 5 Illinoian faunas from this region. The majority of the molluscan species occurring in the Mount Scott local fauna are now found living in northwest Iowa in the area of Lake Okoboji. Some of the more southern species, however, only reach as far north in the Plains as the southeast Nebraska-northeast Kansas area. These distribution patterns suggest that the Mount Scott local fauna lived at a time when local winter temperatures were between 25°-35° F, summers between 65°-70° F, with between 20-30 in. of rainfall per year, 10-12 in. of which fell during the warmer part of the year.

SYSTEMATIC DISCUSSION

The systematic discussion in this portion of the paper includes all the mollusks from the Mount Scott and Doby Springs local faunas. Materials collected from post-Kingsdown sediments at locality UM-K2-60 are also included here because of their relevance to the dating of the Mount Scott local fauna. Only previously unreported species of mollusks appearing in the faunal lists of the Berends, Adams and Butler Spring local faunas are described. A summary of information is given for each species, consisting of geologic range, distribution, ecology and such taxonomic changes as are considered necessary. References listed under the synonymies for some of these species are not necessarily complete and usually include only some of the more important reports.

The treatment of the various species has not been uniform, since many of the mollusks have been quite thoroughly discussed in recent papers by Taylor (1960) and Hibbard & Taylor (1960). However, species not covered in these papers, as well as species requiring taxonomic changes have generally received detailed attention in this report. The superfamilial and familial taxa used for the gastropods follow the arrangement proposed by Taylor & Sohl (1962). The terminations for the superfamily names, however, follows recommendation 29a of the International Commission on Zoological Nomenclature (Stoll, 1961: 29), and end in *"-oidea"*.

The ecologic and distributional data included for each species are in large part based on published information. The more important references include: Pilsbry (1946; 1948), Baker (1939), Leonard (1959), Taylor (1960) and Hibbard & Taylor (1960), for the terrestrial gastropods; Baker (1911; 1928a), Leonard (1959), Taylor (1960) and Hibbard & Taylor (1960), for the aquatic gastropods; and Baker (1928b), Herrington & Taylor (1958), Herrington (1962), Simpson (1914), Ortmann (1919) and Murray & Leonard (1962), for the pelecypods. Additional information obtained from personal collections and study of materials in the United States National Museum and University of Michigan Museum of Zoology, has also been included. The geologic range of each species is based primarily on the information published by Taylor (1960) and Hibbard & Taylor (1960), and in general only includes records for the southwest Kansas-northwest Oklahoma region.

In the discussion that follows, the University of Michigan Museum of Zoology (UMMZ) catalogue number, and the number of specimens counted (in parenthesis), are entered after "Material" for each species. Numbers in excess of 200 have usually been estimated volumetrically. Integers are used to indicate specimens of pelecypods that have both valves intact. Fractions indicate separate pelecypod valves.

Class Pelecypoda
Order Prionodesmacea
Family Unionidae

Uniomerus tetralasmus (Say)
Plate II, Figs. 3-5

Geological Range. Late Pleistocene (Illinoian) to Recent.

Distribution. "Throughout the Mississippi Valley as far north as forty degrees latitude and southwest to Mexico. It is also found in the Ohio and Alabama river systems" (Scammon, 1906: 337).

Ecology. It is found living in temporary ponds, tanks, sloughs and intermittent streams, in situations where no other mussels are likely to be found. This species is capable of withstanding periods of drought by burrowing into the substrate and hibernating over the dry period (Isely, 1925; Baker, 1928b). "In Kansas it occurs in habitats of soft or hard mud bottoms in shallow water" (Murray & Leonard, 1962: 84).

Material. Doby Springs local fauna, locality 4, 208937 (1 + 4/2). Mount Scott local fauna, locality UM-K4-53, 200649 (2/2); locality UM-K1-60, 213802 (1/2); locality UM-K3-60, 214173 (4/2).

Anodonta grandis Say
Plate I, Fig. 3

Geologic Range. Late Pleistocene (Illinoian) to Recent.

Distribution. Entire Mississippi system; upper St. Lawrence drainage; Red River of the North; Lake Winnepeg, Manitoba; southwest to Texas; southeast to Pennsylvania. It is in the Tennessee and Cumberland drainages (Ortmann, 1919: 147).

Ecology. In the southwestern part of its range it is usually a pond or lake form. The typical form is an inhabitant of smaller creeks, where it prefers quiet pools and eddies, and often lives in fine sand and mud (Ortmann, 1919: 145).

Material. Doby Springs local fauna, locality 4, 213832 (1/2). Butler Spring local fauna, locality 1, 208898 (1/2).

Remarks. An early Pleistocene record, from the Sand Draw local fauna of Brown County, Nebraska (Taylor, 1960: 45), is based on fragmentary material, and was questionably referred to genus and species. An identifiable portion of a left valve from locality 1, of the Butler Spring local fauna, confirms the presence in this assemblage of *Anodonta grandis*, which had previously been queried (Hibbard & Taylor, 1960: 74).

Lasmigona complanata (Barnes)

Geologic Range. Late Pleistocene (Illinoian) to Recent.

Distribution. Upper Mississippi drainage as far south as Arkansas in the west; Ohio River system; upper St. Lawrence and its tributaries; north in MacKenzie River; Alabama drainage; it is found in northern Louisiana and extends westward to Iowa, Kansas, Arkansas and Oklahoma (Ortmann, 1919: 136). The record of Recent occurrence of this species nearest to the Meade County area is from the Little Arkansas River, Wichita, Sedgwick County, Kansas (Murray & Leonard, 1962).

Ecology. Prefers deep and quiet water with muddy bottoms; but is found occasionally in riffles and in gravel (Ortmann, 1919: 135).

Material. Adams local fauna, locality 3, 208899 (1/2), 214072 (2/2).

Remarks. Parts of the umbone region

PLATE II

FIGS. 1, 2. *Sphaerium rhomboideum* (Say), Doby Springs locality 1. Inner and outer views of right valve. X4, UMMZ 213739a.

FIGS. 3-5. *Uniomerus tetralasmus* (Say), Doby Springs locality 4. Figs. 3, 4, Inner and outer views of right valve. X0.8, UMMZ 208937a. Fig. 5, Outer view of left valve showing umbonal sculpture. X4, UMMZ 208937b.

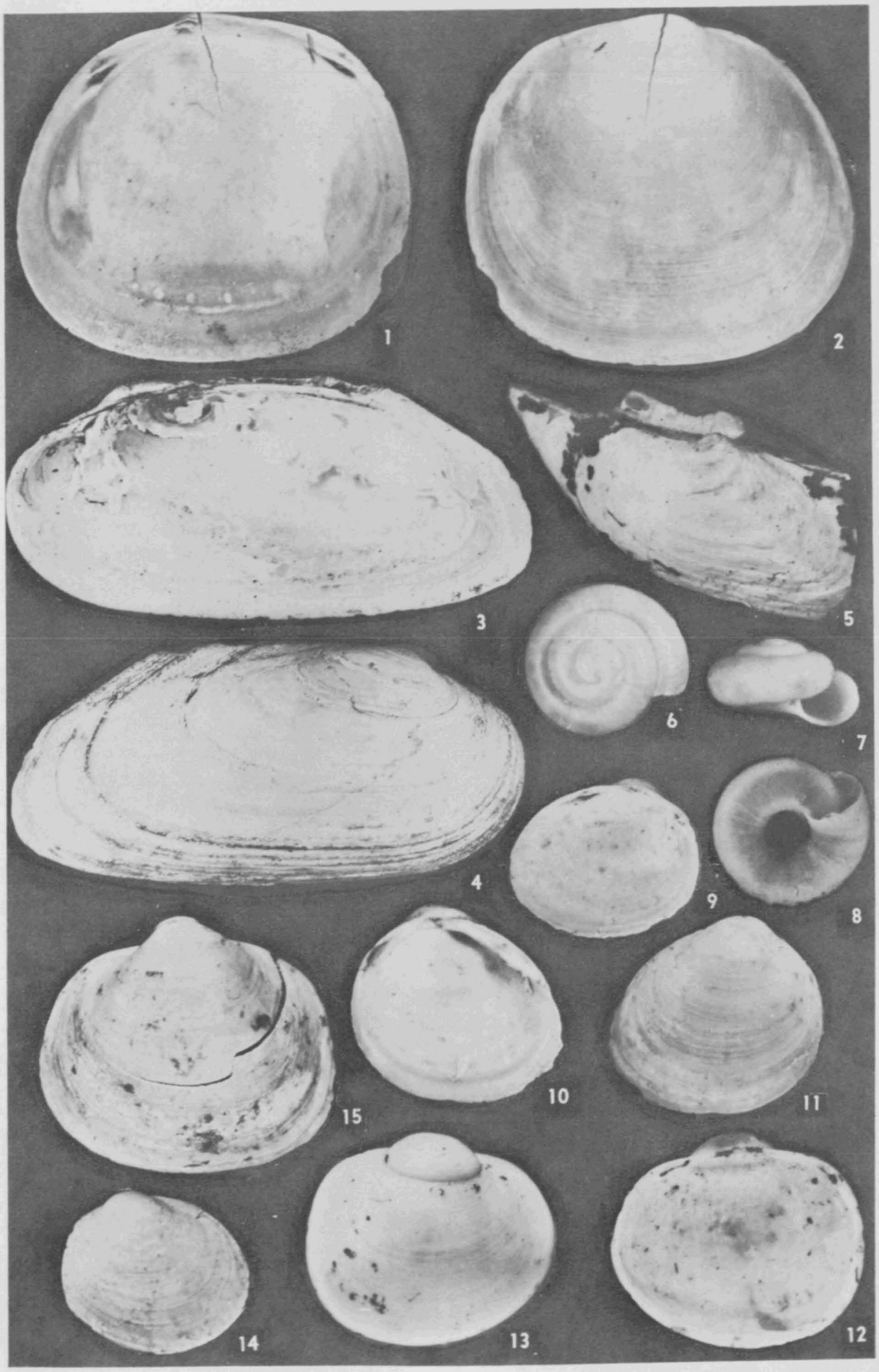
FIGS. 6-8. *Punctum minutissimum* (Lea), Mount Scott locality UM-K4-53. Apical, apertural and basal views. X16, UMMZ 200636a.

FIGS. 9, 14. *Pisidium walkeri* Sterki, Mount Scott locality UM-K1-60. Inner and outer views of right valve. X8, UMMZ 208873a.

FIGS. 10, 11. *Pisidium variabile* Prime, Mount Scott locality UM-K2-59. Inner and outer views of left valve. X8, UMMZ 208887a.

FIGS. 12, 13. *Sphaerium securis* Prime, Berends local fauna. Inner and outer views of left valve. X8, UMMZ 208840a.

FIG. 15. *Sphaerium lacustre* (Müller), Mount Scott locality UM-K4-53. Outer view of right valve. X4, UMMZ 200642a.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of 2 valves (UMMZ 213072) are only identifiable to genus, but it seems probable that they belong to the same species as the more complete specimen found at the same locality. This is the first record of this species from the Meade County region.

Ligumia cf *L. recta* (Lamarck)

Geologic Range. Late Pleistocene (Illinoian) to Recent.

Distribution. "Entire Mississippi drainage; Alabama River Drainage; Red River of the North; St. Lawrence drainage" (Simpson, 1914: 95). The river form of this species *L. r. latissima* has been reported from the Marais des Cygnes and Elk Rivers in southeastern Kansas (Murray & Leonard, 1962).

Ecology. It prefers lakes and large rivers, where it may be found living under a variety of conditions (Ortmann, 1919).

Material. Butler Spring local fauna, locality 1, 214070 (1/2).

Remarks. The material at hand is a fragmentary left valve, in which the beak sculpture is somewhat worn. The double loop sculpture is characteristic of *Ligumia* and is probably *Ligumia recta.* The specimen represents the first fossil record of this species from the southwest Kansas-northwest Oklahoma area.

Order Teleodesmacea
Family Sphaeriidae

Sphaerium lacustre (Müller)
Plate II, Fig. 15

Geologic Range. Middle Pleistocene (Kansan) to Recent.

Distribution. Throughout most of North America, north of Mexico; Japan; Hawaii; Europe (Herrington, 1962).

Ecology. "Most plentiful in small lakes and ponds, but also found in large lakes, rivers and creeks. It appears to have preference for a muddy bottom. I have collected the *S. lacustre* form *rychkholti* from ponds and bog-ponds, and *S. lacustre* form *jayense* from the mud of Rice Lake, Peterborough Co., Ontario, and in Hay Bay, Lennox and Addington Co., Ontario. In the latter place most specimens were obtained from black ooze a quarter to a half mile from shore, at a depth of 6-8 meters" (Herrington, 1962: 20).

Material. Mount Scott local fauna, locality UM-K4-53, 200642 (12/2).

Remarks. *Sphaerium lacustre* form *ryckholti* has been reported from the Dixon local fauna, Kingman County, Kansas, which is believed to be either latest Nebraskan or earliest Aftonian in age (Herrington & Taylor, 1958). The earliest record of this form in the Meade County area is from the Cudahy fauna of Kansan age (Herrington & Taylor, 1958). The one valve from the UM-K4-53 material which is complete, possesses a straighter hinge, truncated ends, and a more gently rounded central margin than *S. lacustre* form *ryckholti*, giving the shell a rectangular outline, characteristic of the ecologic form *jayense.* The Mount Scott shells represent the only known fossil occurrence of this form from the southwest Kansas-northwest Oklahoma area; all of the older records belong to *S. lacustre* form *ryckholti.*

Sphaerium occidentale Prime
Plate I, Figs. 9-10

Geologic Range. Late Pleistocene (Illinoian) to Recent.

Distribution. Northern North America: New Brunswick, Quebec, Ontario; Eastern United States from Vermont, south to Georgia and Alabama; west to Great Lakes region; Western United States from Montana south to Utah and Colorado, west to Oregon and Washington (Herrington, 1962).

Ecology. "Still waters of swamps, ditches, and ponds; among grass and leaves. This species has a preference for, or requires, a habitat that dries up for part of the year" (Herrington, 1962: 22).

Material. Doby Springs local fauna,

locality 4, 213833 (1/2). Mount Scott local fauna, locality UM-K4-53, 200643 (1/2); locality UM-K2-59, 208877 (85/2), 208880 (9/2).

Remarks. The Doby Springs local fauna record represents the oldest known occurrence of this species in the southern Great Plains.

Sphaerium partumeium (Say)

Geologic Range. Late Pliocene (Rexroad Formation) to Recent.

Distribution. Southern Canada from New Brunswick west to Saskatchewan. Most of the United States east of Mississippi River; Minnesota, Nebraska, Iowa, Missouri, Kansas, Oklahoma, Louisiana, Texas, Montana, California and Nevada (Herrington, 1962).

Ecology. "Ponds, swamps, small lakes, and slow-moving streams. It has a preference for a muddy bottom, and is fairly common" (Herrington, 1962: 24).

Material. Mount Scott local fauna, locality UM-K2-59, 208878 (5/2).

Remarks. The late Pliocene record is based on fragmentary material from locality UM-K1-59, of the Bender local fauna, of Meade County, which, because of its condition was only questionably referred to this species (Miller, 1964).

Sphaerium rhomboideum (Say)
Plate II, Figs. 1-2

Geologic Range. Late Pleistocene (Illinoian) to Recent.

Distribution. Ontario (as far north as James Bay and Manitoba); New England and New York west to Minnesota and Iowa; Montana and Idaho. Questionably recorded from Alaska, British Columbia and Nevada (Herrington, 1962).

Ecology. In still water of enlargements in creeks and rivers; sheltered places in small lakes. It has a preference for a soft muddy bottom, with considerable vegetal growth of weeds and algae (Herrington, 1962).

Material. Doby Springs local fauna, locality 1, 213739 (9/2); locality 4, 213834 (3/2). Mount Scott local fauna, locality UM-K4-53, 200644 (1/2).

Remarks. The Doby Springs record represents the oldest fossil occurrence of this species from the southern Plains region.

