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FIVE ILLINOIAN MOLLUSCAN FAUNAS FROM THE SOUTHERN GREAT PLAINS

by
Barry Bennett Miller

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy in the
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INTRODUCTION

Under supervision of Claude W. Hibbard, field parties from the University of Kansas (1936-1946) and University of Michigan (1947 to date) have been engaged in an intensive study of the late Cenozoic fossils and stratigraphic sequences of the southwest Kansas-northwest Oklahoma area. During this 27 year period thirteen Pleistocene faunas ranging in age from Aftonian to Wisconsin, have been studied (see summaries in Taylor, 1960; Hibbard and Taylor, 1960).

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 (1962). 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, 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 late Illinoian molluscan assemblages from the Mount Scott and Doby Springs local faunas. For the sake of completeness, the study has also involved the mapping and description of the surficial geology of the Big Springs Ranch area of Meade County, Kansas, as well as additions and changes to the molluscan faunas of the Butler Spring, Adams, and Berends local faunas.

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.

GEOLOGY OF THE BIG SPRINGS RANCH AREA, MEADE COUNTY, KANSAS.

Introduction

Sometime during the late Yarmouth-early Illinoian interval ancestral Spring Creek flowed in a southeast direction across the Big Springs Ranch area. This stream entrenched itself on the top of the Crooked Creek Formation of Yarmouth age and continued to cut downward to at least the Angell member of the underlying Ballard Formation. A change in stream regimen from one of erosion to aggradation sometime in the late Illinoian resulted in the accumulation of sediments that have been referred to as the Kingsdown Formation.

Location and General Description of Area

The mapped portions of the Big Springs and the Jerry D. Golliher Ranches together occupy an area of approximately 9½ square miles, situated in T. 32 S., R. 28 and 29 W., Meade County, Kansas (Figs. 1 and 2). It is situated on the south side of U. S. Highway 54-160, about 3 miles west of the city of Meade.

This portion of Meade County is located near the boundary of the High Plains and Plains Border sections of the Great Plains Physiographic Province (Fenneman, 1931, Pl. 2). The Plains Border section in the Big Springs Ranch area occurs between 2500 and 2700 feet elevation and locally forms part of the Spring Creek drainage basin.

Spring Creek, the principal drainage in the area mapped, heads on the High Plains surface, in sec. 6, T. 31 S., R. 29 W., approximately 4 miles north northwest of the Big Springs

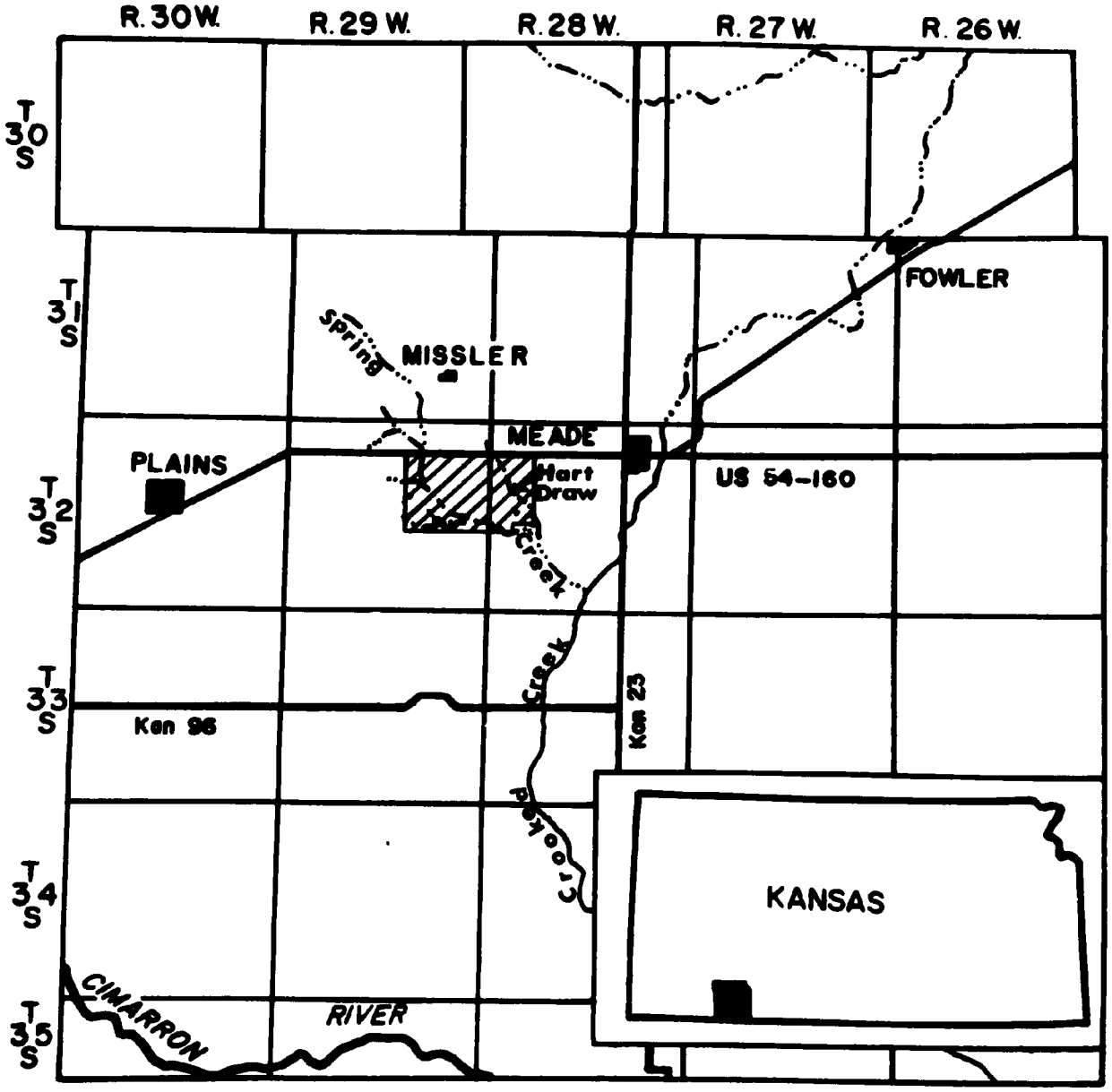


Fig. 1. Index map showing location of Big Springs Ranch area (shaded zone), Meade County, Kansas.

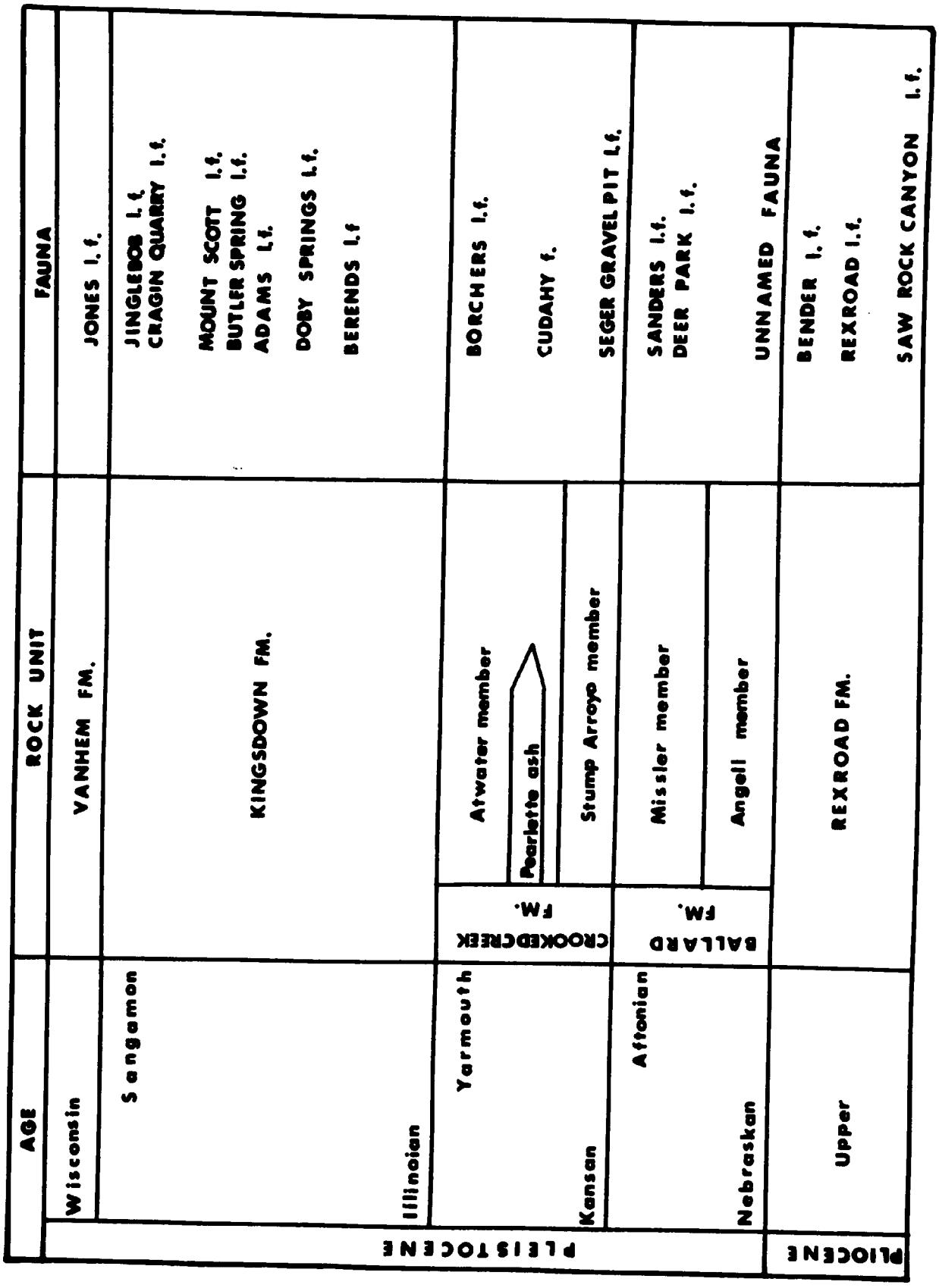


Fig. 3. Stratigraphic sequence in southwest Kansas-northwest Oklahoma.