Sphaerium securis Prime
Plate II, Figs. 12-13

Geologic Range. Late Pleistocene (Illinoian) to Recent.

Distribution. Newfoundland, Maritime Provinces, Quebec, Ontario (southern part), British Columbia; most of states of Mississippi River in United States; Minnesota, Nebraska, Iowa, Arkansas, Texas, Montana and Washington (Herrington, 1962).

Ecology. "Ponds, lakes and rivers. Frequently found in fine sand" (Herrington, 1962: 26). Taylor (1960: 46) collected it from a small permanent or nearly permanent pond in sandy bottom among dense vegetation in shallow water.

Material. Berends local fauna, 208840 (7/2).

Remarks. This is the first known fossil record of this species from the southern Great Plains.

Sphaerium striatinum (Lamarck)

Geologic Range. Late Pliocene (Rexroad Formation) to Recent.

Distribution. Most of North America from Panama to the Great Slave Lake, Northwest Territories (Hibbard & Taylor, 1960).

Ecology. The typical form of this species is restricted to perennial bodies of water with some current action. It has been found living in sand, sandy gravel and sandy mud substrates, in water from 2-3 in. down to a depth of 13.5 meters. It has never been collected from ponds, lagoons, bog-ponds, swamps or anywhere in stagnant water (Herrington, 1962).

Material. Doby Springs local fauna, locality 4, 213826 (52/2). Mount Scott local fauna, locality UM-K4-53, 200645 (14/2); locality UM-K2-59, 208875 (3/2).

Remarks. The first occurrence of this species in the Meade County area is in the Saw Rock Canyon local fauna, Seward County (Taylor, 1960).

Sphaerium sulcatum (Lamarck)
Plate I, Figs. 1-2

Geologic Range. Late Pliocene (Rexroad Formation, Bender local fauna) to Recent.

Distribution. Northeastern North America from Quebec south to Virginia, west to South Dakota, Wyoming, Montana and Washington (?). It does not apparently occur south of those areas that were glaciated (Herrington, 1962).

Ecology. *S. sulcatum* lives on the soft bottom of small lakes, creeks or rivers, that have areas of still water (Herrington & Taylor, 1958). It prefers soft sand, with vegetation, and is never found in swamps or ponds (Herrington, 1962).

Material. Berends local fauna, 208829 (62/2). Doby Springs local fauna locality 1, 213736 (42/2); locality 4, 213826 (116/2); locality 5, 213753 (1/2). Mount Scott local fauna, locality UM-K4-53, 200646 (54/2); locality UM-K1-60, 208882 (26/2); locality UM-K2-59, 208885 (23/2).

Sphaerium transversum (Say)

Geologic Range. Early Pleistocene (Nebraskan) to Recent.

Distribution. North America east of the Rocky Mountains, north to the Northwest Territories and south to Mexico. Europe (Herrington, 1962).

Ecology. "Large lakes, rivers, and sloughs" (Herrington, 1962: 30). Hibbard & Taylor (1960: 77) state that: "In Meade County, Kansas, it occurs commonly in Crooked Creek, and lives in both sand and mud in slow current or quiet water. Empty shells were abundant in a dry metal stock tank, usually kept full by a windmill pump. Before the water had dried up the habitat was a soft mud bottom, with a thin cover of submerged vegetation."

Material. Berends local fauna, 208947 (1/2). Mount Scott local fauna, locality UM-K2-59, 208892 (1/2).

Remarks. This species has been reported from the Sand Draw and Dixon local faunas (Herrington & Taylor, 1958; Taylor, 1960), but the material from the Berends local fauna represents the oldest record from the Meade County area.

Sphaerium sp.

Included here are shells, which, because of their fragmentary condition or immaturity, could not be identified to species.

Material. Doby Springs local fauna, locality 2, 185789 (2/2); locality 4, 213828 (1/2); locality 5, 213752 (2/2). Mount Scott local fauna, locality UM-K2-59, 208893 (5/2), 208894 (1/2); UM-K3-60, 214167 (2/2).

Pisidium casertanum (Poli)

Geologic Range. Early Pliocene (Laverne Formation, Laverne local fauna, Beaver County, Oklahoma) to Recent (Herrington & Taylor, 1958).

Distribution. Almost cosmopolitan. In the Western Hemisphere from Patagonia to the Arctic Circle. It has been recorded from all of the states in the United States, with the exception of Hawaii, Kentucky and North Dakota (Herrington, 1962).

Ecology. This widespread species is capable of adapting itself to a diverse range of habitats and has a correspondingly variable shell. It has been found living in bog ponds, swamps that dry up for several months of the year, swamp-creeks, creeks with considerable current, rivers and lakes, including the Great Lakes (Herrington, 1962). "The form *roperi* Sterki, as well as somewhat similar shells with thin walls and smooth outlines, comes from ponds, swamps, bog ponds, and small lakes that are filling up with marl. The heavier-shelled, typical *casertanum* lives in rivers or fairly large creeks" (Herrington & Taylor, 1958: 14).

Material. Berends local fauna, 208835 (29/2). Doby Springs local fauna, locality 1, 213738 (95/2); locality 4, 213829 (87/2); locality 5, 213748 (200/2). Mount Scott local fauna, locality UM-K4-53, 200629 (600/2); locality UM-K1-60, 208870 (200/2); locality UM-K2-59, 208896 (60/2), 208876 (3/2), 208879 (200/2), 208891 (33/2); locality UM-K3-60, 214183 (1/2). Recent in Harper County, Oklahoma.

Remarks. The variability of this species has evidently been greatly underestimated, for in a recently published revision of the North American Sphaeriidae, 41 names are listed under the synonymy of *Pisidium casertanum* (Herrington, 1962: 33).

Pisidium compressum Prime

Geologic Range. Middle Pleistocene (Kansan, Cudahy Fauna) to Recent.

Distribution. North America, from Great Slave Lake, Northwest territories, south to Mexico (Herrington, 1962).

Ecology. It is restricted to permanent water situations, such as creeks, rivers and lakes, with some current, and prefers a sandy bottom with some vegetal growth. It never occurs in ponds, swamps, lagoons or bog-ponds (Hibbard & Taylor, 1960; Herrington & Taylor, 1958).

Material. Berends local fauna, 208839 (313/2). Doby Springs local fauna, locality 1, 213740 (160/2); locality 2, 185788 (9/2); locality 4, 213830 (4960/2); locality 5, 213746 (620/2). Mount Scott local fauna, locality UM-K4-53, 200629 (1095/2); locality UM-K1-60, 208869 (500/2); locality UM-K2-59, 208886 (5/2), 208890 (4/2); locality UM-K3-60, 214194 (1/2).

Pisidium nitidum Jenyns

Geologic Range. Early Pliocene (Laverne Formation, Laverne local fauna) to Recent (Herrington & Taylor, 1958).

Distribution. Holarctic; Eurasia and North Africa; in North America from Mexico to Northwest Territories, but absent from the southeast United States.

Ecology. "Large ponds, bog ponds, lakes, creeks, and rivers. Seems to prefer shallow water" (Herrington, 1962: 46). *Pisidium nitidum* form *pauperculum* Sterki lives in lakes, now filling with marl, rivers and large creeks, where it thrives in soft sand. Unlike the typical form, *P. n. pauperculum* does not apparently inhabit ponds (Herrington & Taylor, 1958).

Material. *P. n.* form *nitidum* Jenyns: Berends local fauna, 208828 (64/2). Doby Springs local fauna, locality 1, 213737 (74/2); locality 4, 213831b (6/2); locality 5, 213750b (700/2). Mount Scott local fauna, locality UM-K4-53, 200630b (91/2); locality UM-K1-60, 208868 (2 + 200/2).

P. n. form *pauperculum* Sterki: Doby Springs local fauna, locality 4, 213831a (425/2); locality 5, 213750a (200/2). Mount Scott local fauna, locality UM-K4-53, 200630a (234/2); locality UM-K2-59, 208881 (2/2), 208884 (1/2).

Pisidium obtusale (Lamarck)
Plate I, Figs. 4-5

Geologic Range. Middle Pleistocene (Kansan, Cudahy fauna) to Recent.

Distribution. Holarctic; in North America from New Jersey and New York west through Ohio, Illinois, Minnesota and the Dakotas, to the west coast; northward to Northwest Territories; a single record from Mexico (Herrington, 1962).

Ecology. The form *rotundatum* prefers shallow water and sheltered spots in lakes, creeks, ponds, lagoons and flood plains, where there are considerable accumulations of grassy vegetation or fallen leaves from trees (Herrington, 1962).

Material. Berends local fauna, 208946 (1/2). Doby Springs local fauna, locality 1, 214160 (2/2); locality 4, 213835 (21/2); locality 5, 213751 (3/2). Mount Scott local fauna, locality UM-K4-53, 200631 (63/2); locality UM-K1-60, 208874 (1/2); locality UM-K2-59, 208872 (11/2), 208889 (450/2). Locality UM-K2-60, 214186 (1/2).

Remarks. Only the ecologic form *rotundatum* Prime is represented in the fossil record.

Pisidium subtruncatum Malm
Plate I, Figs. 6-7

Geologic Range. Late Pleistocene

(Illinoian) to Recent.

Distribution. Eurasia; in North America it is found from the Great Slave Lake, Northwest Territories, south to the northern tier of states in the United States; New York, the Great Lakes, Colorado, Wyoming and California (Herrington, 1962).

Ecology. "Streams, bays, and lakes, including the Great Lakes" (Herrington, 1962: 49). Baker (1928b) reports it from mud, sand and gravel bottom, at depths ranging from 0.8-5.6 meters.

Material. Mount Scott local fauna, locality UM-K4-53, 200632 (1/2).

Remarks. Herrington & Taylor (1958) suggest that the northern distribution of this species may reflect its inability to survive the warmer summers that prevail further to the south.

Pisidium variabile Prime
Plate II, Figs. 10-11

Geologic Range. Late Pleistocene (Illinoian) to Recent.

Distribution. Prince Edward Island west to British Columbia; New England states south to District of Columbia; Tennessee, Alabama, Ohio, Michigan, Indiana, Wisconsin, Illinois, South Dakota, Iowa, Montana, Washington, Idaho, California, Utah and Colorado (Herrington, 1962).

Ecology. *P. variabile* has been taken from both lake and river situations. It lives on a variety of substrates (marl, clay, mud, silt, sand and gravel), at depths down to 12 meters (Baker, 1928b). "Creeks, rivers, and lakes; usually in still water where soft sediments accumulate" (Herrington, 1962: 50).

Material. Berends local fauna, 208838 (4/2). Doby Springs local fauna, locality 1, 213735 (200/2); locality 4, 208888 (69/2); locality 5, 213747 (150/2). Mount Scott local fauna, locality UM-K4-53, 200633 (9/2); locality UM-K1-60, 208871 (79/2); locality UM-K2-59, 208883 (4/2), 208887 (3/2).

Remarks. These records represent the only known fossil occurrence of *Pisidium variabile* from the High Plains.

Pisidium walkeri Sterki
Plate II, Figs. 9, 14

Geologic Range. Late Pleistocene (Illinoian) to Recent.

Distribution. "Northern North America: Canada from Ontario to Alberta, northward to James Bay and Northwest Territories: in the United States, Maine to Virginia, and Michigan, Ohio, Missouri, Iowa, South Dakota, Minnesota, Montana and Arizona" (Herrington & Taylor, 1958: 17).

Ecology. *Pisidium walkeri* lives "in rivers, creeks, and small lakes" (Herrington & Taylor, 1958: 17).

Material. Mount Scott local fauna, locality UM-K4-53, 200634 (1/2); locality UM-K1-60, 208873 (6/2).

Remarks. The Mount Scott material represents the oldest confirmed fossil record of *P. walkeri*.

Class Gastropoda
Subclass Prosobranchia
Order Mesogastropoda
Superfamily Valvatoidea
Family Valvatidae

Valvata tricarinata (Say)

Geologic Range. Early Pliocene (Laverne Formation, Laverne local fauna) to Recent (Hibbard & Taylor, 1960).

Distribution. "Eastern United States west to Iowa. Great Slave Lake south to Virginia and the Ohio River" (Baker, 1928a: 14). Cherry County, Nebraska (Taylor, 1960).

Ecology. "*Valvata tricarinata* is a species of rivers, lakes, and permanent ponds, particularly where there is abundant vegetation. It is found on all varieties of bottoms and in all depths down to 18 ft. It is usually associated with the filamentous algae *Oedogonium* and *Cladophora*, and has been observed on *Vaucheria* upon which it was apparently feeding ... it prefers habitats where the bottom sediments are more or less firm and will enable the individuals to move freely about" (Reynolds, 1959: 160).

The single Nebraska occurrence of this snail was from a spring-fed pond with a water temperature of 15° C, where it was found living in association with *Ceratophyllum*, *Elodea* and algae (Taylor, 1960).

Material. Berends local fauna, 208821 (319). Doby Springs local fauna, locality 1, 213705 (1900); locality 2, 185775 (26); locality 4, 208900 (8800); locality 5, 213744 (1600). Mount Scott local fauna, locality UM-K4-53, 200652 (3600); locality UM-K1-60, 213788 (2600); locality UM-K2-59, 213700 (102).

Remarks. The variations in number and arrangements of the carinae in *V. tricarinata* have long been recognized (Robertson, 1915; Baker, 1928a; La Roque, 1956), and given sub-specific designations. However none of these variations have been definitely related to any known fixed set of conditions, either geographic, stratigraphic or ecologic, and probably do not deserve subspecific rank. In this work they are all treated as *V. tricarinata*.

Superfamily Rissoidea
Family Hydrobiidae

Probythinella lacustris (Baker)

Geologic Range. Late Pleistocene (Illinoian) to Recent.

Distribution. "North America between the Rocky Mountains and the Appalachians, from Great Slave Lake to Arkansas, Alabama, and New York. The species is known from the MacKenzie River, Hudson Bay, St. Lawrence River and Mississippi River drainages, but not from the shorter streams of the Atlantic or Gulf Coastal plains" (Hibbard & Taylor, 1960: 80).

Branson (1959) records this species from Hughes and Payne counties, Oklahoma. Fossil occurrences of *P. lacustris* in McPherson County, Kansas (UMMZ uncat.), the Butler Spring local fauna, Meade County, Kansas (Hibbard & Taylor, 1960), the Doby Springs local fauna, Harper County, Oklahoma, and Lake Thatcher beds, Caribou County, Idaho (Miller, 1963), indicate a much wider distribution for this species during the Late Pleistocene.

Ecology. The geographic and bathymetric range of this species indicates that it occurs almost exclusively in rivers and lakes at depths of about 5 ft or more. It has been found living on vegetation, as well as a variety of substrates, including fine sand, coarse sand, gravel, marl and soft mud (Hibbard & Taylor, 1960).

Material. Doby Springs local fauna, locality 4, 213789 (10,750), 185789 (3).

Subclass Euthyneura
Order Basommatophora
Superfamily Ellobioidea
Family Ellobiidae

Carychium exiguum (Say)

Geologic Range. Late Pliocene (Rexroad Formation, Rexroad local fauna, Meade County, Kansas) to Recent (Taylor, 1960).

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

Ecology. "*C. exiguum* lives in the crevices of rotten logs or on dead leaves in moist places, or sometimes it is found in very wet places, such as *Pomatiopsis lapidaria* frequents" (Pilsbry, 1948: 1054). In northern Nebraska it was found living on wet leaves in seepage areas and along a spring-fed brook (Taylor, 1960).

Material. Berends local fauna, 208837 (188). Doby Springs local fauna, locality 2, 195781 (1); locality 4, 208941 (160); locality 5, 213745 (570). Mount Scott local fauna, locality UM-K4-53, 200603 (1500); locality UM-K2-59, 213659 (350).

Superfamily Lymnaeoidea
Family Lymnaeidae

Lymnaea stagnalis jugularis Say

Geologic Range. Late Pleistocene (Illinoian) to Recent. The oldest definite occurrence of this species is from the Illinoian Doby Springs local fauna, of

Harper County, Oklahoma.

Distribution. "Found over most of northern North America north of about 41 degrees; southward in the Western United States to northern California, Nevada, and southern Colorado; unknown in the northern Great Plains between the Rocky Mountains and the eastern Dakotas and northwestern Nebraska" (Hibbard & Taylor, 1960: 85).

Ecology. "The American form of *stagnalis* is usually found in more or less stagnant parts of ponds or lakes and rivers about vegetation. It may frequently be seen floating among pond weeds and algae, the foot applied to the surface film of the water, the shell hanging downward" (Baker, 1928a: 202).

Material. Doby Springs local fauna, locality 1, 213742 (8); locality 4, 208902 (21); locality 5, 213756 (2).

Remarks. All the material from the Doby Springs local fauna consists of fragments of spires. These compare well with the more complete material from the Bar M. local fauna of Harper County, Oklahoma (Taylor & Hibbard, 1955).

Hibbard & Taylor (1960: 86) have suggested the possible presence of *Lymnaea stagnalis jugularis* in the Cudahy fauna of Lincoln County, Kansas. They surmised that the record of *Acella haldemani* from that fauna reported by Frye, Leonard & Hibbard (1943: 41) might have been based on a misidentification of immature spires of *L. s. jugularis*. Neither of these species has been recorded from that locality in subsequent faunal lists for the Cudahy fauna (Leonard, 1950: Frye & Leonard, 1952). *Acella haldemani*, however, has been recently collected by a University of Michigan Museum of Paleontology field party, along with other undescribed mollusks, from younger beds in nearby McPhearson County, Kansas, thus posing the question of whether the original record from Lincoln County was indeed based on *Lymnaea stagnalis jugularis*.

Stagnicola caperata (Say)

Geologic Range. Middle Pliocene (Ogallala Formation, Buis Ranch local fauna, Beaver County, Oklahoma, to Recent (Hibbard & Taylor, 1960).

Distribution. "From Quebec and Massachusetts west to California; Yukon Territory and James Bay south to Maryland, Indiana, Colorado, and California" (Baker, 1928a: 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 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 the late spring and summer. The species hibernates to a greater degree than any of the other Lymnaeas, a fact attested to be the many rest varices observed on the shell of large individuals. 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, 1928a: 263). Hibbard & Taylor (1960) have found *S. caperata* in association with *Stagnicola palustris*, *Promenetus umbilicatellus* and *Aplexa hypnorum* in temporary bodies of water in northern Nebraska.

Material. Berends local fauna, 208830 (25). Doby Springs local fauna, locality 1, 213721 (16); locality 4, 208901 (350); locality 5, 213755 (27). Mount Scott local fauna, locality UM-K4-53, 200647 (1200); locality UM-K1-60, 213790 (6); locality UM-K2-59, 213703 (4000). Locality UM-K2-60, 214197 (1).

Stagnicola exilis (Lea)

Geologic Range. Late Pliocene (Rexroad Formation) to Recent. The oldest reported occurrence of *S. exilis* in the Meade County area is from the Rexroad local fauna (Hibbard & Taylor, 1960).

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

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

Material. Berends local fauna, 208814 (21). Mount Scott local fauna, locality UM-K2-59, 213696 (8).

Stagnicola reflexa (Say)

Geologic Range. Late Pliocene (Rexroad Formation, Bender local Fauna) to Recent (Miller, 1964).

Distribution. Eastern Quebec from approximately 65^{o} longitude, west to Nebraska to about 100^{o} longitude, north to Manitoba to near 50^{o} latitude, south to southern Illinois and southern Kansas, 37^{o} latitude (Baker, 1911; 1928a).

Ecology. *S. reflexa* is found in creeks, ponds, lakes and rivers, in sheltered localities, attached to floating debris, submerged vegetation, stones, etc. Many of these habitats become dry in the summer. In northern Illinois and Wisconsin it has been collected from small pools or ponds and in swales located in woods or open field; none have been found in large streams or lakes (Baker, 1911; 1928a).

Material. Berends local fauna, 208830 (25). Doby Springs local fauna, locality 1, 213743 (1); locality 4, 208942 (133); locality 5, 213754 (2). Mount Scott local fauna, locality UM-K4-53, 200648 (12); locality UM-K1-60, 213791 (8); locality UM-K2-59, 213661 (700).

Fossaria dalli (Baker)

Geologic Range. Early Pliocene (Laverne Formation) to Recent. The oldest Cenozoic record of this species in the Meade County area is from the Laverne local fauna (Hibbard & Taylor, 1960).

Distribution. "Ohio to northern Michigan and Montana, south to Kansas and Arizona" (Baker, 1928a: 288). It has been collected in Meade County, Kansas at the State Park (Leonard, 1943).

Ecology. This species is semi-aquatic in its habits and is only rarely found submerged in water. It lives in marginal situations, near water, on the mud, moist leaves and other debris. In Meade County, Leonard (1943) reports it to prefer living on wet ground among sedge and grass. I have collected it from leaf litter in a seepage area near the Doby Springs local fauna locality in Harper County, Oklahoma, where it was associated with *Succinea*, *Vertigo milium*, *Gastrocopta tappaniana* and *Fossaria obrussa*.

Material. Berends local fauna, 208832 (60). Doby Springs local fauna, locality 1, 213712 (137); locality 2, 185779 (4); locality 4, 208903 (286); locality 5, 213785 (27). Mount Scott local fauna, locality UM-K4-53, 200608 (159); locality UM-K1-60, 213792 (8); locality UM-K2-59, 213660 (110). Recent, Harper County, Oklahoma.

Fossaria obrussa (Say)

Geologic Range. Late Pliocene (Rexroad Formation) to Recent. The earliest tertiary record of this species in the Meade County area is from the Bender local fauna (Miller, 1964).

Distribution. "From the Atlantic to the Pacific Oceans, and from the MacKenzie Territory, Canada, south to Arizona and northern Mexico" (Baker, 1928a: 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, 1928a: 296).

Material. Berends local fauna, 208807 (39). Doby Springs local fauna, locality 4, 208904 (50). Mount Scott local fauna, locality UM-K4-53, 200609 (90); locality UM-K1-60, 213793 (11); locality UM-K2-59, 213662 (2). Recent, Harper County, Oklahoma.

Superfamily Ancyloidea
Family Planorbidae

Armiger crista (Linnaeus)

Geologic Range. Late Pleistocene to

PLATE III

FIGS. 1-3. *Zonitoides nitidus* (Müller), Mount Scott locality UM-K4-53. Apertural, basal and apical views. X8, UMMZ 213789a.

FIG. 4. *Laevapex fuscus* (Adams), Doby Springs locality 4. Apical view. X8, UMMZ 208916a.

FIGS. 5-7. *Gyraulus deflectus* (Say), Doby Springs locality 1. Apertural, basal and apical views. X8, UMMZ 213706a.

FIGS. 8-10. *Strobilops labyrinthica* (Say), Mount Scott locality UM-K4-53. Apertural, apical and basal views. X8, UMMZ 200640a.


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Recent. In the southwest Kansas-northwest Oklahoma area, the oldest record is from the Berends local fauna, of Beaver County, Oklahoma.

Distribution. "Holarctic; in North America, north of about 41 degrees, but south of this latitude on the Pacific Coast to San Mateo County, California, and southward in central Utah" (Hibbard & Taylor, 1960: 101).

Ecology. *Armiger crista* is a species of ponds and marshes (Hibbard & Taylor, 1960). Goodrich (1932: 65) states that this snail "lives upon water-logged sticks and rotting leaves in stagnant water." In temporary ponds in southern Michigan, U. S. A., *A. crista* is believed to hibernate after burrowing into the mud (Kenk, 1949). Beetle (1965) collecting from ponds in Grand Teton National Park, Wyoming, U. S. A., found this species to be restricted to one pond. This pond, which was subjected to periodic drying, was the only one that posessed a bottom composed of colloidal muck, interspersed with a mat of decaying vegetation. The surface of the pond was completely covered with a marsh trefoil.

Material. Berends local fauna, 208811 (19). Doby Springs local fauna, locality 1, 213709 (2); locality 4, 208905 (32); locality 5, 213763 (146). Mount Scott local fauna, locality UM-K4-53, 200602 (19); locality UM-K1-60, 213794 (1), locality UM-K2-59, 208663 (77).

Gyraulus circumstriatus (Tryon)

Geologic Range. Middle Pleistocene (Kansan, Cudahy Fauna) to Recent.

Distribution. "North America approximately between 40° and 50° N. latitude: south in Rocky Mountains to central New Mexico" (Taylor, 1954: 3). "In the Great Plains it ranges south to northern Nebraska" (Taylor & Hibbard, 1955: 14).

Ecology. "*Gyrulus circumstriatus* is characteristic of small, seasonal water bodies, such as wood 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" (Taylor, 1960: 57).

Material. Berends local fauna, 208818 (99). Doby Springs local fauna, locality 1, 213708 (75); locality 2, 185788 (2); locality 4, 208907 (114); locality 5, 213759 (35). Mount Scott local fauna, locality UM-K4-53, 200616 (900), 200617a (3800); locality UM-K1-60, 213795 (200); locality UM-K2-59, 213664 (7300).

Gyraulus deflectus (Say)
Plate III, Figs. 5-7

Planorbis deflectus Say, 1824: 261, Pl. XV, Fig. 8

Planorbis hirsutus Gould, 1840: 196

Planorbis obliquus DeKay, 1843: 62, Pl. IV, Fig. 57a,b

Gyraulus deflectus (Say), F. C. Baker, 1928a: 370, Pl. XXIII, Figs. 15-18, 20-21

Gyraulus deflectus obliquus (DeKay), F. C. Baker, 1928a: 372, Pl. XXIII, Figs. 22-26

Gyraulus hirsutus (Gould), F. C. Baker, 1928a, Pl. XXIII, Figs. 8-14

Gyraulus deflectus (Say), Taylor, 1960: 57

Geologic Range. Middle Pleistocene (Kansan) to Recent. The earliest known occurrence in the Meade County area is from the Cudahy fauna (UMMZ 177244).

Distribution. Maritime Provinces in Canada, south to Potomac River, Virginia; northwest to Montana, Idaho, British Columbia, Northwest Territories and Alaska.

The distribution map (Fig. 5) is based on published records and materials examined in the U. S. National Museum (USNM) and University of Michigan Museum of Zoology (UMMZ) collections. The following is a list of localities along the southern periphery of its distribution:

Virginia: Roaches Run (UMMZ 87959); Belvoir, Ft. Humphrey's, drift of Potomac River (USNM 466527); Fairfax County, Potomac River at Mt. Vernon (USNM 572015); Potomac River at Alexandria (UMMZ 156782).

District of Columbia: Anacostia,

FIG. 5. Distribution of *Gyraulus deflectus*.

Poplar Point (USNM uncat.).

Ohio: Hamilton County, Cincinnati (USNM 121165); Franklin County, Columbus (USNM 30228a).

Illinois: Mason County, Quiver Creek; Quiver and Dogfish Lakes (Baker, 1906). Champaign County, Crystal Lake, Urbana (Zetek, 1918).

Iowa: Muscatine County, Muscatine (USNM 476433); Linn County, Cedar Rapids (USNM 476528); Cerro Gordo County, Mason City (USNM 506111); Dickenson County, Robinson Lake (USNM 476519); Palo Alto County, Ruthven (UMMZ 66256).

Nebraska: Cherry County, Fort Niobrara National Wildlife Refuge, 5 miles east of Valentine. Pond and seepage area at old fort reservoir (Taylor, 1960).

Montana: Flathead County, sec 1, T 28 N, R 21 W, 8 miles east of Kalispell (UMMZ 181060).

Idaho: Coeur d'Alene County, Coeur d'Alene (USNM 474743).

British Columbia: Kamloops (USNM 382125).

Ecology. "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" (Taylor, 1960: 57).

Material. Doby Springs local fauna, locality 1, 213705 (200); locality 2, 185787 (12); locality 4, 208908 (140).

Remarks. Examination of material in the collections of University of Michigan Museum of Zoology and the U. S. National Museum indicates that the name combinations *Gyraulus obliquus*, *G. deflectus obliquus* and *G. hirsutus*, are all junior synonyms of *Gyraulus deflectus*.

The differentia used by DeKay (1843: 62) to distinguish *G. obliquus* from *G. deflectus* are the obliquity of the aperture and the absence of the medial peripheral angulation. Neither of these characters are considered valid. There are many lots with individuals in which both of these characteristics attain different degrees of development, and include intermediates which grade into the *G. deflectus* form. Baker (1928a: 372) has tried to preserve the *G. deflectus obliquus*, even though he admitted that it was not always possible to separate it from *G. hirsutus*.

Gyraulus hirsutus has been separated from *G. deflectus* by its (1) rounded, subangular periphery (2) deeper umbilicus, and (3) more hirsute condition. None of these characters are consistent, with the *hirsutus*, *deflectus* and intermediate forms frequently occurring in the same lot.

The material in the National Museum and University of Michigan Museum of Zoology collections, deposited under the name *Gyraulus borealis* Westerlund, falls within the range of variation of *G. deflectus* as understood here, and has been included in the distribution map.

Some authors (Binney, 1865; Dall, 1905; Baker, 1928a) have suggested that *Gyraulus deflectus* might be a synonym of the European *G. albus* (Müller). Comparison of *G. deflectus* with 8 lots of *G. albus* from Europe, in the University of Michigan Museum of Zoology, indicates that they differ in the type of sculpture. *G. albus* has more regularly spaced, raised, spiral and axial ornamentation. The spiral sculpture is better developed and appears as fine lirae resting on the more subdued axial sculpture. In *G. deflectus* the sprial sculpture, when present, is produced by the alignment of impressed pits, which accommodate the hair-like projections in the fresh shell. These pits are lower than the axial growth lines.

The differences in sculpture appear distinct enough to at least justify their specific separation, but sufficient European material has not been examined to determine the consistency of this character.

Gyraulus parvus (Say)

Geologic Range. Late Pliocene (Rexroad Formation) to Recent. The first occurrence of this species in the Meade County area is in the Saw Rock Canyon local fauna, Seward County, Kansas (Hibbard & Taylor, 1960).

Distribution. "Eastern North America east to the Rocky Mountains from Florida northward to Alaska and northern British Columbia" (Baker, 1928a: 377).

Ecology. "Usually in quiet bodies of water; often of small size .... This species is more often found in vegetation than in any other situation" (Baker, 1928a: 376-377). In Meade County, Kansas, and Harper County, Oklahoma, this species was collected from rooted vegetation growing in premanent water situations.

Material. Berends local fauna, 208801 (45). Doby Springs local fauna, locality 1, 213707 (700); locality 2, 185782 (50); locality 4, 208906 (1700); locality 5, 213760 (1900). Mount Scott local fauna, locality UM-K4-53, 200618 (1340), 200617b (5660); locality UM-K1-60, 213797 (1650); locality UM-K2-59, 213665 (226). Recent, Harper County, Oklahoma.

Helisoma anceps (Menke)

Geologic Range. Late Pliocene (Rexroad Formation, Saw Rock canyon local fauna) to Recent (Taylor, 1960).

Distribution. "Oregon to Maine, southwestward to western Mexico and Alabama" (Hibbard & Taylor, 1960: 103).

Ecology. ". . . primarily a river and creek species, not living in large lakes" (Baker, 1928a: 319).

Material. Berends local fauna, 208805 (17). Doby Springs local fauna, locality 1, 213714 (32); locality 2, 185785 (3); locality 4, 208909 (126); locality 5, 213758 (600). Mount Scott local fauna, locality UM-K4-53, 200621 (161); locality UM-K1-60, 213798 (175).

Helisoma trivolvis (Say)

Geologic Range. Early Pleistocene (Nebraskan-Aftonian, Dixon local fauna) to Recent (Taylor, 1960).

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, 1928a: 332).

Ecology. This species is primarily an inhabitant of quiet, stagnating water. In the Meade County area, it has been found living in temporary ponds and more permanent bodies of water (Leonard, 1943).