Ranch area, and flows as an intermittent stream in a southeasterly direction for a distance of 7½ miles before it joins Crooked Creek, in sec. 22, T. 32 S., R. 28 W. The channel of Spring Creek and that of its main tributary, Hart Draw, are usually filled with water only after rainstorms. Springs and seeps along the valley floor of Spring Creek and Hart Draw produce two flows of water which join about 3/4 mile downstream from these source areas, continuing as a permanent stream for a short distance below this confluence.

Stratigraphy

A sequence of sediments ranging in age from upper Pliocene to Recent, is exposed in the Pig Springs Ranch area (Fig. 3). 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 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 dip, the greatest angle measured not exceeding 4°. All these made mapping difficult and accurate measurement of strike and dip impossible.

Rexroad Formation.-The upper Pliocene in this area is repres-

ented 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 two exceptions to this usual mode of occurrence: the first is an outcrop, composed of approximately 3½ feet of orange, yellow, and green sands and clays, exposed in a low bank, along a tributary of Spring Creek in the SW¼ NW¼ sec. 24, T. 32 S., R. 29 W.; the second is an exposure in the floor of the Sanders Gravel pit, SE¼ NW¼ 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 NW¼ NE¼ sec. 18, T. 32 S., R. 28 W. It is composed of 23 feet 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 NW¼ NE¼ 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 been used in various ways (see summaries in Hibbard, 1955, Chart I; and Hibbard and 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 feet of cemented basal sand and gravel, overlain by 12 feet of buff-gray silt and clay. The upper 3 feet 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 SE¼ NW¼ sec. 19, T. 32 S., R. 28 W. At this locality, the Ballard is 42.5 feet thick and has a dip of about 4° east (see Measured Section 5).

Hibbard (1958) introduced the name Angell member, for the basal portion of the Ballard Formation, designating the 13.7 feet of cross-bedded, partly cemented, sand, gravel and cobbles, exposed near the base of the Sanders Gravel pit in SE¼ NW¼ sec. 7, T. 32 S., R. 28 W., as the type section.

Differences in amount of cementation have produced some lateral variation in the appearance 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, manganese and iron stained, sand and gravel, best displayed in outcrops along Spring Creek and its tributaries, in sections 10, 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 NE¼ SE¼ sec. 14, T. 32 S., R. 29 W., and NW¼ SE¼ 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 SW¼ NW¼ 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 in sections 6 and 7, T. 32 S., R. 28 W. Good outcrops, where the member is as much as 35 feet thick, occur along Spring Creek and its tributaries in sections 12, 14, 22 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 inches 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 feet.

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 feet. 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 feet 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 N½ 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 S½ 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 feet of reddish-brown sand and silt, intermixed with stringers and nodules of caliche, and ash. It is exposed in the E½ of sec. 14, T. 32 S., R. 29 W. (see Measured Section 2). The Pearlette ash, the most distinctive unit in the Atwater when present, is well exposed in the NW¼ sec. 18; SW¼ and NW¼ SE¼ sec. 7, T. 32 S., R. 29 W., and in the NE¼ sec. 14, T. 32 S., R. 28 W. The greatest thickness of ash measured was a 160 inch section exposed in the NW¼ SE¼ 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 NW¼ 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 greatest development in the SE¼ sec. 18, T. 32 S., R. 28 W., at Mount Scott ("The Lookout"), on the north side of Spring Creek, where a thick sequence of at least 61 feet of gravel, sand, silt, clay and caliche are exposed (see Measured Section 3). Other outcrops of the Kingsdown occur in the SW¼ sec.17, T. 32 S., R. 28 W., on the south side of Hart Draw; in the SW¼ sec. 13, the SE¼ and the NW¼ sec. 14, and the S½ sec. 18, T. 32 S., R. 29 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) is exposed some 42 feet above the base of a high bluff on the south side of Spring Creek, in the NW¼ 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 two exposures is the same there must have been approximately 42 feet 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 two 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 S½ 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).

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 foot fossiliferous, greenish brown to green silt, representing a floodplain phase of deposition. Overlying these sediments, is a 6.5 foot channel phase sequence of cut and fill structures, composed of lenses of sand and gravel containing cobbles up to 10 inches 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), 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 and Taylor, 1960, p. 29). A dark brown silt containing mollusks and pollen (Kapp, 1962) is exposed at locality UM-K3-60, near the base of Hart Draw, several hundred feet downstream from the section measured by Taylor (Hibbard and Taylor, 1960, p. 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 two cycles of post-Kingsdown incision and deposition are recognizeable in the Fig 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 feet, 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, p. 105), and placed in the Vanhem Formation, even though, at that 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), 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 feet in thickness, filling channels that have been cut through the Crooked Creek and Ballard 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 feet above the present stream floor of Spring Creek and Hart Draw and by the series of terrace deposits of Late Winconsin age located along the north side of the Cimarron River (Hibbard and Taylor, 1960, p. 22; McLaughlin, 1946,



Fig. 4. Photograph showing sediments of Vanhem Formation (Wisconsin) filling channels cut into Kingsdown Formation. Photograph taken near locality UM-K4-53.

p. 36; Byrne and McLaughlin, 1948, p. 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 not frequent enough to permit determination of the areal extent of this formation. These difficulties made it impractical to seperate the Vanhem from the younger Recent sediments, and the entire sequence of post-Kingsdown deposits have consequently been mapped as one unit.

Measured Sections

Measured Section 1.-Section measured in SW¼ NE¼ SE¼ sec. 14, T. 32 S., R. 29 W., on north bank of Spring Creek. The section is a composite, with the upper 86" measured about 85' upstream from the lower 67".

Feet

Top of bank

Vanhem Formation

8. Gravel, sand, and silt, light brown-buff; channeled into gray clay below.....2.25

Kingsdown Formation

Feet

Kingsdown Formation (continued)

7. Clay, light gray, with joints apparently dipping 43° W., 75° N., and 80° E.....2.30
6. Clay, "varved", with light and dark gray laminae.....2.60

Measured section continued 85' upstream.

5. Clay, gray-black, with sandy limonitic nodules..2.20
4. Clay, black, with caliche nodules.....0.75
3. Clay, silty, greenish-brown, grading upward into black clay (loc. UM-K4-53).....1.33
2. Clay, black, streaked with white flecks.....0.25
1. Silty clay, greenish-brown on fresh exposures, gray-black when dry; limonite stains; shell zone in upper 15" (Base not exposed).....1.80

Floor of Spring Creek

Measured Section 2.-Section measured on north bank of Spring Creek, NW¼ SE¼ sec. 14, T. 32 S., R. 29 W., Meade County, Kansas, and was measured northward to the High Plains surface.

Feet

Crooked Creek Formation

Atwater member

11. Silts and caliche, gray-brown, containing caliche nodules and stringers.....28.75
10. Volcanic ash (Pearlette ash), white, impure, containing reworked fragments of jasper, feldspar; contact above and below very

Feet

Crooked Creek Formation

Atwater member

10. (continued) irregular.....2.50

9. Sandy silt, thin bedded, thin clay layer on top, olive color with orange mottling.....1.00

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

Ballard Formation

7. Silt, brown.....1.50

6. Clay, green.....0.80

5. Caliche, fine grained, well indurated.....0.50

4. Clay, thinly laminated, light brown, high in organic content.....1.20

3. Silts, red, interbedded with caliche nodules.....3.20

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

Angell member

1. Sand and gravel, medium to coarse yellow-buff, indurated in places. Light buff color on dry surface. Top 18" crossbedded (Base not exposed).4.00

Measured Section 3.-Section measured on the north side of Spring Creek, in the SE¼ 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 in a north northwest direction to the top of Mount Scott. The description of sediments is based on fresh exposures. The stratigraphic section is approximately 3 feet greater than the topographic thickness due to the channeling of the Kingsdown into the Crooked Creek and Ballard formations.

Feet

Topsoil

Kingsdown Formation

19. Caliche, white, indurated, porous, with irregular cavities. Surface covered with a black lichen.....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, loc. 3, comes from red-brown silt near top of unit).....11.40

17. Silt, gray-green, with limonite blotches and stringers; shell at base.....0.80

16. Sand, medium to fine, light brown, grading upward to fine sand with orange limonite blotches and stringers.....7.40

15. Silt, brown, with some limonite stringers. Contains Sphaerium and other mollusks. (Cragin Quarry local fauna, loc. 2 from this unit).....6.70

Feet

Kingsdown Formation (continued)

14. Clay, gray-green, with some fine silt; silt component increases towards top; with manganese dioxide and limonite stains; contains shell..7.30

13. Clay, brown, with some silt; grades upward to light brown-buff clay.....11.00

12. Silty clay, light brown.....1.60

11. Sandy clay, red-brown.....5.00

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 shell and clay balls.....5.50

9. Gravel, over 2 inches in diameter (reworked Stump Arroyo gravel) in yellow sand; cobbles of caliche (reworked Ballard caliche) up to 10 inches long; base irregular, channeled into lower unit.....0.50-1.10

8. Silt, coarse greenish brown, with mollusks (Mount Scott local fauna, loc. UM-K2-59) grading upward into green silt and olive green clay with orange limonite clay.....2.00

Quarry floor. Base of Kingsdown is not exposed.

Crooked Creek Formation

Stump Arroyo member (exposed approximately 75 feet east southeast of quarry).

Feet

Crooked Creek Formation (continued)

7. Gravel and sand; sand colored yellow-orange.....2.50

Ballard Formation

Missler member

6. Silt, green; indurated, dense, white caliche at top forms small ridge.....1.90

5. Sand, fine, orange-brown.....0.90

4. Clay, green, with lime enriched zone near top....1.20

3. Silt, red-brown.....1.20

2. Clay, silty, green, with caliche nodules.....2.30

1. Covered interval.....11.30

Floor of Spring Creek

Measured Section 4.-Section measured in the SW¼ SW¼ sec. 13, T. 32 S., R. 29 W., on the north side of Spring Creek. The Vanhem at this locality is channeled into the Kingsdown and is topographically lower than the upper portion of this formation.

Feet

Topsoil

Kingsdown Formation

7. Clay, gray-green, with red-brown limonite stringers; base not exposed. Top 2 feet contain mollusks.....5.66

Vanhem Formation

6. Covered interval.....5.66

Top of bank

Feet

Vanhem Formation (continued)

5. Sands and silts, reddish-brown, with small caliche nodules; coarser at base, grading upward into finer sands and silts; contains lenses up to 6½ inches thick of light gray clay. These sediments are channeled into the black clay of unit 4.....7.00

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.....0.20-1.20

3. Silt, light gray, with layers ½ inch thick, stained with limonite; white limy stringers interspersed throughout the unit; unit containing many mollusks (Mt. Scott local fauna, loc. UM-K1-60).....1.30

2. Marl; interbedded with very thin layers of yellow-orange sand. Contains mollusks, bone and plant impressions (Mt. Scott local fauna, loc. UM-K1-60).....0.25

1. Sand, yellow on fresh exposures; gray-buff when dry; with mollusks and bones of fishes (Mt. Scott local fauna, loc. UM-K1-60).....0.85

Floor of Spring Creek

Measured Section 5.-Section measured up the slope of a steep bluff, on the south side of Spring Creek, SW_4 NW_4 NW_4 sec. 19, T. 32 S., R. 29 W., Big Springs Ranch, Meade County, Kansas. The beds exposed in this section have an apparent dip of 4° to the east.

Feet

Top of Bluff

Topsoil

Ballard Formation

Missler member

12. Clay, brown, grading upward into reddish brown silt.....7.33
11. Clay, green with small nodules of caliche.....1.93
10. Silt, red, with caliche nodules.....7.25
9. Caliche, indurated.....0.50
8. Clay, silty, green; grading upward to silt with layer of caliche stringers at top.....2.00
7. Silt, red; with orange limonite blotches; zone of caliche stringers near top.....3.33
6. Silts and clays, red; with local zones of lime enrichment and sand pockets.....5.66
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

Feet

Ballard Formation (continued)

Angell member

4. Sand, medium, yellow, becoming orange towards top; fine gravel concentrated towards bottom of unit; crossbedded near base. Sand is case-hardened in areas, with lime cement.....5.17

Rexroad Formation

3. Caliche, indurated.....0.50

2. Clay, rust colored; with 2" caliche layer at bottom. Clay contains nodules of caliche, 1" and less in diameter, in top 20".....3.50

1. Sand, red-rust colored, with green blotches.....7.33

Floor of Spring Creek

LATE CENOZOIC GEOLOGIC HISTORY

The late Cenozoic history of southwestern Kansas and northwestern Oklahoma has been reviewed in papers by Hibbard (1949a; 1950; 1954; 1955), and Hibbard and 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, p. 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, p. 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, p. 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 next episode of downcutting and deposition, which followed the Ballard. Increased precipitation and uplift are implied by the channels cut into the Ballard and the 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 and Taylor, 1960, p. 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. The thick sequence of Kingsdown exposed at Mount Scott is the result of this stream aggradation, aided by subsidence on the west side of the Crooked Creek fault. A dip of about 4° E. on the Ballard Formation (see Measured Section 5), is believed to be related to this event. The Kingsdown sediments occurring along Spring Creek record only the late Illinoian-early Sang-

amon part of this sequence. The lower portion of the Kingsdown, representing sediments equivalent to those containing the earlier Illinoian Butler Spring, Adams, Doby Springs and Seminole local faunas, were 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 southeast of Mt. Scott, migrated to the south of the present valley as it became entrenched in the older formations. Those portions of the Kingsdown that were 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 precipitation and runoff, such as is implied by the Jinglebob local fauna (Hibbard, 1955, p. 24; Hibbard and Taylor, 1960, p. 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 and McLaughlin, 1948; Hibbard and Taylor, 1960) and at least one terrace level along Spring Creek and Hart Draw.

FAUNAL DISCUSSION

The Mount Scott, Butler Spring, Adams, Doby Springs and Berends local faunas show compositional differences which seem best explained by assuming climatic change. Evidence presented in this portion of the report indicates that the Mount Scott and Doby Springs local faunas represent the climatic end points in this sequence of faunas. Assuming that the climatic changes that took place in the southern Great Plains between the time the Mount Scott and Doby Springs local faunas lived were unidirectional, it is possible to fit these five assemblages into a chronology based on their climatic implications. This sequence based on the mollusks suggests that the Berends probably represents the oldest, followed by the Doby Springs, Adams, Butler Spring and Mount Scott local faunas.

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 two miles upstream from Mount Scott ("The Lookout"), 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 and Hibbard, 1963) from localities UM-K4-53, UM-K1-60 and UM-K2-59; and the pollen (Kapp, 1962) 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, p. 181) for the fossil material recovered from locality UM-K2-59, near the base of Mount Scott ("The Lookout").

Faunal List.

	UM-K4-53	UM-K1-60	UM-K2-59	UM-K3-60
CLASS OSTRACODA				
Candona reonensis Gutentag and Benson		x	x	
Cypridopsis vidua (O. F. Müller)		x	x	
Candona sp. "a"			x	
CLASS PELECYPODA				
Order Prionodesmacea				
Uniomerus tetralasmus (Say)	x[1]	x		x
Order Teleodesmacea				
Sphaerium lacustre (Müller)	x			

	UM-K4-53	UM-K1-60	UM-K2-59	UM-K3-60
Order Teleodesmacea (continued)				
Sphaerium 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[1]	
Pisidium casertanum (Poli)	x	x	x	x
P. compressum Prime	x	x	x	x
P. nitidum Jenyns	x	x	x	
P. obtusale Pfeiffer	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[1]	x	x	
Fossaria dalli (Baker)	x	x	x	
F. obrussa (Say)	x	x	x	

Order Basommatophora (continued)				
Armiger crista (Linné)	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 exacuous (Say)	x	x	x	
P. umbilicatellus (Cockerell)			x	
Physa anatina Lea	x	x	x	
P. gyrina Say	x	x	x	
P. skinneri Taylor	x		x	
Aplexa hypnorum (Linné)	x		x	
Ferrissia meekiana (Stimpson)	x	x	x	
Laevapex fuscus (Adams)	x	x	x	
L. kirklandi (Walker)		x	x	x
Order Stylommatophora				
Strobilops labyrinthica (Say)	x	x	x	
Gastrocopta armifera (Say)	x	x	x	x
G. contracta (Say)	x	x	x	
G. cristata (Pilsbry and 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	

	UM-K4-53	UM-K1-60	UM-K2-59	UM-K3-60
Order Stylommatophora (continued)				
Pupoides albilabris (Adams)	x	x	x	x
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 retusa (Lea)	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	
Retinella 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	
Cionella lubrica (Müller)				x
CLASS OSTEICHTHYES				
Lepisosteus platostomus Rafinesque		x	x	
Esox masquinongy Mitchill		x		