Material. Berends local fauna, 208836 (43). Doby Springs local fauna, locality 4, 208910 (12); locality 5, 213757 (2). Mount Scott local fauna, locality UM-K4-53, 200622 (10); locality UM-K2-59, 213701 (49). Recent, Harper County, Oklahoma.

Planorbula armigera (Say)

Geologic Range. Middle Pleistocene (Kansan, Cudahy fauna) to Recent.

Distribution. "New England west to Nebraska, south to Georgia and Louisiana, north to Great Slave Lake" (Baker, 1928a: 359).

Ecology. "*Planorbula armigera* is largely a species of swales or of small stagnant bodies of water" (Baker, 1928a: 358).

Material. Berends local fauna, 208823 (700).

Promenetus exacuous-kansasensis Complex
Promenetus exacuous form *exacuous* (Say)

Geologic Range. Late Pleistocene (Illinoian) to Recent.

Distribution. "North America north to 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, Kansas" (Hibbard & Taylor, 1960: 107).

Ecology. "*Promenetus exacuous* is found in shallow, perennial or subpermanent, quiet-water bodies, such as ponds, oxbow lakes, marshes, and sloughs or back waters along streams. It is usually on the submerged vegetation in such habitats" (Hibbard & Taylor, 1960: 108).

Material. Mount Scott local fauna, locality UM-K4-53, 200635 (500); locality UM-K1-60, 213799 (200); locality UM-K2-59, 213667 (190).

Remarks. Hibbard & Taylor (1960: 106) recognize 2 distinct species of *Promenetus* from the late Cenozoic of the southern Great Plains, *P. kansasensis*, which occurs in faunas from Pliocene to late Pleistocene, and *P. exacuous*, that has a geologic range of late Sangamon to Recent. They state that "Pliocene to late Pleistocene series of *P. kansasensis* differ consistantly from *P. exacuous* in that all or most shells have a sculpture of riblets instead of growth-lines." Evolutionary replacement of *P. kansasensis* by *P. exacuous* sometime in the Sangamon between the time the Cragin Quarry and Jinglebob local faunas lived, is suggested by these authors. The shells from the Mount Scott local fauna do not contain the characteristic riblet sculpture of *P. kansasensis*, and must be considered *P. exacuous*. The occurrence of *P. exacuous* in the Illinoian, makes untenable the suggested placement of the nomenclateral change from *P. kansasensis* to *P. exacuous*, sometime in the Sangamon.

Examination of the *P. kansasensis*-*P. exacuous* complex from 11 faunas occurring in beds that range in age from Upper Pliocene (Saw Rock Canyon local fauna) through Wisconsin (Jones local Fauna), confirms Hibbard & Taylor's observation that there are no consistent differences in size, compression of whorls, or strenth of carina through time. However, the strength of the axial sculpture, its persistence to the adult stage, and the proportion of riblet to non-riblet-bearing individuals in a given population also appear to be inconsistent.

There is a higher proportion of non-riblet to riblet-bearing individuals in the Pliocene Saw Rock Canyon local fauna than in the younger Bender local fauna population from locality UM-K1-59. The *Promenetus* examined from the sequence of Pleistocene faunas from Nebraskan-Aftonian (Dixon and Sand Draw local faunas) through the late Illinoian (Mount Scott local faunas), seem to indicate a trend toward a decrease in the proportion of riblet-bearing to non-riblet-bearing individuals. This trend appears to be reversed in the younger Cragin Quarry local fauna, in which most of the shells possess well developed riblet sculpture. The younger Jinglebob and Jones local faunas contain shells that are predominantly without riblets. In most of the Recent lots examined the sculpture consists almost entirely of growth lines, with only an occasional individual possessing riblets in the later whorls. However, at least 5 lots of Recent shells examined in the University of Michigan Museum of Zoology collections (UMMZ 47019; 36844; 179041; 179040; 179038) contain individuals in which all or most possess well developed axial riblets in the adults.

The distribution of riblet and non-riblet-bearing shells through time seems susceptible of several possible interpretations:

(1) The 2 types of sculpture may represent distinct sympatric species which have existed together since at least the Pliocene Saw Rock Canyon fauna. The fluctuating proportions of riblet to non-riblet-bearing individuals in the different faunas may be due to sampling error and/or selective environmental pressures.

(2) There may be 2 species involved, with *P. kansasensis* evolving into *P. exacuous* sometime in the late Illinoian, between the time represented by the Butler Spring and Mount Scott faunas. The coarse riblet shells in the Cragin Quarry local fauna might be a phenotypic response to the effects of increasing aridity, a condition suggested by some of the other faunal elements (Hibbard & Taylor, 1960).

(3) The 2 types of sculpture may represent the extremes of variation within one very variable species, with the changes in the proportions of riblet to non-riblet-bearing individuals a function

of selection pressures by different environmental conditions.

The first of these explanations is rejected on the grounds that there appear to be no conchologic characteristics that can be used to separate individuals of these 2 species if they occur together in the same fauna. Hibbard & Taylor (1960: 106) in a discussion of the variability of *P. kansasensis* state that "Axial riblets, the most conspicuous element of sculpture, vary from strong and widely spaced ... through weaker and closely spaced ... to a point at which the sculpture may be said to consist of growth lines rather than riblets ...." At this point the sculpture is indistinguishable from *P. exacuous*.

The proportion of riblet to non-riblet-bearing individuals in a population cannot be used to separate these 2 forms since they show no consistent tendency with respect to these ratios through time. Thus, while the Mount Scott population is composed primarily of the non-riblet-bearing form, the younger Cragin Quarry local fauna, which is located approximately 50 ft higher up the slope of the same hill, contains shells in which individuals with riblets predominate. In the still younger Jinglebob and Jones local faunas the non-riblet-bearing form is dominant.

There is the possibility that the shells possessing strong riblet sculpture in the Cragin Quarry local fauna might be the result of increased aridity, with a concomitant rise in the concentrations of alkaline salts. This explanation receives some support from the xeric character of the lizard fauna and the 2 mammals, *Notiosorex crawfordi* and *Dasypterus golliheri* (Hibbard & Taylor, 1960). However, the absence of riblets in the associated aquatic mollusks would seem to argue against this interpretation.

At the present time there appears to be no satisfactory way of separating the predominantly riblet and non-riblet-bearing populations. More faunas must be studied before it can be determined whether the observed variations in the populations of *P. kansasensis-P. exacuous* complex are the result of environmental or genetic differences. It seems best at this stage to recognize the 2 types of populations, i.e., those composed predominantly of shells bearing riblets, and those in which the non-riblet-bearing shells are in the majority, with the names *Promenetus exacuous* form *kansasensis* and *P. exacuous* form *exacuous*, respectively.

Promenetus exacuous form *kansasensis* (Baker)

Geologic Range. Late Pliocene (Rexroad Formation) to Late Pleistocene (Kingsdown Formation). The oldest record of this form in the Meade County area is from the Saw Rock Canyon local fauna (Hibbard & Taylor, 1960).

Distribution. Pliocene in southern Idaho, northern Texas and southwestern Kansas; early Pleistocene in the Great Plains, from Iowa to Texas; late Pleistocene southwestern Kansas, northwestern Oklahoma (Hibbard & Taylor, 1960).

Ecology. *P. e.* form *kansasensis* is assumed to have had habitat requirements similar to those of the form *exacuous*.

Material. Berends local fauna, 208808 (469). Doby Springs local fauna, locality 1, 213715 (257); locality 4, 208911 (850); locality 5, 213761 (350).

Promenetus umbilicatellus (Cockerell)

Geologic Range. Late Pliocene (Rexroad Formation, Saw Rock Canyon local fauna) to Recent (Hibbard & Taylor, 1960).

Distribution. North America north of about the 41st parallel from western New York, northwest to Alaska, south to Washington and Oregon; in Rocky Mountains south to Colorado; sporadic in eastern Kansas and Oklahoma (Hibbard & Taylor, 1960).

Ecology. This species is an inhabitant of temporary bodies of water, where it frequently is found associated with *Stagnicola caperata*, *S. palustris* and

Aplexa hypnorum (Hibbard & Taylor, 1960).

Material. Doby Springs local fauna, locality 1, 213715 (1); locality 2, 185791 (1); locality 5, 213762 (3). Mount Scott local fauna, locality UM-K2-59, 213666 (5200). Locality UM-K2-60, 214187 (2).

Family Ancylidae

Ferrissia fragilis (Tryon)

Ferrissia meekiana (Stimpson), Hibbard & Taylor, 1960: 113; Miller, 1961: 108
Ferrissia fragilis (Tryon), Basch, 1963: 435

Geologic Range. Late Pliocene (Rexroad Formation) to Recent. In the southern Plains it is first known from the Bender local fauna, locality UM-K1-59, UMMZ 208848.

Distribution. "*Ferrissia fragilis* appears to be among the most widely distributed of North America freshwater snails" (Basch, 1963: 436). It probably occurs in suitable habitats throughout the United States. It has been recorded from Alabama, North Carolina, Missouri, Virginia, District of Columbia, Texas, California, Oregon, Washington, Nebraska, Kansas, Oklahoma and from Iowa eastward to Massachusetts (Hibbard & Taylor, 1960; Basch, 1963; Branson & Peters, 1964).

Ecology. "These snails often may be found on the bottom inch of stems of *Typha* and other rooted flowering plants growing in ditches and swamps .... The water in which they live is often dark and foul-smelling, and the habitats usually have a mud bottom. One often finds leeches, sphaeriid clams, and small planorbid snails such as *Gyraulus* and *Menetus* associated with these limpets .... Septate forms are known from 2 principal types of habitat, temporary woods pools such as those found in the northern states, and roadside ditches from which water presumably disappears for part of the year" (Basch, 1963: 436-437).

Material. Doby Springs local fauna, locality 4, 208915 (6); locality 5, 213784 (2). Mount Scott local fauna, locality UM-K4-53, 200607 (4); locality UM-K1-60, 213803 (7); locality UM-K2-59, 213698 (7).

Remarks. Basch (1963) in a recent review of the North American freshwater limpets found that the significant characteristics of *Ferrissia meekiana* overlap those of *F. fragilis* in such a manner as to make equivocal their specific distinction, and placed *F. meekiana* in the synonymy of *F. fragilis*. Many of the collections of *F. fragilis* examined by Basch contained both septate and nonseptate individuals. Specimens with septa, however, were found to be indistinguishable from those in which there was no septum formation, and he conconcluded "that there is no reasonable basis for placing the North American septate forms in a separate genus (*Gundlachia*)" (Basch, 1963: 438).

In this report the writer follows the specific dispositions of the freshwater limpets proposed by Basch.

Laevapex fuscus (Adams)
Plate III, Fig. 4

Laevapex kirklandi (Walker), Hibbard & Taylor, 1960: 114
Laevapex fuscus (C. B. Adams), Basch, 1963: 419-420, Fig. 7

Geologic Range. Late Pleistocene (Illinoian) to Recent. The earliest record is from the Doby Springs local fauna, in the Meade County area.

Distribution. "United States and Canada, generally east of the Great Plains. Great Lakes area, Florida and southeastern states. Generally absent from mountainous areas" (Basch, 1963: 420).

Ecology. "Commonly in impoundments or cut-off stagnant backwaters of rivers. The species is also found in lakes and occasionally in slow-flowing rivers on dense vegetation near the shores ... *L. fuscus* is often found on the under sides of lily pads, on cat-tails, sedges, and other emergent rooted vegetation." (Basch, 1963: 420).

Material. Doby Springs local fauna, locality 4, 208916 (27), 213825 (8). Mount Scott local fauna, locality UM-K4-53, 200623 (17); locality UM-K1-60, 213804

(75), 213805 (68); locality UM-K2-59, 213703 (6); locality UM-K3-60, 214174 (5). Recent, Harper County, Oklahoma.

Remarks. Basch (1963) found sufficient overlap in the characters of *L. fuscus* and *L. kirklandi* which led him to believe that they are conspecific. The classification proposed by Basch is followed herein, and *L. kirklandi* is placed in the synonymy of *L. fuscus*.

Family Physidae

Physa anatina Lea

Geologic Range. Late Pliocene (Rexroad Formation, Saw Rock Canyon local fauna) to Recent (Hibbard & Taylor, 1960).

Distribution. Some of the problems which have resulted in the confused taxonomic state of the genus *Physa* have recently been summarized by Branson (1961). Until such time as the entire family is revised, the geographic distribution, ecology, life history and fossil record of members of this group will remain unclear.

Ecology. "*Physa anatina* is an inhabitant of quiet and stagnant water; it thrives in small ponds, or even in metal stock tanks" (Leonard, 1950: 21). In Meade County, Kansas, and Harper County, Oklahoma, this snail has been collected in small spring fed streams.

Material. Berends local fauna, 208816 (58). Doby Springs local fauna, locality 1, 213723 (20); locality 4, 208912 (300). Mount Scott local fauna, locality UM-K4-53, 200625 (320); locality UM-K1-60, 213800 (125); locality UM-K2-59, 213670 (170).

Physa gyrina Say, form *hildrethiana* Lea

Geologic Range. Middle Pleistocene (Kansan, Cudahy fauna) to Recent.

Distribution. Probably found throughout most of North America north of Mexico. Baker (1928a: 454) states "*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." It has been found living in a stock tank on the Big Springs Ranch, Meade County, Kansas.

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 form being 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 the cracks in the pool where the mollusk has descended for moisture. Large specimens may have as many as four rest marks on the shell. In some sloughs the water may become very low in summer but does not completely disappear. In such localities *hildrethiana* attains its finest development ...." (Baker, 1928a: 454).

Material. Berends local fauna, 208817 (97). Doby Springs local fauna, locality 4, 208913 (300). Mount Scott local fauna, locality UM-K4-53, 200626 (270); locality UM-K1-60, 213801 (45); locality UM-K2-59, 213669 (135).

Remarks. Branson (1961) reports that *Physa gyrina* occurs in all the counties of Oklahoma. The Big Springs Ranch record is the first reported occurrence of this species from Meade County, Kansas.

Physa skinneri Taylor

Physa elliptica minor Crandall, 1901, Nautilus, 15: 55 (*non Physa fontinalis minor* Moquin-Tandon, 1855: 451, 452)

Physa skinneri Taylor, 1954. Taylor & Hibbard, 1955; Hibbard & Taylor 1960; Taylor, 1960; Miller, 1961

Geologic Range. Lower Pleistocene (Nebraskan) to Recent. Earliest record from the southern Great Plains is from the Nebraskan Dixon local fauna (UMMZ 182208, 191518) (Hibbard & Taylor, 1960).

Distribution. From Alaska southward to northern Utah; eastward through South Dakota, Iowa, Michigan to southeastern Ontario. The following is a list of additional Recent localities, which supplements the one published in Hib-

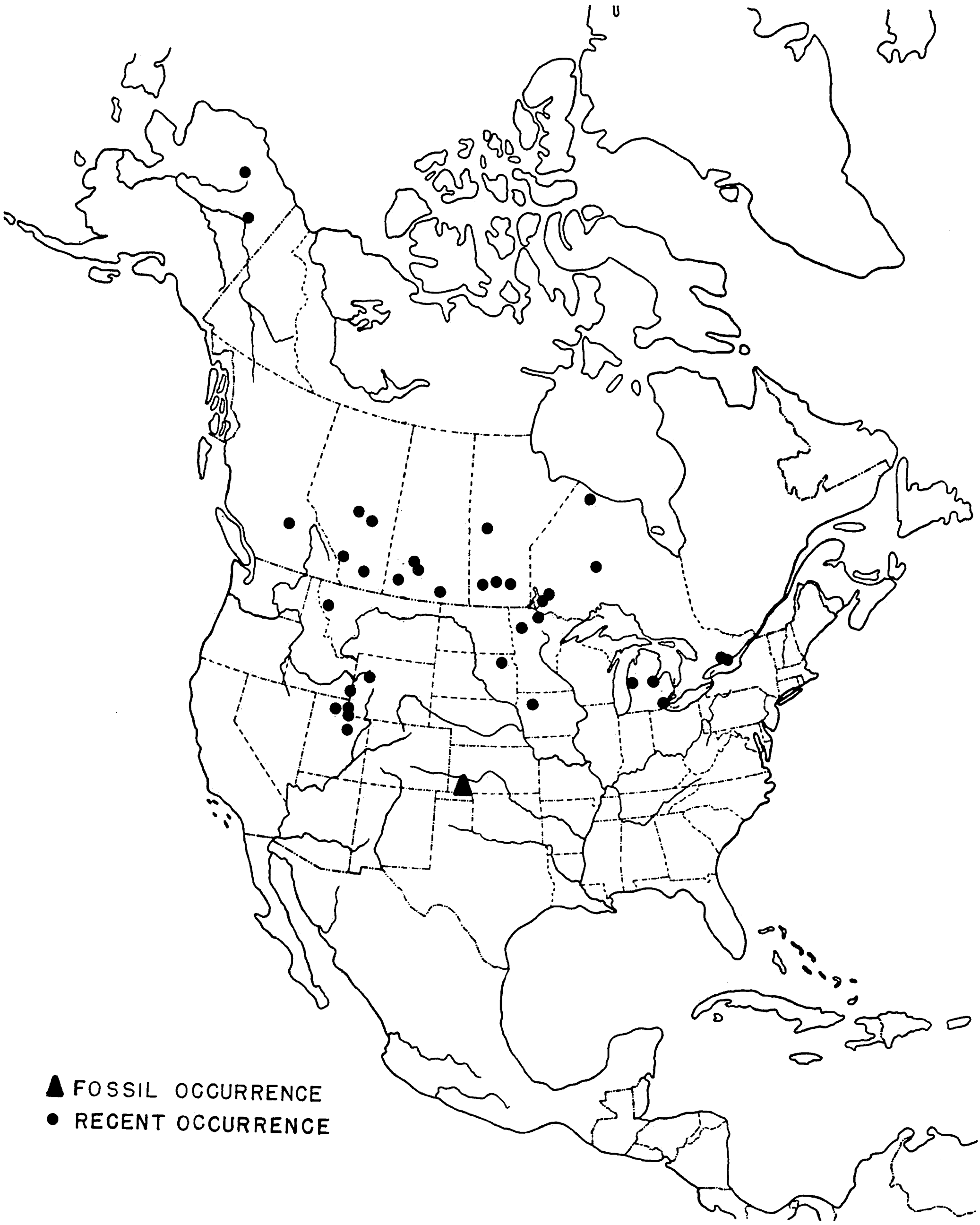

FIG. 6. Distribution of *Physa skinneri*.

bard & Taylor (1960: 119-120). The distribution map (Fig. 6) is based on all known Recent occurrences of this species.

British Columbia: Stoney Creek, near Vanderhoof (USNM 601340).

Alberta: Beaver Hills Lake, Tofield (USNM 471229). Taber (UMMZ 214557, 214558). Hays (UMMZ 214554, 214555). Rolling Hills (UMMZ 214556). Shore, Hastings Lake, 30 miles east of Edmonton (UMMZ 214159).

Manitoba: Pothole 9, near Minnedosa (UMMZ uncat.). Pike Lake, The Pass (UMMZ 214154).

Ontario: Cochrane District; Smoky Falls, Kapuskasing (UMMZ 214157). Hastings Co.; Bay of Quinte, 3 miles east of Belleville (UMMZ 214158); Pond 2 miles south of Thomasburg, Hungerford Township (UMMZ 214155, 214156).

Wyoming: Teton County (Beetle, 1962: 74).

Iowa, Palo Alto County: Elbow Lake, Ruthven (UMMZ 157548); Trumbell Lake (UMMZ 157549); Lost Island Lake (UMMZ 157547).

South Dakota: Roberts County, Big Stone Lake (UMMZ 157551).

Michigan: Wayne County, Grosse Isle (UMMZ 28800). Kent County, Grand Rapids (UMMZ 118096, 118095). Bay County, Saginaw Bay, Union Beach (UMMZ 28795).

Ecology. The Recent records of this species suggest that it lives in shallow bodies of water, either perennial or temporary, ponds, sloughs or backwaters along streams. The presence of *P. skinneri* in the Bay of Quinte on Lake Ontario, may indicate a new type of habitat not previously recorded, but there is no detailed information on the label to indicate the local environmental conditions. "In Lincoln County, Wyoming, Taylor collected it from a shallow perennial pond on the floodplain of the Bear River. This pond contained a rich growth of submergent aquatic plants growing in a soft organic mud bottom, marginal cattails, and many mollusks. *Valvata*, *Lymnaea*, *Promenetus* and *Physa* were common" (Hibbard & Taylor, 1960: 120-121). The collections made from Hays, Alberta, contain *Physa skinneri* associated with *Stagnicola caperata*, *Physa gyrina*, *Gyraulus parvus*, *Helisoma trivolvis* and *Promenetus umbilicatellus*.

Material. Berends local fauna, 208817 (97). Doby Springs local fauna locality 1, 213722 (1); locality 4, 208914 (21). Mount Scott local fauna, locality UM-K4-53, 200627 (3); locality UM-K2-59, 213671 (40).

Remarks. There is every reason to believe that the lot catalogued under UMMZ 118095 are the specimens on which Crandall based *Physa elliptica minor*. Enclosed with the shells is a note stating "These little shells were sent to me by Streng from Grand Rapids." This agrees with the statement made by Crandall (1901: 55) "*Physa elliptica minor* n.v. was sent to me from Grand Rapids, Mich., by Mr. Streng." This material is part of the Crandall collection acquired by Bryant Walker.

The measurements in millimeters of 11 individuals from this lot (UMMZ 118095) are given below:

Height mm	Width mm	Height of Aperture mm	Number of Whorls
3.5	2.75	2.5	3.25
3.5	2.25	2.5	2.75
3.6	2.3	2.5	2.75
3.6	2.25	2.3	2.5
3.75	2.3	2.55	2.5
3.12	2.0	2.3	2.25
2.66	1.87	1.75	2.25
3.0	2.25	2.6	2.25
3.12	2.12	2.5	2.25
3.5	2.12	2.6	2.25
3.5	2.25	2.5	2.5

Examination of this series of syntypes of *P. e. minor* and the types of *P. skinneri*, indicates that the latter is a junior synonym of the former. The name combination *Physa minor*, however, is preoccupied by a European species, *Physa fontinalis minor* Moquin-Tandon, 1855.

The first available name for this species is *Physa skinneri* Taylor.

Aplexa hypnorum (Linnaeus)

Geologic Range. Early Pleistocene (Ballard Formation) to Recent. The oldest record of this species in the Meade County area is from the Sanders local fauna, Meade County, Kansas (Hibbard & Taylor, 1960).

Distribution. Circumpolar: in North America it occurs from the Cascade Mountains east to the Atlantic and from Alaska and Hudson Bay south to Nevada, Colorado, the Platte River; the Ohio River and the District of Columbia.

Ecology. According to Baker (1928a: 474) *Aplexa hypnorum* is a species of swales and intermittent streams or stagnant pools in Wisconsin. It is reported as especially abundant in woodland pools which become dry in summer, in company with *Stagnicola caperata*, *Physa hildrethiana* and *Sphaerium occidentale*.

Material. Berends local fauna, 208831 (25). Doby Springs local fauna locality 4, 208943 (4); locality 5, 213783 (1). Mount Scott local fauna, locality UM-K4-53, 200601 (142); locality UM-K2-59, 213672 (500).

Order Stylommatophora
Superfamily Cionelloidea
Family Cionellidae

Cionella lubrica (Müller)
Plate I, Fig. 8

Geologic Range. Late Pliocene (Rexroad Formation, Rexroad local fauna) to Recent (Taylor, 1960: 77).

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: 1048).

Ecology. "*C. lubrica* lives among the damp under-leaves in densely shaded places; under wood, such as old board sidewalks; in chinks of stone walls and under stones" (Pilsbry, 1948: 1049).

Material. Doby Springs local fauna, locality 4, 208944 (1); locality 5, 213781 (1). Mount Scott local fauna, locality UM-K3-60, 214171 (1).

Superfamily Pupilloidea
Family Strobilopsidae

Strobilops labyrinthica (Say)
Plate III, Figs. 8-10

Geologic Range. Late Pliocene (Rexroad Formation, Saw Rock Canyon local fauna) to Recent (Hibbard & Taylor, 1960).

Distribution. Eastern North America, from Quebec to northern Alabama, westward to Manitoba, Black Hills, South Dakota, eastern Kansas and Oklahoma.

Ecology. "This snail inhabits forested areas, and is found in and among the leaf litter, decaying logs, and beneath started bark and other debris of the forest floor" (Leonard, 1959: 167).

Material. Berends local fauna, 208799 (1). Doby Springs local fauna, locality 1, 213741 (4); locality 4, 208917 (4). Mount Scott local fauna, locality UM-K4-53, 200640 (338); locality UM-K1-60, 213806 (90); locality UM-K2-59, 213673 (55).

Remarks. Branson (1961), in one of his series of papers summarizing the Recent gastropod fauna of Oklahoma, listed the occurrence of *Strobilops labrinthica* in that state without distinguishing between Recent and fossil material. The Recent records of *S. texasiana* (which he considers a synonym of *S. labyrinthica*) cited from Harper County, may be based on fossil shells.

Family Pupillidae

Gastrocopta armifera (Say)

Geologic Range. Early Pliocene (Laverne Formation, Laverne local fauna) to Recent (Hibbard & Taylor, 1960).

Distribution. Eastern North America from the Maritime Provinces in Canada, south to northern Florida; west to Rocky Mountains.

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 & Leonard, 1947: 329). I have collected this species in large numbers in tall grass, under boards and beneath dead wood in cottonwood groves, in Meade County State Park. At drier stations it was often associated with *Gastrocopta cristata* and *Pupoides albilabris*.

Material. Berends local fauna, 208824 (29). Doby Springs local fauna, locality 1, 213717 (3); locality 2, 185783 (1); locality 4, 208918 (27); locality 5, 213766 (97). Mount Scott local fauna, locality UM-K4-53, 200610 (1500); locality UM-K1-60, 213807 (50); locality UM-K2-59, 213678 (1150); locality UM-K3-60, 214178 (17). Locality UM-K2-60, 214189 (87). Recent, Harper and Beaver counties, Oklahoma.

Gastrocopta tappaniana (Adams)

Geologic Range. Late Pliocene (Rexroad Formation, Saw Rock Canyon local fauna) to Recent (Hibbard & Taylor, 1960).

Distribution. "Ontario and Maine to Virginia and Alabama, west to South Dakota and Kansas, southwest to Arizona, but not known from the south eastern Atlantic States, Virginia to Florida" (Pilsbry, 1948: 889).

Ecology. "This snail is found beneath wood, logs and similar debris in moist places, especially on floodplains and in moist upland forested areas" (Leonard, 1959: 177).

Material. Berends local fauna, 208802 (696). Doby Springs local fauna, locality 1, 213728 (64); locality 2, 185794 (6); locality 4, 208922 (800); locality 5, 213765 (560). Mount Scott local fauna, locality UM-K4-53, 200615 (2100); locality UM-K1-60, 213812 (96); locality UM-K2-59, 213674 (2500). Locality UM-K2-60, 214188 (1). Recent, Beaver and Harper counties, Oklahoma.

Gastrocopta procera (Gould)

Geologic Range. Middle Pleistocene (Kansan, Cudahy fauna) to Recent.

Distribution. Maryland to South Carolina and Alabama; west to Black Hills, South Dakota, southeastern Wyoming, and Arizona (Hibbard & Taylor, 1960; Reigle, 1963).

Ecology. "*Gastrocopta procera* is typically an inhabitant of timbered slopes near streams, where it lives in leaf mold, beneath fallen logs or loosened bark, or beneath stones, but sometimes it is found living in meadows in dead grass" (Leonard, 1950: 32). Its distribution in Kansas is indicative of its ability to withstand periods of high temperature and drought (Leonard & Goble, 1952).

Material. Berends local fauna, 208825 (5). Doby Springs local fauna, locality 2, 195796 (1); locality 4, 208921 (110); locality 5, 213764 (15). Mount Scott local fauna, locality UM-K4-53, 200615 (2100); locality UM-K1-60, 213871 (19); locality UM-K2-59, 213680 (83); locality UM-K3-60, 214175 (7). Recent, Beaver and Harper counties, Oklahoma.

Gastrocopta cristata (Pilsbry & Vanatta)

Geologic Range. Late Pliocene (Rexroad Formation, Bender local fauna) to Recent (Hibbard & Taylor, 1960).

Distribution. Arizona and New Mexico, east to Arkansas and Louisiana; north to Nebraska, Indiana.

Ecology. This snail can be found in timbered areas, both upland and floodplain situations, as well as in grasslands (Leonard, 1943). In Meade County State Park, I have collected it in large numbers from under pieces of scrap wood lying in a dry upland meadow. At this locality it was frequently an associate of *Pupoides albilabris*. Both of these species are apparently xerophilic.

Material. Berends local fauna, 208826 (67). Doby Springs local fauna, locality 1, 213731 (1); locality 4, 219920 (350); locality 5, 213767 (8). Mount Scott local fauna, locality UM-K4-53, 200612 (710); locality UM-K1-60, 213809 (88); locality UM-K2-59, 213677 (850); locality UM-K3-60, 214180 (2). Recent, Beaver and Harper counties, Oklahoma.

Gastrocopta pellucida hordeacella (Pilsbry)

Geologic Range. Late Pliocene (Rexroad Formation, Rexroad local fauna) to Recent (Hibbard & Taylor, 1960).

Distribution. "Southern and Baja, California (locally) through southeastern Colorado and Kansas to Florida; south to Sinaloa and Tampico, Mexico; northward on the Atlantic Coastal Plain to southern New Jersey" (Hibbard & Taylor, 1960: 123-124). "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: 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, perhaps sometimes even on exposed slopes. So far as known, the snail has not been collected alive in the Plains" (Hibbard & Taylor, 1960: 124).

Material. Mount Scott local fauna, locality UM-K2-59, 213675 (2). Recent, Harper County, Oklahoma.

Gastrocopta contracta (Say)

Geologic Range. Early Pliocene (Laverne Formation, Laverne local Fauna) to Recent (Hibbard & Taylor, 1960).

Distribution. Eastern North America from Maine, westward to Manitoba, South Dakota, central Kansas, Oklahoma and western Texas, south to the states of Morelos and Vera Cruz, in Mexico. The typical form is replaced by a different subspecies along the Gulf Coastal Plain (Hibbard & Taylor, 1960).

Ecology. "On shaded slopes along the water courses, under dead wood, leaf mold and grass" (Franzen & Leonard, 1947: 331).

Material. Doby Springs local fauna, locality 4, 208919 (1). Mount Scott local fauna, locality UM-K4-53, 200611 (830); locality UM-K1-60, 213808 (118); locality UM-K2-59, 213676 (735).

Gastrocopta holzingeri (Sterki)

Geologic Range. Late Pliocene (Rexroad Formation, Saw Rock Canyon local fauna) to Recent (Hibbard & Taylor, 1960).

Distribution. "Ontario and western New York to Helena, Montana, south to Illinois, Kansas, and Albuquerque and Mesilla, New Mexico" (Pilsbry, 1948: 883).

Ecology. "*Gastrocopta holzingeri* is found on timbered slopes under leaf mold .... 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 that obtain in the summer time. *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 & Leonard, 1947: 334-335).

Material. Berends local fauna, 208809 (29). Doby Springs local fauna, locality 4, 208940 (1); locality 5, 213749 (1). Mount Scott local fauna, locality UM-K4-53, 200613 (980); locality UM-K1-60, 213810 (1); locality UM-K2-59, 213679 (180); locality UM-K3-60, 214169 (1).

Vertigo ovata (Say)

Geologic Range. Early Pliocene (Laverne Formation, Laverne local fauna) to Recent.

Distribution. Labrador south to the West Indies, west to Mexico, Arizona, Utah, Oregon and Alaska.