	UM-K4-53	UM-K1-60	UM-K2-59	UM-K3-60
CLASS OSTEICHTHYES (continued)				
Hybognathus hankinsoni Hubbs		x		
Campostoma anomalum (Rafinesque)	x	x		
Semotilus atromaculatus (Mitchill)	x	x	x	
Dionda nubila (Forbes)		x		
Cyprinidea, indeterminate	x	x		
Ictiobus, sp. Rafinesque		x		
Catostomus commersoni (Lacépède)		x	x	
Moxostoma duquesnei (LeSueur)		x		
Ictalurus punctatus (Rafinesque)			x	
I. melas (Rafinesque)	x	x		
Micropterus salmoides (Lacépède)	x	x		
Lepomis cyanellus Rafinesque	x			
L. humillis?(Girard)		x		
Perca cf. P. flavescens (Mitchill)	x	x		
CLASS AMPHIBIA				
Order Salienta				
Bufo sp.			x	
?Acris sp.		x	x	
Rana pipiens Schreber		x	x	
CLASS REPTILLIA				
Order Chelonia				
Terrapene llanensis Oelrich			x	

	UM-K4-53	UM-K1-60	UM-K2-59	UM-K3-60
CLASS REPTILLIA (continued)				
Order Squamata				
Ophisaurus attenuatus Baird	x	x	x	
CLASS AVES				
Unstudied				
CLASS MAMMALIA				
Order Insectivora				
Sorex cinereus Kerr	x		x	
S. arcticus Kerr			x	
S. palustris Richardson			x	
Blarina brevicauda carolinensis (Bachman)	x	x	x	
Cryptotis parva (Say)	x	x		
Order Chiroptera				
Lasiurus cinereus (Beauvois)			x	
Order Rodentia				
Cynomus sp.			x	
Citellus cf. C. tridecimlineatus (Mitchill)			x	
Citellus sp.		x	x	
Geomys sp.	x		x	
Paradipoides or Castor sp.		x		
Reithrodontomys sp.		x	x	
Peromyscus berendsensis Starrett	x		x	
P. progressus Hibbard	x		x	
Peromyscus sp.			x	

	UM-K4-53	UM-K1-60	UM-K2-59	UM-K3-60
Order Rodentia(continued)				
Neotoma cf. N. floridana (Ord)			x	
Oryzomys fossilis Hibbard		x	x	
Synaptomys australis Simpson	x	x	x	
Ondatra zibethica Linné	x	x	x	
Microtus pennsylvanicus (Ord)	x	x	x	
Pedomys ochrogaster (Wagner)	x	x	x	
Zapus hudsonius transitionalis Klingener		x	x	
Order Carnivora				
Mustela vison Schreber			x	
Order Lagomorpha				
Sylvilagus sp.		x	x	
Lepus sp.	x	x		
Order Artiodactyla				
Bison cf. B. latifrons (Harlan)			x	

Localities. - The Mount Scott local fauna is known from the following four localities, situated on the Big Springs ranch, Meade County, Kansas:

Locality UM-K4-53. SE¼ sec. 14, T. 32 S., R. 29 W., approximately 1914 feet north and 1254 feet west, of the southeastern section corner. The fossils were recovered from a greenish-brown silty clay(unit 3 in Measured Section 1), 2-3 feet

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1. cf.

above the stream bed of Spring Creek (Miller , 1961,p. 104). Five tons of matrix have been removed from this locality since it was first worked in 1953. About ten percent of the concentrate from these collections has been sorted for mollusks.

Locality UM-K1-60. SW¼ sec. 13, T. 32., R. 29 W., approximately 528 feet north and 396 feet east of the southwestern section corner, about ½ 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 four. Seven tons of matrix were washed from this site during the 1960-1961 field sessions. Only about twelve percent of this concentrate has been sorted for mollusks.

Locality UM-K2-59. SE¼ sec. 18, T. 32 S., R. 28 W., 396 feet north and 1386 feet west of the southeastern section corner, a little over two 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), exposed in a quarry excavated on the lower slope of Mount Scott ("The Lookout"). approximately 23 feet above the bed of spring creek. Twenty-seven tons of matrix have been removed from this locality, less than five percent of which has been sorted for mollusks.

Locality UM-K3-60. NE¼ SW¼ sec. 17, T. 32 S.,R. 28 W., about 1980 feet north and 924 feet 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 feet below locality 1 of the Cragin Quarry local fauna

(Hibbard and Taylor, 1960). The mollusks represent all the fossils recovered from about 10 pounds of matrix.

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) The Mount Scott local fauna 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 ("The Lookout"), to locality 3 of the Cragin Quarry local fauna of Sangamon age (Hibbard and 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 from both localitites UM-K4-53 and UM-K1-60 are from the same strata-

igraphic interval of the Kingsdown Formation, which can be traced downstream about ½ mile (see Fig. 2) as an almost continuous bed. The stratigraphic position of the Kingsdown in this area indicates that it is post-Crooked Creek in age.

The Kingsdown Formation has been dissected by a younger episode of channel cutting (see Fig. 4), and filled with gravel and light brown-buff sand and silts. Mollusks recovered from this interval (locality UM-K2-60), include six species no longer living in the 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, p. 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, suggests 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 five 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, 1962, p. 182). The mollusks imply a similar trend with the number of species with southern distributions increasing from four, in the Doby Springs local fauna (Uniomerus tetralasmus, Physa anatina, Gastrocopta procera and G. cristata), to six in Mount Scott local fauna (U. tetralasmus, P. anatina, G. procera, G. cristata, G. pellucida hordeacella and Helicodiscus singleyanus).

Paleoecology.-Inferences pertaining to the local habitat and climatic conditions that existed at the time the Mount Scott local fauna lived may be made from the physical characteristics of the fossil-bearing sediments and the ecologic data and distributional patterns of the extant elements of the fauna.

Habitat.-Table I lists by habitat group, the species of mollusks occurring in the Mount Scott local fauna. 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.

Miller (1961, p. 123), concluded that the molluscan assemblage at locality UM-K4-53 represented three major habitats: "(1) a small permanent stream of the same approximate size as

TABLE I.-Summary of the Local Habitats Represented by the Mollusks of the Mount Scott Local Fauna. R=<25; S=26-49 C=50-100; A=>100 shells. (Modified from Hibbard and Taylor, 1960)

Habitat	Species	Locality			
		TM-K3-54	TM-K1-[illegible]	TM-K2-59	TM-K3-[illegible]
Semiaquatic: among vegetation and debris near water's edge.	Oxyloma retusa	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	-
	Retinella electrina	C	-	R	-
	Euconulus fulvus	C	R	R	-
	Strobilops labyrinthica	A	C	C	-
	Punctum minutissimum	S	-	-	-
	Helicodiscus parallelus	A	R	A	C

TABLE I (continued)

Habitat	Species	Locality			
		UM-K3-58	UM-K1-60	UM-K2-59	UM-K3-60
Sheltered areas: live 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.	Gastrocopta 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	Pisidium casertanum	A	A	A	R
	Sphaerium occidentale	R	-	C	-
	Stagnicola exilis	-	-	R	-

TABLE I (continued)

Habitat	Species	Locality			
		UM-K3-54	UM-K1-[illegible]	UM-K2-59	UM-K3-60
floodplain, that may become dry during part of the year.	Stagnicola caperata	A	R	A	-
	S. reflexa	A	R	A	-
	Armiger crista	R	R	C	-
	Gyraulus circumstriatus	A	A	A	-
	Promenetus umbilicatellus	-	-	A	-
	Physa gyrina	A	S	A	-
	Aplexa hypnorum	A	-	A	-
	Ferrissia meekiana	R	R	R	-
Shallow, quiet water: small ponds, 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.	Unionerus 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 exacuous	A	A	A	-
	Physa anatina	A	A	A	-
	P. skinneri	R	-	S	-
	Laevapex fuscus	R	C	R	-
	L. kirklandi	-	C	R	R

TABLE I (continued)

Habitat	Species	Locality			
		UM-K3-54	UM-K1-60	UM-K2-59	UM-K3-60
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	-	-

the present Spring Creek; (2) a temporary water 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, 1962), 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 existance 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, Valvata tricarinata, Gyraulus parvus, Physa anatina, Sphaerium sulcatum, Pisidium variabile, P. walkeri, P. nitidum, and P. compressum. These species, which con-

stitute the largest portion of the total number of individual mollusks 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 the 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" (Miller, 1961, p. 104). 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; Miller, this paper), suggest permanent 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 (Miller, 1961; Smith, 1963).

The presence of ephemeral bodies of water on the floodplain of ancestral Spring Creek is evidenced by the occurrence of prominant "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, 1962) and the abundance of Strobilops labyrinthica, Gastrocopta contracta, G. tappaniana, Vertigo ovata, V. milium, Oxyloma retusa, Helicodiscus parallelus, Deroceras aenigma, Carychium exiguum, and Zonitoides nitidus. Some of the mammals represented by Sorex cinereus, S. arcticus,

Oryzomys fossilis, Synaptomys australis, Blarina brevicauda carolinensis, Microtus pennsylvanicus and Lepus hudsonius transitionalis (Hibbard, 1963), support this conclusion.