Ecology. "*Vertigo ovata* ... lives only in moist environs afforded by shaded slopes near streams and shores of ponds. Its range in Kansas extends westward to the generally dry regions of the High Plains. In these regions are local ponds and streams, many of which are fed by the artesian springs, along whose shaded slopes *V. ovata* is found, though not in great numbers" (Franzen & Leonard, 1947: 355).

Material. Berends local fauna, 208803 (1070). Doby Springs local fauna, locality 1, 213718 (438); locality 2, 185795 (7); locality 4, 208925 (166); locality 5, 213768 (300). Mount Scott local fauna, locality UM-K4-53, 200654 (1280); locality UM-K1-60, 213814 (85); locality UM-K2-59, 213682 (5500); locality UM-K3-60, 214176 (2). Recent, Beaver and Harper counties, Oklahoma.

Vertigo milium (Gould)

Geologic Range. Late Pliocene (Rexroad Formation, Saw Rock Canyon local fauna) to Recent (Hibbard & Taylor, 1960).

Distribution. "Maine and Quebec to the Florida Keys, west to South Dakota, Grand County, Colorado, and southeastern Arizona; Tampico, Mexico; Jamaica; Santo Domingo" (Pilsbry, 1948: 945).

Ecology. "Found in numbers under sticks, stones and leaves in moist situations along flood-plains and wooded stream borders" (Leonard, 1959: 185). It has been collected from beneath pieces of moss covered wood, in a seepage area at Doby Springs Park, Harper County, Oklahoma.

Material. Berends local fauna, 208820 (21). Doby Springs local fauna, locality 4, 208924 (92); locality 5, 213769 (255). Mount Scott local fauna, locality UM-K4-53, 200653 (245); locality UM-K1-60, 213820 (2); locality UM-K2-59, 213681 (350). Recent, Harper County, Oklahoma.

Vertigo elatior Sterki
Plate I, Fig. 11

Vertigo elatior, Pilsbry, 1948: 956, Figs, 514; 515, number 6
Vertigo elatior, Franzen & Leonard, 1947: 357, Pl. XX, Fig. 2
Vertigo gouldi, Hibbard & Taylor, 1960: 134-135, Pl. XI, Fig. 10 (*non* Binney)

Geologic Range. Middle Pleistocene (Kansan) to Recent. The earliest records from the Meade County area are from the Cudahy fauna, Sunbrite Ash Pit, UMMZ 177255a, and the Cudahy Mine UMMZ uncatalogued.

Distribution. The distribution map (Fig. 7) is based on material examined in the collections of the University of Michigan Museum of Zoology, the U.S. National Museum, and published records. The following is a list of peripheral localities:

British Columbia: Field; Pilsbry, 1948: 956

Alberta: Laggan; Pilsbry, 1948: 956.

Manitoba: Ilford (UMMZ 180135).

Montana: Darby and White's Spring (West of Ward); Vanatta, 1914: 370).

Wyoming: Teton County, Moran Junction; Beetle, 1962: 74.

Colorado: Lake George, Henderson, 1924: 136.

New Mexico: Socorro County, Oscoro Mountains; Pilsbry, 1948: 956.

Ontario: Moose Factory (UMMZ 55957); Cochrane District, Smokey Falls (UMMZ 180148); Patricia District, Borthwick Lake, (UMMZ 180150).

Quebec: Hull County, Hull, Fairy Lake (UMMZ 180136).

Newfoundland: Boone Bay, Brooks & Brooks, 1940: 72.

Maine: Aroostook County, Caribou (USNM 160160).

New York: Staten Island (USNM 47497a).

West Virginia: Jefferson County; Brooks & Kutchka, 1938: 77; Preston County, Camp Dawson (USNM 533530).

Virginia: Montgomery County, Radfor (USNM 523439); Fredrick County, 1 mile east of Hayfield (USNM 533414).

Ohio: Summit County, Hudson (UMMZ 112178); Tuscarawas County, vicinity of New Philadelphia; Sterki, 1894: 5.

Indiana: Hendricks County, Danville (USNM 160140b).

Illinois: Winnebago County; Baker, 1939: 106.

Iowa: Cerrogordo County, Mason City, dredged in Big Slough (USNM

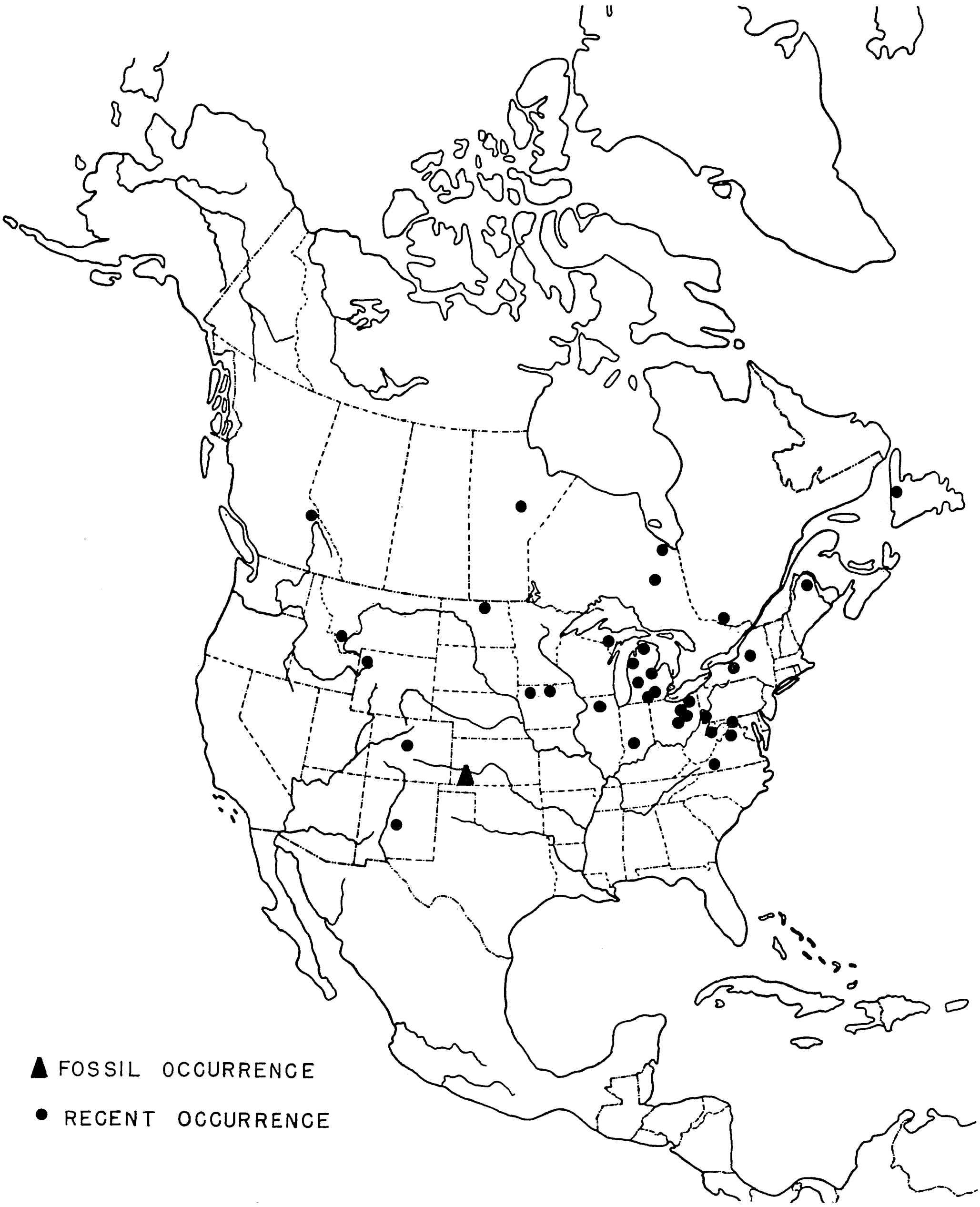

FIG. 7. Distribution of *Vertigo elatior*.

508637); West Lake Okoboji; drift on north shore of Millers Bay (USNM 476262).

North Dakota: Polette County, Upsilon Lake; Winslow, 1921: 9.

Ecology. "*Vertigo elatior* prefers a cool humid climate characteristic of northern United States or mountainous areas of southern states .... Prolonged drought and high temperatures, characteristic of Kansas' summers, are factors excluding *V. elatior* from Kansas today" (Franzen & Leonard, 1947: 357).

Material. Doby Springs local fauna, locality 1, 213730 (30); locality 4, 208938 (165); locality 5, 213770 (450). Butler Spring local fauna, 197569 (1).

Remarks. *Vertigo elatior*, as understood in this report, may be recognized by (1) its elongate-oval to conic-ovate shell; (2) a strongly biarcuate aperture, produced by a fold, which leaves an elongate groove on the exterior of the palatal wall about halfway from its adapical end; (3) the outer margin of the aperture, below this groove in the palatal wall, which is slightly reflected; (4) the base of the shell which tends to be constricted and appears pinched; (5) a crest, parallel to the outer margin of the aperture, which is usually present; (6) the number of lamellae and folds, characteristically 5 in number: one high, short angular lamella, located at the center of the parietal wall, which is directed downward and towards the outer margin of the aperture; 2 palatal folds, an upper, which merges outwardly toward the mouth of the aperture with the indentation in the palatal wall; and a more deeply immersed lower palatal fold; a low basal fold, located at the base of the collumelar wall; and a subvertical, collumelar fold, which ascends rapidly inwardly. The palatal and basal folds are usually situated on and joined by a callus.

The chief variations observed occur in the number and size of the palatal folds. A small, weak tubercle, in the position of the suprapalatal fold, may be developed in some individuals. The basal fold can occur as a single high tubercle, alone or in close proximity to an infrapalatal fold, that is also small, low and tuberculate; or as a high tubercle, with a closely associated infrapalatal tubercle. The palatal callus is also variable, and is completely lacking or poorly developed in some individuals.

Hibbard & Taylor (1960: 134) referred one shell (UMMZ 197569) from locality 1 of the Butler Spring local fauna to *Vertigo gouldi*. However, this specimen lacks the well developed axial sculpture characteristic of that species. It does, though, compare favorably with the large series of fossil *Vertigo elatior* from the Doby Springs local fauna, and with the lots of Recent *V. elatior* shells in the U. S. National Museum and University of Michigan Museum of Zoology collections.

The description and illustration of *V. gouldi* in Franzen & Leonard (1947: 358, Pl. II, fig. 3) suggests that their material is probably *V. elatior*. The presence of *V. elatior* in a collection of shells made in 1958, by a University of Michigan Museum of Paleontology field party from the same locality listed by Franzen & Leonard for *Vertigo gouldi* (Cudahy Mine, sec 2, T 31 S, R 28 W, Meade County, Kansas), tends to support this conclusion.

Pupoides albilabris (Adams)

Geologic Range. Early Pliocene (Laverne Formation, Laverne local fauna) to Recent (Hibbard & Taylor, 1960).

Distribution. "Eastern North America from southern Canada to the Gulf of Mexico, west to the Dakotas, Colorado, and Western Arizona; northern Mexico, Cuba, Haiti, Puerto Rico, Bermuda" (Leonard, 1959: 181).

Ecology. "This species, tolerant of high summer temperatures and drought, is found in woodlands, in deep grass, or even among the roots of short grass in unshaded areas" (Franzen & Leonard, 1947: 371). In Meade County, I have observed this species crawling about on a barren outcrop during a bright sunny day after a good rain. In this area, the animal must seek shelter in fractures and joints in the dried ground during the hotter part of the day, coming out only at night or after a rain.

Material. Berends local fauna, 208819 (11). Doby Springs local fauna, locality 4, 208923 (15); locality 5, 213771 (14). Mount Scott local fauna, locality UM-K4-53, 200637 (620); locality UM-K1-60, 213813 (36); locality UM-K2-59, 213685 (275), locality UM-K3-60, 214181 (13). Locality UM-K2-60, 214191 (1). Recent, Beaver and Harper counties, Oklahoma.

Pupilla blandi Morse

Geologic Range. Middle Pleistocene (Kansan, Cudahy fauna) to Recent.

Distribution. "Rocky Mountains, from New Mexico (at high elevations) to southern Alberta; northern Great Plains east to western North Dakota; Black Hills, South Dakota" (Hibbard & Taylor, 1960: 130). One lot in the U. S. National Museum collection (USNM 598457) from river drift of the Little Missouri River, Dunn County, North Dakota, contains many shells that still have the periostracum and indicate a more easterly occurrence than any reported by Taylor (Hibbard & Taylor, 1960: 131).

Ecology. "In the higher, forested parts of the Rocky Mountains *Pupilla blandi* is widespread. It occurs in forest, or in meadows and parks where cover and some moisture are available. Together with *Vallonia*, it may often be found in protected situations somewhat less damp than those required by snails such as *Vitrina*, *Vertigo* or *Discus*" (Hibbard & Taylor, 1960: 131).

Material. Doby Springs local fauna, locality 5, 213772 (21). Mount Scott local fauna, locality UM-K4-53, 200638 (1); locality UM-K2-59, 213683 (5). Locality UM-K2-60, 214185 (405).

Remarks. The large series of *Pupilla blandi* from locality UM-K2-60 is relatively consistent in the number and development of the denticles. The most variable characters in this series are the height and diameter, which range from 2.5-3.5mm and 1.60-1.75mm respectively.

Pupilla muscorum (Linnaeus)

Geologic Range. Middle Pleistocene (Kansan, Cudahy fauna) to Recent (Frye & Leonard, 1952: 158-159).

Distribution. Holarctic. In North America, from Newfoundland, "... Anticosti Island south to Atlantic City, New Jersey, westward in Canada and in the northern tier of states to Milton, Oregon; south in the Rocky Mountain region through Colorado to Socorro County, New Mexico, and northern Arizona; north to Anuk, Alaska" (Pilsbry, 1948: 934).

Ecology. "Lives in regions having a cool, humid climate. Is found living on the ground, under wood, stones, and leaves" (Franzen & Leonard, 1947: 376).

Material. Doby Springs local fauna, locality 1, 213727 (105); locality 4, 208939 (58); locality 5, 213773 (190).

Family Valloniidae

Vallonia gracilicosta Reinhardt

Geologic Range. Late Pliocene (Rexroad Formation, Rexroad local fauna) to Recent, (Hibbard & Taylor, 1960).

Distribution. Rocky Mountains from southern Arizona and New Mexico (at high elevations) northward to Alberta and Fort Norman, Northwest Territories; eastward to Manitoba, Nebraska, Minnesota and Iowa. The eastern limits of its distribution are uncertain because of the difficulty of distinguishing *V. gracilicosta* from *V. albula*, which extends further east.

Ecology. In northern Nebraska, on the Fort Niobrara Wildlife Refuge, I have collected *V. gracilicosta* from amongst moist leaf mold, bark and fallen timber in cottonwood groves.

Material. Berends local fauna, 208806 (7). Doby Springs local fauna, locality 1, 213725 (1650); locality 2, 185797 (12); locality 4, 208926 (620); locality 5, 213774 (1120). Mount Scott local fauna, locality UM-K4-53, 200650 (800); locality UM-K1-60, 213815 (20); locality

UM-K2-59, 213687 (110); locality UM-K3-60, 214166 (32). Locality UM-K2-60, 214193 (500).

Vallonia parvula Sterki

Geologic Range. Late Pliocene (Rexroad Formation, Bender local fauna) to Recent (Hibbard & Taylor, 1960).

Distribution. "Great Plains from South Dakota to north-central Oklahoma eastward to northern Missouri, northern Ohio, southern Ontario, and western New York" (Hibbard & Taylor, 1960: 138).

Ecology. "*Vallonia parvula* inhabits wooded areas in both upland and flood-plain situations. It has been found in and about logs, sticks, rocks and similar niches, and often buries itself in the ground to a depth of several times its diameter" (Leonard, 1959: 189). In Meade County, it has been collected from leaf litter, in a cottonwood grove near the west end of Lake Larrabee.