A better drained upland, containing some trees, herbaceous composites, and grasses, is indicated by the pollen (Kapp, 1962). 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 the 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 have 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 in the earlier paper (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 and 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 require 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, quite far to the north. The molluscs 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.

Shimek (1915) reported 47 of the species represented in the Mount Scott local fauna within 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 distributions, 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 prevailing in the Lake Okoboji region represent fairly closely those that existed in southwestern Kansas at the time the Mount Scott local fauna lived.

Fifteen of the extant species not occurring in the Lake Okoboji area form part of the three major distribution groups mentioned above. The northern element includes Pisidium variabile, P. walkeri, P. nitidum, P. subtruncatum, Sphaerium occidentale and Pupilla blandi. The first two 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). Three species are included in the northeastern category. Ferrissia meekiana and Laevapex kirklandi occur in Iowa to the south and east of Lake Okoboji (Leonard, 1959). L. fuscus, according to distribution data given by Baker (1928a), should occur in the eastern part of Iowa in the Mississippi River valley.

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 II). The normal summer temperatures in the Okoboji area are about 5 degrees cooler than in Meade County. In contrast with the Lake Okoboji region however, Meade County possesses higher maximum

TABLE II.-Summary of Climatic Data for the Mount Scott Local Fauna and the Lake Okoboji Region of Northwest Iowa. (Based on Visher, 1954)

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 number 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

TABLE II (continued)

Precipitation	Meade County	Lake Okoboji
Percent of precipitation that occurs in summer	30-40	40-50
Normal summer precipitation	6-8 inches	10-12 inches

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 to 30 inches, 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, and presently extends as far north as the southeastern Nebraska-northeastern Kansas area. It is probably prevented from going further north by the colder winters. 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 to 30 inches of rainfall, 10 to 12 inches of which falls during the warmer part of the year (see Table II).

Butler Spring Local Fauna

Previous Work.- The name Butler Spring local fauna was first used by Herrington and Taylor (1958, p. 4) for the fossils recovered from one locality in the SE¼ sec. 32, T. 34 S., R. 29 W., Meade County, Kansas. Smith (1958) reported on the fishes from this locality. Hibbard and Taylor (1960) discussed the stratigraphy of the area and described additional mollusks and vertebrates from this locality and from four 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, 1962), indicates that there are significant differences between locality 1 and localities 2, 3, 4, and 5, of Hibbard and Taylor (1960). In this report the Butler Spring local fauna is restricted to include only the fossils reported from locality 1 (U.S.G.S. Cenozoic locality 21042) of Hibbard and Taylor (1960) and locality UM-K3-61 (undescribed), in the NW¼ NE¼ NE¼ sec. 5, T. 35 S., R. 29 W., Meade County, Kansas.

Faunal list.

CLASS PELECYPODA

Order Prionodesmacea

Ligumia cf. *L. recta* (Lamarck)

Anodonta grandis (Say)

Order Prionodesmacea

Sphaerium striatinum (Lamarck)

S. transversum Say

Order Prionodesmacea (continued)

Sphaerium indet.

Pisidium casertanum (Poli)

P. compressum Prime

P. nitidum Jenyns

P. walkeri Sterki ?

CLASS GASTROPODA

Order Mesogastropda

Valvata tricarinata (Say)

Probythinella lacustris (Baker)

Order Basommatophora

Carychium exiguum (Say)

Stagnicola reflexa (Say)

S. caperata (Say)

Fossaria obrussa (Say)

F. dalli (Baker)

Lymnaea stagnalis jugularis Say

Anisus pattersoni (Baker)

Gyraulus circumstriatus (Tryon)

G. parvus (Say)

Helisoma anceps (Menke)

H. trivolvis (Say)

Promenetus exacuous kansasensis (Baker)

P. umbilicatellus (Cockerell)

Ferrissia meekiana (Stimpson)

Laevapex kirklandi (Walker)

Physa anatina Lea

Order Basommatophora (continued)

Physa gyrina Say

P. skinneri Taylor

Aplexa hypnorum (Linné)

Order Stylommatophora

Gastrocopta armifera (Say)

G. contracta (Say)

G. cristata (Pilsbry and Vanatta)

G. holzingeri Sterki

G. procera (Gould)

G. tappaniana (Adams)

Pupoides albilabris (Adams)

P. inornatus Vanatta

Pupilla muscorum (Linné)

P. blandi (Morse)

Vertigo elatior (Sterki)

V. milium (Gould)

V. ovata (Say)

Vallonia cyclophorella Sterki

V. gracilicosta Reinhardt

V. parvula Sterki

cf. Succinea

Oxyloma retusa (Lea)

Discus cronkhitei (Newcomb)

Helicodiscus singleyanus (Pilsbry)

Hawaiia minuscula (Binney)

Zonitoides arboreus (Say)

Stenotrema leai (Binney)

Pupilla sinistra Franzen

CLASS OSTEICHTHYES

Lepisosteus sp.

Catostomus commersoni (Lacépède)

Cyprinid indet.

Ictalurus cf. I. punctatus (Rafinesque)

I. melas (Rafinesque)

Perca flavescens (Mitchill)

CLASS REPTILIA

Order Chelonia

Chelydra serpentina (Linné)

CLASS MAMMALIA

Order Rodentia

Microtus pennsylvanicus (Ord)

Age and Correlation.- Examination of the mollusks from the Mount Scott, Butler Spring and Doby Springs local faunas, suggests that the Butler Spring is intermediate between the other two in terms of first and last occurrences of species. The first Illinoian occurrence of the four 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 lcal fauna, but in greatly reduced relative numbers. The absence of three of these species, P. lacustris, L. s. jugularis and V. elatior, 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 ten

pounds of matrix, whereas the Butler Spring local fauna was picked from about 750 pounds of matrix [Hibbard and 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 towards a slightly warmer climate between the time the Doby Springs and Mount Scott local faunas lived. These changes 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 towards 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 and 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 species 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 Springs local

fauna (Hibbard and Taylor, 1960) consisted of cooler summers than now occur in Meade County. These conditions are similar to those now occurring in the eastern North Dakota region. Winters were probably no more severe than those in north-central Nebraska.

Adams Local Fauna

Previous work. The term Adams local fauna was proposed by Kapp (1962) 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 and Taylor, 1960), in the SE¼ 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 and Taylor (1960, p. 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 indicate an erosional unconformity between a cool, moist and a drier and/or warmer interval. This sharp transformation in the composition of the pollen spectra 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 and 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

CLASS PELECYPODA

Order Prionodesmacea

Order Prionodesmacea (continued)

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 kansasensis (Baker)

Physa antatina Lea

Order Stylommatophora

Gastrocopta cristata (Pilsbry and Vanatta)

G. procera(Gould)

G. tappaniana(Adams)

Pupilla blandi Morse

Pupilla muscorum (Linné)

P. sinistra Franzen

Vertigo millum (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)

Order Chelonia

Emydoidea twentei (Taylor)

CLASS MAMMALIA

Order Edentata

Megalonyx sp.

Order Rodentia

Citellus sp.

cf. Geomys

Castoroides cf. ohioensis Foster

Microtus pennsylvanicus (Ord)

Order Proboscidea

Mammuthus sp.

Order Artiodactyla

Camelops sp.

Order Perissodactyla

Equus scotti Gidley

Equus sp.

Age and Correlation.- Kapp (1962) tentatively correlated the Adams local fauna with the Illinoian Doby Springs and Berends local faunas on the occurrence of spruce pollen. The presence of spruce at these three sites represent 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, 1962) and the mollusks (Miller, this report) indicate a trend towards a warmer climate between the time the Doby Springs and Mount Scott faunas 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, occurs 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 the Doby Springs local fauna (locality 5).

Habitat.- The medium to coarse, cross-bedded sands from which the fauna was recovered (Hibbard and 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 woodland 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 and Taylor, 1960). A relatively southern element represented by Gastrocopta procera, G. cristata, Physa anatina, and Helicodiscus singleyanus, reaches as far south 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°

to 20° F., with normal summer temperatures of 65° to 70° F. (Visher, 1954). The precipitation was perhaps similar to that now occurring in Meade County, about 18.43 inches per year (Frye, 1942), but because of the lower evapotranspiration rates during the warm months (Visher, 1954), it was more effective.

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 N½ SW¼ 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 and Taylor (1960) listed 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 and Benson (1962, on the Ostracods). Kapp (1962) has recorded the pollen found associated with the Doby Springs local fauna.

Faunal List.

CLASS OSTRACODA

Candona nyensis Gutentag and Benson

CLASS PELECYPODA

Order Prionodesmacea

Anodonta grandis Say

Uniomerus tetralasmus (Say)

Order Teleodesmacea

Sphaerium occidentale Prime

Order Teleodesmacea (continued)

Sphaerium rhomboideum (Say)

S. striatinum (Lamarck)

S. sulcatum (Lamarck)

Pisidium casertanum (Poli)

P. compressum Prime

P. nitidum Jenyns

P. obtusale Pfeiffer

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 (Linné)

Gyraulus circumstriatus (Tryon)

G. deflectus (Say)

G. parvus (Say)

Helisoma anceps (Menke)

H. trivolvis (Say)

Promenetus exacuous kansasensis (Baker)

Order Basommatophora (continued)

Promenetus umbilicatellus (Cockerell)

Physa anatina Lea

P. gyrina Say

P. skinneri Taylor

Aplexa hypnorum (Linné)

Ferrissia meekiana (Stimpson)

Laevapex fuscus (Adams)

L. kirklandi (Walker)

Order Stylommatophora

Strobilops labyrinthica (Say)

Gastrocopta armifera (Say)

G. contracta (Say)

G. cristata (Pilsbry and Vanatta)

G. holzingeri (Sterki)

G. procera (Gould)

G. tappaniana (Adams)

Pupoides albilabris (Adams)

Pupilla blandi (Morse)

P. muscorum (Linné)

Vertigo elatior (Sterki)

V. milium (Gould)

V. ovata (Say)

Vallonia gracilicosta Reinhardt

V. parvula Sterki

cf. Succinea

Oxyloma retusa (Lea)

Discus cronkhitei (Newcomb)

Order Stylommatophora (continued)

Helicodiscus parallelus (Say)

Deroceras laeve (Müller)

Euconulus fulvus (Müller)

Retinella electrina (Gould)

Hawaiia minuscula (Binney)

Zonitoides arboreus (Say)

Stenotrema leai (Binney)

Cionella lubrica (Müller)

CLASS OSTEICHTHYES

Catostomus commersoni (Lacepède)

Semotilus atromaculatus (Mitchill)

cf. Hybopsis gracilis (Richardson)

Pimephales promelas Rafinesque

Cyprinidae sp.

Ictalurus melas (Rafinesque)

Lepomis cf. L. cyanellus Rafinesque

Perca flavescens (Mitchill)

CLASS AMPHIBIA

Order Salienta

Bufo "Americanus group"

CLASS REPTILIA

Order Squamata

Ophisaurus attenuatus Baird

CLASS MAMMALIA

Order Insectivora

Sorex arcticus Kerr

S. cinereus Kerr

Order Insectivora (continued)

Sorex palustris Richardson

Blarina brevicauda brevicauda (Say)

Order Rodentia

Citellus cf. C. richardsonii (Sabine)

Citellus tridecemlineatus (Mitchill)

Thomomys sp.

Geomys bursarius (Shaw)

Castorid, genus and species indet.

Peromyscus cf. P. cochrani Hibbard

P. oklahomensis Stephens

Onychomys cf. O. leucogaster (Wied-Neuwied)

Ondatra zibethica (Linné)

Microtus pennsylvanicus (Ord)

Zapus hudsonius transitionalis Klingener

Order Carnivora

a large form, fam. indeterminate

a small form, fam. indeterminate

Order Proboscidea

Mammuthus sp.

Order Lagomorpha

Lepus sp.

Order Artiodactyla

Camelops sp.

Antilocaprid sp.

Bison cf. B. latifrons (Harlan)

Order Perissodactyla

Equus cf. E. niobrarensis Hay

Equus sp.

Age and Correlation. The Doby Springs 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 Big Spring Ranch local faunas (Smith, 1958; Stephens, 1960; Hibbard and Taylor, 1960). However, studies of the pollen, collected from samples of sediment associated with these assemblages (Kapp 1962), indicate that the Doby Springs fauna is only equivalent to the lower part of the Butler Spring local fauna. This lower portion of the Butler Spring local fauna (localities 2, 3, 4, and 5 of Hibbard and Taylor, 1960), has been designated the Adams local fauna by Kapp (1962).

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

Habitat - Stephens (1960) recognized four 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 III 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

TABLE III.-Summary of Local Habitats Represented by the Mollusks of the Doby Springs Local Fauna. R=<25; S=26-49; C=50-100; A=>100 shells. (Modified from Hibbard and Taylor, 1960)

Habitat	Species	Locality			
		1	2	4	5
Semiaquatic: among vegetation and debris near water's edge.	Oxyloma retusa	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	-	A	A
	V. milium	R	-	C	A
	V. elatior	S	-	-	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	-	A	-
	Zonitoides arboreus	R	R	A	-
	Retinella electrina	R	-	R	S
	Euconulus fulvus	R	-	R	S
	Strobilops labyrinthica	R	-	R	-
	Helicodiscus parallelus	S	-	A	A
Sheltered areas: live among rocks, shrubs, grass, or in timbered situations.	Gastrocopta armifera	R	R	S	C
	G. contracta	-	-	R	-
	G. holzingeri	-	-	R	R

TABLE III (continued)

Habitat	Species	Locality			
		1	2	4	5
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	R	C	A
	Pupoides albilabris	-	-	R	R
	Hawaiia minuscula	R	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[1]
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[1]	-	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	-

[1]. = cf.

TABLE III (continued)

Habitat	Species	Locality			
		1	2	4	5
	Aplexa hypnorum	R	-	R	R[1]
	Ferrissia meekiana	-	-	R	R
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 to significant seasonal drying.	Uniomerus tetralasmus	R	-	R	R
	Lymnaea stagnalis jugularis	R	-	R	R
	Sphaerium rhomboideum	R	-	R	-
	S. sulcatum	S	-	A	R
	Pisidium obtusale	-	-	R	R
	Gyraulus parvus	A	C	A	A
	Helisoma trivolvis	-	-	R	R
	Promenetus exacuous kansasensis	A	-	A	A
	Physa anatina	R	-	A	-
	Physa skinneri	R	R	R	-
	Laevapex fuscus	-	-	S	-
	L. kirklandi	-	-	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 striatinum	-	-	C	-
	Pisidium compressum	A	R	C	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	-

at least five feet. The carbonaceous dark-gray to black silty clay and silt from which P. lacustris (Hibbard and Taylor, 1960, p. 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, 1962). These plants provided suitable habitats for Sphaerium sulcatum, S. rhomboideum, Valvata tricarinata, Gyraulus parvus, Promenetus exacuous 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 meekiana. 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 hygrophillic species, which also lived in the marsh near the lake margin. The vegetational cover postu-

lated for this area by Kapp (1962, p. 74), "...probably included a few ash trees, some willow, and possibly spruce, along with grass, occasional sedges, some cattail or burreed and a ground cover of moss". It would have provided suitable habitats for most of the terrestrial species listed in Table III.

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

Climate.- Most of the molluscan species present in the Doby Springs local fauna are now living in the Great Plains well to the north of the fossil locality. The Lake Okoboji region of Iowa, contains 46 of the 57 species still extant. 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 occurring 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, Laevapex kirklandi) 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° to 70° F. (Visher, 1954, map 5). The normal annual precipitation in this area is about 18 to 20 inches (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° to 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° to 70° F. The normal annual precipitation was about 18 to 20 inches, 8 to 10 inches of which fell during the summer months. The normal evaporation during the warmer part of the year was between 30 to 35 inches, compared with today's 50 to 60 inches in Harper County (Visher, 1954, map 483). The normal winter temperatures were probably between 15° to 20° F.

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 sinkhole deposits, after collapse of the underlying Crooked Creek Formation. The fauna collected from these sediments has been summarized by Hibbard and Taylor (1960, p. 55-57) from previous reports (Herrington and Taylor, 1958; Hibbard , 1956b; Mengel, 1952; Rinker and Hibbard, 1952; Smith, 1954, 1958; Starrett, 1956; Taylor, 1954; Taylor and Hibbard, 1955). Kapp (1962) has recently analysed the pollen from the Berends local fauna locality.

Faunal list.

CLASS PELECYPODA

Order Teleodesmacea

Sphaerium lacustre (Müller)

S. securis Prime

S. sulcatum (Lamarck)

Pisidium casertanum (Poli)

P. compressum Prime

P. nitidum Jenyns

P. obtusale Pfeiffer

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 (Linné)

Helisoma anceps (Menke)

H. trivolvis (Say)

Planorbula armigera (Say)

Promenetus exacuous kansasensis (Baker)

Physa anatina Lea

P. gyrina Say

P. skinneri Taylor

Aplexa hypnorum (Linné)

Order Stylommatophora

Strobilops labyrinthica (Say)

Gastrocopta armifera (Say)

G. cristata (Pilsbry and Vanatta)

G. procera (Gould)

G. tappaniana (Adams)

Pupoides albilabris (Adams)

Vertigo milium (Gould)

V. ovata (Say)

Order Stylommatophora (continued)

Vallonia gracilicosta Reinhardt

V. parvula Sterki

cf. Succinea

Oxyloma retusa (Lea)

Helicodiscus parallelus (Say)

Deroceras laeve (Müller)

Euconulus fulvus (Müller)

Hawaiia minuscula (Binney)

Stenotrema leai (Binney)

CLASS OSTEICHTHYES

Lepisosteus sp.