Material. Berends local fauna, 208800 (23). Doby Springs local fauna, locality 4, 208927 (4). Mount Scott local fauna, locality UM-K4-53, 200651 (561); locality UM-K1-60, 213816 (8); locality UM-K2-59, 213686 (145); locality UM-K3-60, 214168 (4). Recent, Harper County, Oklahoma.

Superfamily Succineoidea
Family Succineidae

Oxyloma sp.

Oxyloma naverrei Leonard, 1950: 23, Pl. 4, Fig. H. Frye & Leonard, 1952: 158, Pl. 15, Fig. ee

Oxyloma haydeni (Binney), Taylor, 1954: 5. Taylor & Hibbard, 1955: 8

Oxyloma retusa (Lea), Taylor, 1960: 78. Hibbard & Taylor, 1960: 141. Miller, 1961: 108

Material. Berends local fauna, 208810 (188). Doby Springs local fauna, locality 1, 213720 (8); locality 4, 208929 (12). Mount Scott local fauna, locality UM-K4-53, 200624, (143); locality UM-K2-59, 213697 (200).

Remarks. Recent studies of *Oxyloma retusa* and *O. haydeni* by Franzen (1963, 1964) have shown that it is not possible to separate these 2 species on shell characteristics. Fossil shells belonging to the genus *Oxyloma* may, therefore, have been incorrectly assigned to species in earlier reports (Leonard, 1950; Frye & Leonard, 1952; Taylor, 1954, 1960; Taylor & Hibbard, 1955; Hibbard & Taylor, 1960; Miller, 1961).

cf *Succinea*

Material. Berends local fauna, 208834 (6). Doby Springs local fauna, locality 1, 213719 (160); locality 2, 185793 (13); locality 4, 208928 (163); locality 5, 213780 (5). Mount Scott local fauna, locality UM-K4-53, 200641 (66); locality UM-K1-60, 213817 (9); locality UM-K2-59, 213693 (71); locality UM-K3-60, 214179 (1). Locality UM-K2-60, 214196 (150).

Remarks. Most succineids cannot be satisfactorily placed to genus or species, on the basis of shell characteristics (Miles, 1958; Taylor, 1960). In the present study, it has only been possible to identify shells belonging to the genus *Oxyloma* with reasonable confidence. All the remaining succineid material has been referred to cf *Succinea*.

Superfamily Endodontoidea
Family Endodontidae

Discus cronkhitei (Newcomb)

Geologic Range. Middle Pleistocene (Kansan, Cudahy fauna) to Recent (Frye & Leonard, 1952: 158-159).

Distribution. Alaska south to the mountains of southern California; south in Rocky Mountains to Colorado, Arizona and New Mexico; eastward across northern Canada from British Columbia to Labrador and Newfoundland. East of the Rocky Mountains the southern limits of its range are reached in south-central Nebraska, Missouri, Illinois, Indiana, Ohio, West Virginia, Kentucky, Maryland. A collection made from the flood-plain of the Republican River, in Red

Willow County, Nebraska, represents the southernmost record for this species in the High Plains.

Ecology. "In the east it lives in humid forest, under dead wood, and among rotting leaves or grass in rather wet situations. It is a common snail in the Canadian and Transition faunas, and occurs sporadically in the Carolinian" (Pilsbry, 1948: 604). In Red Willow County, Nebraska, it was found under sticks, logs and forest litter, on the flood plain of the Republican River, in association with *Zonitoides arboreus*, *Gastrocopta armifera*, *Deroceras laeve* and *Gastrocopta tappaniana*.

Material. Doby Springs local fauna, locality 1, 213724 (132); locality 2, 185776 (14); locality 4, 208930 (104). Mount Scott local fauna, locality UM-K4-53, 200605 (2); locality UM-K1-60, 213818 (10); locality UM-K2-59, 213691 (1); locality UM-K3-60, 214182 (1).

Helicodiscus parallelus (Say)

Geologic Range. Late Pliocene (Rexroad Formation, Bender local fauna) to Recent (Miller, 1964).

Distribution. "Eastern North America, from Newfoundland south to Georgia and Alabama; westward to South Dakota and Oklahoma" (Hibbard & Taylor, 1960: 144).

Ecology. "It lives on decaying wood in shady or humid places, also on damp leaves" (Pilsbry, 1948: 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 & Goble, 1952: 1039).

Material. Berends local fauna, 208812 (7). Doby Springs local fauna, locality 1, 213733 (45); locality 4, 208931 (1425); locality 5, 213776 (195). Mount Scott local fauna, locality UM-K4-53, 200620 (280); locality UM-K1-60, 213819 (20); locality UM-K2-59, 213692 (350); locality UM-K3-60, 214170 (52).

Helicodiscus singleyanus (Pilsbry)

Geologic Range. Late Pliocene (Rexroad Formation, Saw Rock Canyon local fauna) to Recent (Hibbard & Taylor, 1960).

Distribution. "United States from New Jersey and Florida west to South Dakota, southwest to Arizona" (Leonard, 1959: 133).

Ecology. This species has apparently never been taken alive in the High Plains (Hibbard & Taylor, 1960). The occurrence of fresh shells among the fossil bearing matrix that has been washed from various localities in the southwest Kansan-northwest Oklahoma area, seems to indicate that *Helicodiscus singleyanus* can survive the hot dry summers that characterize this region. The animal probably lives among the grass roots during the hot, dry part of the day, and seeks shelter in the fractures and cracks that have formed in the more exposed surfaces.

Material. Mount Scott local fauna, locality UM-K1-60, 213821 (2). Recent, Beaver and Harper Counties, Oklahoma.

Punctum minutissimum Lea
Plate II, Figs. 6-8

Geologic Range. Late Pleistocene (Illinoian) to Recent.

Distribution. Newfoundland south to Florida; west to southern Ontario, the Lake States, South Dakota, Colorado, New Mexico, Oregon and Mexico, (Pilsbry, 1948). The nearest Recent occurrence to the Meade County area is from Phillips County Kansas (Leonard, 1959). Taylor (1960) has collected *Punctum minutissimum* from Brown County, Nebraska.

Ecology. "This dwarf among pygmies lives on damp leaves, around decaying logs, and is chiefly obtained by sifting leaves ... Morse states that '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:

645).

Material. Mount Scott local fauna, locality UM-K4-53, 200636 (43).

Remarks. The only previously reported fossil occurrence of *P. minutissimum* in the southern Plains region, has been from the Sangamon, Jinglebob local fauna (van der Schalie, 1953). Its presence in the Mount Scott local fauna extends its known range to the Illinoian.

Superfamily Zonitoidea
Family Limacidae

Deroceras aenigma Leonard

Geologic Range. Late Pliocene (Rexroad Formation, Saw Rock Canyon local fauna) to Late Pleistocene (Sangamon, Cragin Quarry local fauna) (Hibbard & Taylor, 1960).

Ecology. Unknown. It probably had habitat requirements similar to those of living species of *Deroceras*.

Material. Berends local fauna, 208827 (24). Doby Springs local fauna, locality 1, 213710 (8); locality 4, 208932 (42), 213779 (51). Mount Scott local fauna, locality UM-K4-53, 200604 (200); locality UM-K1-60, 213822 (17); locality UM-K2-59, 213690 (250).

Remarks. Several lots contain specimens that are thinner and smaller than the typical *D. aenigma;* they may perhaps be *D. laeve*. At present, however, it is not possible to separate these 2 species when they occur together, for the smaller, thinner shells may represent either *D. laeve* or immature *D. aenigma* (see discussion in Taylor, 1954).

Family Zonitidae

Euconulus fulvus (Müller)

Geologic Range. Middle Pleistocene (Kansan, Cudahy fauna) to Recent. (Frye & Leonard, 1952: 158-159).

Distribution. "Almost throughout the Holarctic realm, but wanting in the Gulf and South Atlantic States from Texas to North Carolina" (Pilsbry, 1946: 236).

Ecology. "*E. fulvus* lives among leaves in well-shaded places, and may usually be obtained by leaf sifting where its presence would otherwise be unsuspected" (Pilsbry, 1946: 236). I have collected it in Washtenaw County, Michigan, from a marsh on the floodplain of the Huron River among high grass and scattered shrubs.

Material. Berends local fauna, 208815 (1). Doby Springs local fauna, locality 1, 213713 (10); locality 4, 208933 (23); locality 5, 213775 (37). Mount Scott local fauna, locality UM-K4-53, 200606 (84); locality UM-K1-60, 213823 (3); locality UM-K2-59, 213684 (6).

Nesovitrea electrina (Gould)

Geologic Range. Late Pliocene (Rexroad Formation, Rexroad local fauna) to Recent (Hibbard & Taylor, 1960).

Distribution. "North America north of about latitude 38°, southward in the Rocky Mountains to Arizona and New Mexico" (Hibbard & Taylor, 1960: 148).

Ecology. *Nesovitrea electrina* is primarily a wood snail, living among dead leaves, under bark and decaying logs. It is often found in association with *Zonitoides arboreus*, *Strobilops labyrinthica* and *Retinella indentata* (Leonard & Goble, 1952). Leonard (1950: 37) reports that *N. electrina* is a common snail in the forested areas of eastern Kansas, "where the annual rainfall is generally more than 35 in. but it declines in frequency of occurrence towards the more arid Plains Border Province and is unknown in the Plains Province even where timber is locally available." Although this species evidently prefers a woodland habitat, it has been collected from more open situations " in marsh grass; in ferns in meadows; ... in herbacious tall weeds, in grass and under burdocks in open fields ..." (Archer, 1939: 19).

Material. Doby Springs local fauna, locality 1, 213734 (15); locality 4, 208934 (5); locality 5, 213777 (31). Mount Scott local fauna, locality UM-K4-53, 200639 (107); locality UM-K2-59, 213689 (22).

Hawaiia minuscula (Binney)

Geologic Range. Late Pliocene (Rexroad Formation, Saw Rock Canyon local fauna) to Recent (Hibbard & Taylor, 1960).

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 Rocky Mountain States, and has not been seen from Washington, Oregon, Idaho, Nevada and Utah, and only towards the south in California, where some records are probably owing to importation with plants" (Pilsbry, 1946: 421-423).

Ecology. "*Hawaiia minuscula* is found under logs, sticks, stones and in clumps of grass in both floodplains and upland situations" (Leonard, 1959: 120). I have collected this species from sticks buried in moist leaf litter that filled a small gulley, in a stand of cottonwood trees, at the west end of Lake Larrabee, in Meade County State Park.

Material. Berends local fauna, 208822 (543). Doby Springs local fauna, locality 1, 213732 (25); locality 4, 208936 (1300); locality 5, 213778 (108). Mount Scott local fauna, locality UM-K4-53, 200619 (2300); locality UM-K1-60, 213824 (54); locality UM-K2-59, 213688 (650); locality UM-K3-60, 213172 (30). Locality UM-K2-60, 214184 (3). Recent, Harper County, Oklahoma.

Zonitoides arboreus (Say)

Geologic Range. Early Pliocene (Laverne Formation, Laverne local fauna) to Recent (Hibbard & Taylor, 1960).

Distribution. North America from northern Canada south to Banana River, Costa Rica (Pilsbry, 1946). Its northern limit is placed by Dall (1905) at 61^{o} north latitude.

Ecology. "In the eastern states and Mississippi valley this snail is everywhere abundant, to be found wherever there are trees or shelter of any kind; on or under the bark of logs, under boards, bricks or stones in the grass, or in any like situation offering protection from the sun and a reasonable degree of moisture. In the southern Alleghanies I have found it up to about 5800 feet, and in the Colorado Rockies it has been taken at 10,000 feet" (Pilsbry, 1946: 482).

Material. Doby Springs local fauna, locality 1, 213726 (25); locality 2, 185786 (2); locality 4, 208935 (146). Mount Scott local fauna, locality UM-K4-53, 200655 (150); locality UM-K1-60, 213796 (17); locality UM-K2-59, 213695 (131), 213699 (63); locality UM-K3-60, 214177 (7). Locality UM-K2-60, 214192 (1).

Zonitoides nitidus (Müller)
Plate III, Figs. 1,3

Geologic Range. Late Pleistocene (Illinoian, Mount Scott local fauna) to Recent.

Distribution. Holarctic. The accompanying distribution map (Fig. 8) is based on published records, and material examined in the University of Michigan Museum of Zoology (UMMZ), and the U. S. National Museum (USNM) collections.

The following is a list of peripheral occurrences along the southern margin of its distribution:

Newfoundland: Bonne Bay; Brooks & Brooks, 1940: 71.

Quebec: Anticosti Island; Pilsbry, 1948: 477.

Nova Scotia: Victoria County; MacMillan, 1953: 399.

Virginia: Orange County, Orange, UMMZ 115097.

Kentucky: Warren County, USNM 568444.

Tennessee: Knox County, Knoxville, USNM 38881.

Alabama: Jackson County, USNM 116596.

Iowa: Linn County, Cedar Rapids, USNM 507625; Dubuque County, Dubuque, USNM 507744; Bremer County, Waverly, USNM 507820; Cerro Gordo County,

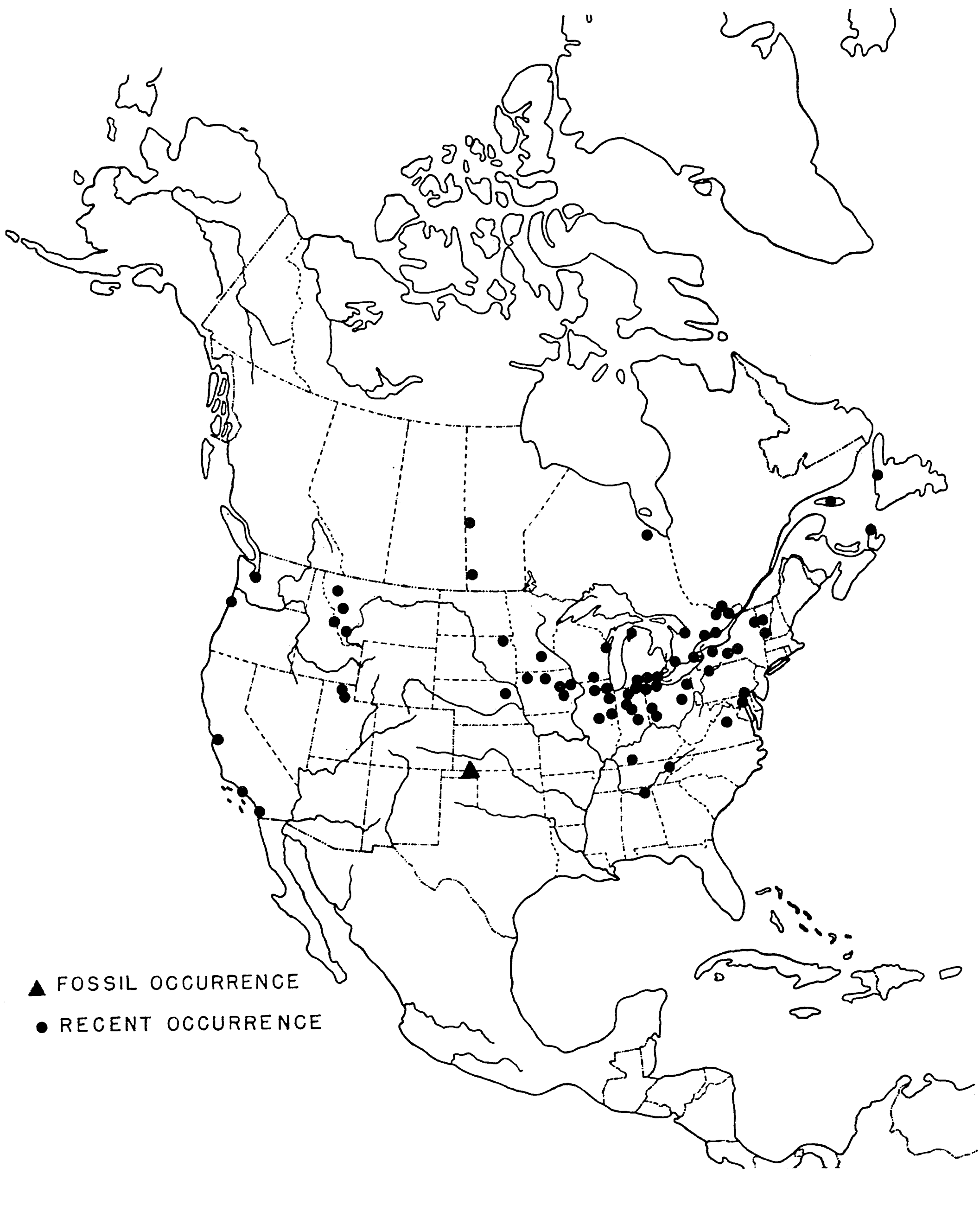

FIG. 8. Distribution of *Zonitoides nitidus*.