Esox masquinongy Mitchill

Catostomus commersoni (Lacépède)

Notemigonus crysoleucus (Mitchill)

Semotilus cf. S. atromaculatus (Mitchill)

Semotilus sp.

Cyprinidae, indet.

Ictalurus melas (Rafinesque)

I. punctatus (Rafinesque)

Lepomis cf. L. cyanellus Rafinesque

Perca flavescens (Mitchill)

Aplodinotus grunniens Rafinesque

CLASS REPTILIA

Order Chelonia

Unidentifiable turtle remains

CLASS AVES

Order Pelicaniformes

Pelicanus erythrorhynchus Gmelin

CLASS MAMMALIA

Order Insectivora

Sorex cf. S. cinereus Kerr

Blarina cf. B. brevicauda (Say)

Order Rodentia

Casteroides sp.

Paradipoides stovalli Rinker and Hibbard

Geomys sp.

Perognathus cf. P. hispidus Baird

Peromyscus berendsensis Starrett

Ondatra triradicatus Starrett

Microtus pennsylvanicus (Ord)

Pedomys cf. P. ochrogaster (Wagner)

Order Carnivora

Canis latrans Say

Order Proboscidea

Mammuthus cf. M. columbi (Falconer)

Order Lagomorpha

Leporidae, indet.

Order Perissodactyla

Equus sp.

Age and Correlation.- The sediments containing the Berends local fauna overly the Pearlette ash, making them post-Kansan in age. Climatic implications of the pollen (Kapp, 1962) and

fauna (Hibbard and Taylor, 1960; Miller, this report), indicate that the assemblage lived 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 (1962) has interpreted the pollen spectrum associated with the Berends fauna as representing maximum Illinoian glaciation and considered it equivelant both to locality 5 of the Doby Springs and to the Adams local faunas. The climatic interpretation presented below, however, suggests 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 IV. Taylor (1954, p. 7) has interpreted the aquatic gastropods of this fauna as representing "...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 sometime is indicated by Valvata, which must have continuity in aquatic conditions." This interpretation is supported by the fishes (Smith, 1954), the sphaeriids (Herrington and Taylor, 1958), and by the additional aqautic mollusks reported herein.

The pollen spectrum (Kapp, 1962, [illegible] large percentages of

TABLE IV.-Summary of Local Habitats Represented by the Mollusks of the Berends Local Fauna. (Modified from Hibbard and Taylor, 1960)

Habitat	Species	Number of individuals*
Semiaquatic: among vegetation and debris near water's edge.	Oxyloma retusa	245
Hygrophilic: moist situations in leaf mold, under sticks and debris; shaded areas, not far from water.	Carychium exiguum	188
	Vertigo ovata	1127
	V. milium	21
	Gastrocopta tappaniana	737
	Deroceras laeve	30
Woodland: moist areas under leaf litter, down timber, among tall marsh grass.	Stenotrema leai	86
	Euconulus fulvus	1
	Strobilops labyrinthica	1
	Helicodiscus parallelus	8
Sheltered areas: live among rocks, shrubs, grass or in timbered situations.	Gastrocopta armifera	30
	G. holzingeri	29
Sheltered situations: these species are not restricted to a woodland habitat and can tolerate drier conditions.	Gastrocopta cristata	67
	G. procera	8
	Pupoides albilabris	12
	Hawaiia minuscula	581
	Vallonia parvula	23
	V. gracilicosta	7

*Based on material published in Taylor, 1954; Herrington and Taylor, 1958; Miller, this report.

TABLE IV (continued)

Habitat	Species	Number of individuals
Marginal situations: wet mud, sticks, stones or any other debris along water's edge; shallow ponds and protected spots.	Fossaria obrussa	62
	F. dalli	97
Shallow quiet water: small stream, pond, slough or marsh that may become dry during part of the year.	Pisidium casertanum	43/2
	Stagnicola reflexa	192
	S. caperata	50
	S. exilis	21
	Armiger crista	26
	Gyraulus circumstriatus	600
	Physa gyrina	135
	Aplexa hypnorum	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 subject to significant seasonal drying.	Sphaerium securis	7/2
	S. sulcatum	71/2
	Pisidium obtusale	6/2
	Gyraulus parvus	86
	Helisoma trivolvis	53
	Planorbula armigera	935
	Promenetus exacuous kansasensis	511
	Physa anatina	58
	P. skinneri	83
Perennial water: stream or	Sphaerium lacustre	2/2

TABLE IV (continued)

Habitat	Species	Number of individuals
lake with slow to moderate current; areas of still water; shallow spots with soft sand or mud substrate not affected by seasonal drying.	Pisidium compressum	322/2
	P. nitidum	66/2
	P. variabile	4/2
	Valvata tricarinata	337
	Helisoma anceps	17

conifers, grasses and composites, with only small quantities of deciduous tree pollen. The relative paucity of terrestrial species usually associated with deciduous woodlands can probably be accounted for by assuming a vegetation cover such as 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 northeastern Nebraska-northwestern Iowa region of the Great Plains presently contains most of the species of mammals, fishes and mollusks found in the Berends local fauna. The Berends assemblage appears to have lived at a time when climatic conditions were similar to those in the overlap area, with a normal annual temperature of about 45° F. (Visher, 1954). Normal summer temperatures averaged about 70° F. and normal winter temperatures 20° F. (Visher, 1954). The precipitation was between 20 to 30 inches (Visher, 1954), which is similar to the present precipitation in Beaver County. Most of this precipitation comes during the hotter part of the year, when it is most needed.

Summary of Illinoian Molluscan Faunas

The five 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 (1962) 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, 1962). Assuming a unidirectional climatic change for that interval of the Illinoian between the time represented by the glacial maximum Doby Springs and the warmer Mount Scott local faunas, it is possible to make a tentative chronology for the remaining faunas (the Berends, Adams and Butler Spring), on the basis of their climatic implications. This chronology based on mollusks suggests that the Berends probably represents the oldest followed by the Doby Springs, 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 of the Berends local fauna, the northeastern Nebraska-northwestern Iowa region,

implies that this fossil assemblage lived at a time when the climate in the panhandle of Oklahoma was similar to that now occurring in the Plains farther to the north. The winters probably averaged about 20° F., with average summer temperatures of 70° F. The precipitation was between 20 to 30 inches (Visher, 1954). This indicates a warmer, more moist climate than that of the time of the Doby Springs and Adams local faunas. Four species, Stagnicola exilis, Planorbula armigera, Sphaerium lacustre and S. securis occur in the Berends that are absent from the Doby Springs and Adams local faunas. Their presence has been interpreted to mean that the Berends assemblage probably lived in this area sometime in the Illinoian, before the interval represented by the Doby Springs and Adams local faunas.

The Doby Springs mollusks represent the coolest of the five Illinoian assemblages considered in this report. A similar conclusion was reached by Kapp (1962) after a study of the associated pollen. The distribution patterns of the Doby Springs mollusks have been interpreted to mean that this assemblage probably lived in a climate that combined winters similar to those in northwestern Nebraska-northwestern Iowa (the area in which the majority of the Doby Springs species currently occurs), 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° to 70° F., with winter temperatures of

between 15° to 20° F., and an annual precipitation of about 18 to 20 inches, 8 to 10 inches 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° to 20° F., with normal summer temperatures of 65° to 70° F. The annual precipitation was perhaps between 18 to 19 inches.

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. Many 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 first Illinoian occurrence in the Meade County area of Helicodiscus singleyanus, a relatively southern species. These two 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 the area. This influx

of southern species continued through at least that portion of the Illinoian represented 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 five Illinoian assemblages considered in this report. At Mount Scott ("The Lookout"), locality UM-K2-59 of the Mount Scott local fauna occurs stratigraphically below the Cragin Quarry local fauna of Sangamon age (Hibbard and 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 which the Mount Scott local fauna was recovered.

Several different lines of evidence, the overlap area of the mollusks, the large number of species with relatively southern distributions, the mammals (Hibbard, 1963), and the pollen (Kapp, 1962), all indicate that the Mount Scott local fauna is the warmest of the five 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° to 35° F., summers between 65° to 70° F., with between 20 to 30 inches of rainfall per year, 10 to 12 inches of which fell during the warmer part of the year.

The climatic changes which produced the fragmentation that resulted in the present impauperate molluscan fauna of the southwest Kansas-northwest Oklahoma region, appears to have occurred later in the Pleistocene after the time of the Jones local fauna of Wisconsin age (Hibbard and Taylor, 1960). A Carbon ^{14} date of >30,000 B.P. (M-1103) for the Jones local fauna has been reported by Crane and Griffin (1961). The Jones molluscan fauna containing 30 species is larger than the one presently inhabiting this area (29 species are listed in Hibbard and Taylor, 1960, as reported from the Meade County area); it contains an association of species (e.g., Pupilla blandi and Gastrocopta procera) which is unkown at the present time.