Clear Lake, USNM 507724; Dickinson County, West Lake Okoboji, USNM 525186.

Nebraska: Cuming County, Beemer, USNM 506141.

Utah: Morgan County, 3 miles east of Morgan, UMMZ 167030; Cache County, Logan, Blacksmith Fork of Bear River, UMMZ 167029.

Washington: King County, Seattle; Pilsbry, 1948: 477.

Oregon: Clatsop County, Astoria; Pilsbry, 1948: 477.

California: Alameda County, Berkeley; Los Angeles County, San Diego County, San Diego; all in Pilsbry, 1948: 477.

The few and scattered west coast records probably represent relatively recent introductions (Pilsbry, 1948).

Ecology. "In Illinois *Zonitoides nitidus* lives in decaying logs and under forest debris on floodplains of streams. It shows a preference for muddy places. Trees usually characteristic of its habitat are elm, maple or hickory" (Baker, 1939: 79). Goodrich (1932: 32) states that *Z. nitidus* "lives in fairly large colonies close to the water's edge of creeks, lakes and marshes."

Material. Mount Scott local fauna, locality UM-K4-53, 213789 (89); locality UM-K2-59, 213786 (13).

Remarks. *Z. nitidus* may be distinguished from *Z. arboreus* by the more rounded base of its aperture and body whorl; its greater diameter and height of shell for any given number of whorls; and the relatively greater width of its umbilicus in relation to the total shell diameter.

In North America, *Z. nitidus* is rare as a fossil. To my knowledge, one lot (U. S. Geological Survey Cenozoic locality 22414) from Weber County, Utah, represents the only other fossil occurrence of this species from west of the Mississippi River. The scarcity of this species as a fossil makes it highly probable that its occurrence at 2 localities in the Mount Scott local fauna were essentially contemporaneous.

Superfamily Polygyroidea
Family Polygyridae

Stenotrema leai (Binney)

Geologic Range. Middle Pleistocene (Kansan, Cudahy fauna) to Recent.

Distribution. New York south to Maryland, west to Kansas; Nebraska and South Dakota (Pilsbry, 1940: 678).

Ecology. *Stenotrema leai* prefers moist wooded areas. Baker (1939: 60) states that it is found "... in lowlands, usually on the floodplains of rivers and creeks or the margins of lakes, in woodlands of oak, hickory, elm and willow." Taylor (1960) has reported it from the floodplain of the Niobrara River in Cherry County, Nebraska, were it was collected from beneath scattered, moist, debris. I have collected it from a similar habitat on the floodplain of the Republican river, south of Franklin, Nebraska.

Material. Berends local fauna, 208804 (73). Doby Springs local fauna, locality 4, 213837 (1); locality 5, 213782 (1). Mount Scott local fauna, locality UM-K1-60, 213704 (2); locality UM-K2-59, 213694 (32).

Remarks. One lot of *S. leai* (s.s.) (UMMZ 206549) collected from the floodplain of the Republican River, south of Franklin, Nebraska, represents the closest confirmed record of this species to the Meade County area.

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RESUMEN

CINCO MALACOFAUNAS DE EDAD ILLINOIANA DE LAS GRANDES LLANURAS SUREÑAS

B. G. Miller

Se enumeran los moluscos de cinco conjuntos del Cenozoico superior (Illinoian) en el sudoeste de Kansas- noroeste de Oklahoma: la fauna local de Berends, de Beaver County, Oklahoma: la fauna local de Doby Springs, Harper Co., Oklahoma; y las faunas locales de Adams, Butler Springs y Mount Scott, de Meade Co., Kansas. Un sumario informativo sobre la distribución geológica, geográfica y ecológica se da para todos los moluscos de Mount Scott y Doby Springs, y para las especies previamente señaladas de los Berends, Adams y Butler Springs.

Cambios taxonómicos incluyen la asignación de *Promenetus exacuous* y *Promenetus kansasensis* a un único complejo específico. No existe manera satisfactoria para separar esas dos "especies" en poblaciones recientes y fósiles que contienen individuos con ambos tipos de ornamentación superficial, costulados y no costulados. El tipo costulado es designado *P. exacuous* form *kansasensis* y el liso *P. exacuous* forma *exacuous*.

En la interpretación de estos conjuntos se asume que los factores climaticos son los agentes primarios que controlan la distribución de los moluscos no-marinos; que ejemplares fósiles similares a los vivientes representan la misma especie y estuvieron sujetas a los mismos factores limitadores; y que los áreas de las Grandes Llanuras del presente, conteniendo asociaciones de moluscos más similares a aquellas de los conjuntos fósiles, simulan probablemente condiciones climaticas en que esas faunas vivieron. Reconstrucción de habitat local y condiciones climaticas de las mismas, has sido basadas sobre una síntesis de la información obtenida de los moluscos fósiles, polen y vertebrados, y en ningún caso estas interpretaciones basadas en moluscos han contradicho conclusiones alcanzadas independientemente por datos de otros fósiles.

Los cinco conjuntos Illinoianos muestran discrepancias de composición que se relacionan probablemente con los cambios climaticos durante aquella época. El número relativamente grande de especies con distribución predominante en el norte, junto con la poca representación de elementos faunisticos exclusivamente sureños, indican que la fauna local de Doby Springs representa el conjunto de clima más frío estudiado y probablemente vivió durante el máximo de la glaciación de Illinois. La fauna de Mount Scott contiene un número mayor de especies de distribución en el sur, sugiriendo que es la fauna de clima más cálido en esa época. No hay evidencia de que esas faunas locales vivieran durante más de una unidad de tiempo (substage). Asumiendo que la transición desde condiciones glaciales máximas, representada por la fauna local de Doby Springs, hacia condiciones interglaciales más calidas, representada por la fauna de Mount Scott, fue unidireccional, entonces las condiciones climaticas implicadas por los conjuntos de Adams y Butler Springs, deben haber ocurrido en algun momento entre el tiempo representado por las faunas de Doby Springs y Mount Scott. Las primeras y últimas apariciones de especies de moluscos, y las implicaciones climaticas de la fauna local de Berends, sugiere que este conjunto es probablemente el más antiguo de los cinco niveles del Illinoian.

El conjunto de Berends contiene 45 especies de moluscos, 15 de los cuales son nuevos para esta fauna local. *Sphaerium securis* representa el primer fósil de esta especie para las Llanuras del Sur. Esta fauna vivió en, y alrededor, de un pequeño y poco profundo lago, donde la vegetación marginal consistía probablemente de coníferas, gramíneas y compuestas, con sólo algunas manchas de árboles de hoja caduca. El clima en ese tiempo era probablemente similar al del presente en el norte de Nebraska y noroeste de Iowa de las Grandes Llanuras.

La fauna local de Doby Springs contiene 59 especies y una de ellas, *Vertigo elatior*, se registra por primera vez como fósil de las Llanuras. Los moluscos indican la existencia de un lago frío bordeado por pantanos con totora, juncos, coníferas y otros árboles dispersos, que engranaban con una zona de mejor desague conteniendo arbustos y árboles a distancia del lago. El clima local combinaba veranos más cortos y más fríos, con inviernos que eran generalmente más fríos y largos que los ocurren en las condiciones presentes de la región.

El conjunto de Adams contiene 22 especies, con *Lasmigona complanata* que se registra pro primera vez en el área. Las areniscas cruzadas de grano grueso y mediano, donde estos fósiles se obtuvieron, junto con la presencia de especies que requieren un habitat acuatico contínuo, indican un cuerpo de agua corriente. Una sola especie de molusco terrestre de habitat boscoso, señala que sólo existía una cubierta delgada de árboles y arbustos. El clima probablemente combinaba inviernos quizá no más severos que los actuales en noreste Nebraska, con veranos más húmedos y fríos, similar a aquellos de las Dakotas y oeste de Montana:

Hay 54 especies de moluscos en la fauna local de Butler Springs, y entre ellas *Ligumia* cf *recta* es nueva para las Grandes Llanuras del Sur. Esta fauna vivió en, o cerca, de un río de tamaño mediano, de corriente moderada y probablemente con varios piés de profundidad. Habia grupos esparcidos de árboles a lo largo del río, pero la vegetación predominante consistía de gramíneas y arbustos. El clima contaba con veranos más fríos, similares a los de hoy en el oeste de N. Dakota. Los inviernos eran probablemente no más severos que aquellos de los Nebraska norcentral.

La malacofauna de Mount Scott contiene 63 especies y es el conjunto más grande conocido para las Llanuras del Sur. Contiene el único fósil de *Zonitoides nitidus* en las Grandes Llanuras. Evidencia paleontológica y estratigráfica indica que hay representadas cinco asociones mayores. El clima de aquel tiempo probablemente combinaba veranos similares a los que ocurren en el Lago Okoboji del noroeste de Iowa, con inviernos no más severos que en el noreste de Kansas y sureste de Nebraska.

АБСТРАКТ

ПЯТЬ ФАУН МОЛЛЮСКОВ ИЛЛИНОЙССКОГО ВРЕМЕНИ ИЗ ЮЖНОЙ ЧАСТИ ВЕЛИКИХ РАВНИН

Б. Миллер

Описываются локальные фауны моллюсков из пяти комплексов Иллинойсского возраста из районов северо-западной Оклахомы-Берендс Бивер Каунти и Доби Спрингс, Харпер Каунти, а также из юго-западного Канзаса: Адамс, Ботлер Спринг и Маунт Скотт, Мид Каунти.

Для локальных фаун из Маунт Скотт и Доби Спрингс приводятся списки моллюсков. Описываются неопубликованные ранее данные по локальным фаунам моллюсков из Берендс, Ботлер Спринг и Адамса. Для каждого вида приводятся сводные данные: геологический возраст и общее распространение, экология, а также необходимые сведения по изменениям их систематики.

Интерпретация этих комплексов моллюсков основывается на том, что климатический фактор является главным моментом, контролирующим распространение не-морских моллюсков; что ископаемые раковины, сходные с ныне-живущими, представляют собой те же самые виды и подчиняются влиянию тех же лимитирующих факторов, и что районы Великих Равнин, содержащие в настоящее время ассоциации моллюсков, наиболее сходные с теми, которые

были найдены здесь в ископаемом состоянии, вероятно очень близки по климатическим условиям к тем, которые существовали здесь тогда, когда здесь жили эти ископаемые формы. Реконструкция локальных условий обитания и климатических показателей, при которых эти фауны существовали, были основаны на сводных данных по ископаемым моллюскам, пыльцевому анализу и по позвоночным животным. Ни в одном случае интерпретация условий, основанная на анализе фауны моллюсков не расходилась с полученными независимо от них данными по другим ископаемым формам.

Все 5 комплексов рассматриваемые в настоящей работе, имеют различия в своем составе, вероятно связанные с изменениями климата втечение Иллинойсского периода. Относительно большое количество южных видов с преимущественно северным распространением и, вместе с тем малое количество представителей исключительно южных элементов фауны, указывает на то, что локальная фауна Доби Спрингс представляет собой наиболее холодолюбивое из всех исследованных сообществ и, возможно обитало здесь во время максимального Иллинойсского оледенения. Поскольку локальная фауна Маунт Скотт имеет в своем составе бо́льшее количество видов с южным распространением, чем любая другая из изученных фаун, можно думать, что она представляет собой наиболее теплолюбивую из рассматриваемых фаун Иллинойсского времени.

Принимая, что изменения климата между периодами обитания обеих фаун шли в одном направлении, то, ввиде опыта, была предложена хронология существования остальных фаун, исходя из их отношения к климатическим условиям: фауна Берендс, видимо является наиболее древней, за ней следуют локальные фауны--Доби Спрингс, Адамс, Ботлер Спрингс и Маунт Скотт.

В фауне Берендс имеется 43 вида моллюсков, 15 из которых являются новыми для этой локальной фауны. Один вид--*Sphaerium securis*, найден в ископаемом состоянии в южной части Равнин впервые. Локальная фауна Берендс обитала в небольшм мелком озере и у его берегов; растительный покров состоял здесь, главным образом из хвойных деревьев, трав и сложноцветных растений, с редкими группами лиственных деревьев. Климат того времени, когда здесь обитала указанная фауна, был вероятно сходен с современным, существующим теперь в районе Великих Равнин (северо-восточной Небраски--северо-западной Айовы).

Локальная фауна Доби Спрингс имеет 57 видов моллюсков, 2 из которых (*Vertigo elatior* и *Gyraulus deflectus*) отмечены в ископаемом состоянии в южной части Великих Равнин впервые. Состав фауны моллюсков указывает на существование холодного проточного озера, окаймленного болотом с растительностью из рогоза, осоки и с редкими лиственными и хвойными деревьями; в лучше-дренированных местах и дальше от озера она постепенно сменяется сообществами кустарников и деревьев.

Можно думать, что прежний локальный климат характеризовался более коротким и более холодным летом, зимы были также несколько холоднее и длиннее, чем те, что наблюдаются теперь в этом районе.

В локальной фауне Адамс имеется 21 вид, из инх *Lasmigona complanata* отмечен в ископаемом состоянии в этом районе впервые. Наличие перекрестно-залегающих песков различной зернистости (от средних до крупных), в которых была найдена эта фауна, а также встреченные здесь виды моллюсков, связанные с постоянноводным образом жизни, указывает на существование здесь текучих вод. Наличие лишь одного лесного вида среди наземных брюхоногих предполагает наличие лишь тонкого древесного покрова и кустарников. Климат вероятно характеризовался не более суровыми зимами, чем те, которые существуют в настоящее время в северо-восточной Небраске, т.е. с более холодным и более влажным летом, сходным с теми, которые характерны для Дакоты и восточной Монтаны.

В локальной фауне Ботлер Спринг имеется 51 вид моллюсков, один из которых--*Ligumia* cf. *L. recta* является новым для южной части Великих Равнин. Эта фауна обитала в реке среднего размера или близ нее; река имела медленное или умеренно-быстрое течение, и, возможно, глубину в несколько футов. Вдоль ее берегов были редкие группы деревьев, но преобладающей растительностью были травы и кустарники. Климат, судя по составу моллюсков, характеризовался более холодным летом, сходным с тем, которое в настоящее время существует в восточном районе Северной Дакоты. Зимы, возможно были не более холодные, чем сейчас в центральной части северной Небраски.

В фауне моллюсков Маунт Скотт имеется 61 вид, т.е. это самый крупный комплекс из всех, известных для южной части Равнин. Единственная находка в ископаемом состоянии *Zonitoides nitidus*, известная для Великих Равнин, отмечена в этой фауне. Судя по осадкам и палеонтологическим данным, здесь существовало 5 крупных местообитаний ассоцаций моллюсков: озеро или постоянный пруд; небольшой постоянный ручей; временный водоем; болотно-лесное сообщество в пойме ручья, где имелись группы высоких трав, осок, а также кустарники и редкие группы деревьев; более дренированные и более высокие места, покрытые некоторыми деревьями, травянистыми сложноцветными растениями и травами. Климат в это время вероятно имел лето, сходное с тем, которое в настоящее время существует в районе озера Окободжи, северо-западная Айова, а зимы были--не более суровы, чем теперь в районе северо-восточного Канзаса--юго-восточной Небраски.