SYSTEMATIC DISCUSSION

The systematic discussion in this portion of the paper includes a listing of the mollusks from the Mount Scott and Doby Springs local faunas, and locality UM-K2-60. Previously unreported materials from the Berends, Butler Spring, and Adams 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.

The treatment of each species has not been uniform, since many of the mollusks have been quite thoroughly discussed in recent papers by Taylor (1960) and Hibbard and 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 ecologic and distributional data included for each species are in large part based on published information. The more important references include: Pilsbry (1940; 1946; 1948), Baker (1939), Leonard (1959), Taylor (1960), and Hibbard and Taylor (1960), for the terrestrial gastropods; Baker (1911; 1928a), Leonard (1959), Taylor (1960), and Hibbard and Taylor (1960), for the aquatic gastropods; and Baker (1928b), Herrington and Taylor (1958), Herrington (1962), Simpson (1914), and Ortmann (1919) 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 and 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 been estimated volumetrically. Intergers 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

Geologic 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, p. 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).

Material.-Doby Springs 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.-Early Pleistocene (Nebraskan) 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, p. 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, p. 145).

Material.-Doby Springs local fauna, locality 4, 213832 (½). Butler Spring local fauna, locality 1, 213899 (½).

Remarks.-The early Pleistocene record from the Sand Draw local fauna is based on fragmentary material, and was questionably referred to genus and species (Taylor, 1960, p. 45). 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 and Taylor, 1960, p. 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, p. 136).

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

Material.-Adams local fauna, locality 3, 208899 (½), 214072 (2/2).

Remarks.-Parts of the umbone region of two valves (UMMZ 214072) 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, p. 95).

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 (½).

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. This 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, p. 21).

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 ryckholti 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, p. 21).

Material.-Mount Scott local fauna, locality UM-K4-53, 20042 (12/2).

Remarks.-The one valve from the UM-K4-53 material which is complete, possesses a straighter hinge, truncated ends, and a more gently rounded ventral 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, p. 22).

Material.-Doby Springs local fauna, locality 4, 213833 (½). Mount Scott local fauna, locality UM-K4-53, 200643 (½); locality UM-K2-59, 200[illegible] (95/2), 200990 (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 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, p. 24).

Material.-Mount Scott local fauna, locality UM-K2-59, 208879 (5/2).

Remarks.-The Late Pliocene record is based on fragmentary material from the Benders local fauna, locality UM-K1-59, which, because of its condition was only questionably referred to this species (Miller, in press).

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, p. 26). Taylor (1960, p. 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.-Upper Pliocene (XI member Rexroad Formation) to Recent.

Distribution.-Most of North America from Panama to the Great Slave Lake, Northwest Territories (Hibbard and 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 two or three inches, 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).

Sphaerium sulcatum (Lamarck)

Plate I, Figs. 1-2

Geologic Range.-Lower Pliocene (Laverne Formation) 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 and 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.-Late Pleistocene (Illinoian) 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, p. 30). Taylor (Hibbard and Taylor, 1960, p. 77) states 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 and 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, 185739 (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.-Lower Pliocene (Laverne Formation) to Recent.

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 and Taylor, 1958, p. 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, p. 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, river 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 and Taylor, 1960; Herrington and 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) to Recent.

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

Ecology.-"Large ponds, bog ponds, lakes, creeks and rivers. Seems to prefer shallow water" (Herrington, 1962, p. 46). The form pauperculum Sterki, lives in lakes, now filling with marl, rivers, and large creeks, where it thrives in soft sand. Unlike the typical form, pauperculum does not apparently inhabit ponds (Herrington and 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 Pfeiffer

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 and Taylor, 1958, p. 18). Baker (1928b) reports it from mud, sand, and gravel bottom, at depths ranging from 0.8 meters to 5.6 meters.

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

Remarks.-Herrington and 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, p. 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 and Taylor, 1958, p. 17).

Ecology.-Pisidium walkeri lives "...in rivers, creeks, and small lakes..." (Herrington and Taylor, 1958, p. 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

Sub-Class Prosobranchia

Order Mesogastropoda

Family Valvatidae

Valvata tricarinata (Say)

Geologic Range.-Early Pliocene (Laverne Formation) to Recent.

Distribution.-"Eastern United States west to Iowa. Great Slave Lake south to Virginia and the Ohio River" (Baker, 1928a, p. 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 feet. 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, p. 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), 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 arrangement of the carinae in V. tricarinata have long been recognized (Robertson, 1915; Baker, 1928a; La Rocque, 1956; et al.), and given subspecific designations. However none of these variations have been definitely related to any known fixed set of conditions,

either geographic, stratigraphic, or ecologic, and do not deserve subspecific rank. In this work they are all treated as V. tricarinata.

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 and Taylor, 1960, p. 80).

Branson (1959) records this species from Hughes and Payne counties, Oklahoma. Fossil occurrences of P. lacustris in the Sandahl local fauna, McPherson County, Kansas (UMMZ uncat.), the Butler Spring local fauna, Meade County, Kansas (Hibbard and Taylor, 1960), the Doby Springs local fauna, Harper County, Oklahoma (see "Material", below), 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 feet 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 and Taylor, 1960).

Material.-Doby Springs local fauna, locality 4, 213789

(10,750), 185789 (3).

Sub-Class Pulmonata

Order Basommatophora

Family Ellobiidae

Carychium exiguum (Say)

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

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

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 northeastern Nebraska" (Hibbard and Taylor, 1960, p. 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, p. 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 are fragments of spires. These compare well with the more complete material from the Bar M local fauna (Taylor and Hibbard, 1955).

Taylor (Hibbard and Taylor, 1960, p.86) queried the presence of Acella haldemani in the Cudahy fauna of Lincoln County, Kansas (Frye, Leonard and Hibbard, 1943, p. 41), suggesting that this record may have been based on a misidentification of the spires or immature shells of Lymnaea stagnalis jugularis. Neither of these species have been recorded from this locality in subsequent molluscan faunal lists for the Cudahy fauna (Leonard, 1950; Frye and Leonard, 1952). However, Acella haldemani 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 increasing the probability that the original record from

Lincoln County was not based on Lymnaea stagnalis jugularis.

Stagnicola caperata (Say)

Geologic Range.-Middle Pliocene (Ogallala Formation) to Recent.

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

Ecology.-"In the Mississippi Valley this species seems to almost invariably occupy intermittent streams or small pools, ponds and ditches which dry up in 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 by the many rest varicies 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 wholly or partially dry" (Baker, 1928a, p. 263). Taylor (Hibbard and Taylor, 1960), has 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.

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

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

Distribution.-Eastern Quebec from approximately 65° longitude, west to Nebraska to about 100° longitude, north to Manitoba to near 50° latitude, south to southern Illinois and southern Kansas (37° 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 fields; 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 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 Cottrell pasture faunule (Miller, in press), which is equivalent to the Benders local fauna.

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

Ecology.-"The normal habitat of this species is in small bodies of water, as creeks, ponds, sloughs, bays, and marshy spots along river banks. It is at home on sticks, stones, and any other debris that may be in the water or along its edge" (Baker, 1928a, p. 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.

Fossaria dalli (Baker)

Geologic Range.-Early Pliocene (Laverne Formation) to Recent.

Distribution.-"Ohio to northern Michigan and Montana, south to Kansas and Arizona" (Baker, 1928a, p. 288. It has been col-

lected in Meade County, Kansas at the State Park (Leonard, 1943).

Ecology.-This species is semi-aquatic in its habits and only rarely is 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, 208708 (159); locality UM-K1-60, 213792 (8); locality UM-K2-59, 213660 (110). Recent, Harper County, Oklahoma.

Family Planorbidae

Armiger crista (Linne)

Geologic Range.-Late Pleistocene to 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 and Taylor, 1960, p. 101).

Ecology.-"'In ponds and marshes, even in those thickly overgrown. A. crista for the most part, tends toward malform-

ations with detached and distorted whorls. It is supposed that the malformations are caused by the vegetation' (Geyer, 1927, p. 149, translation)" (Hibbard and Taylor, 1960, p. 103). Goodrich (1932, p. 65) states that this snail "...lives upon waterlogged sticks and rotting leaves in stagnant water." In temporary pond situations, in southern Michigan, A. crista is believed to aestevate during the winter months, by burrowing into the mud (Kenk, 1949).

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° north latitude: south in Rocky Mountains to central New Mexico" (Taylor, 1954, p. 3). "In the Great Plains it ranges south to northern Nebraska" (Taylor and Hibbard, 1955, p. 14).

Ecology.-"Gyraulus 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, p. 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), 200617 (3800); locality UM-K1-60, 213795 (200); locality UM-K2-59, 213664 (7300).

Gyraulus parvus (Say)

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

Distribution.-"Eastern North America east to the Rocky Mountains from Florida northward to Alaska and northern British Columbia" (Baker, 1928a, p. 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, p. 377). In Meade County, Kansas, and Harper County, Oklahoma, this species was collected from Chara, growing in permanent 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), 200617 (5660); locality UM-K1-60, 213797 (1650); locality UM-K2-59, 213665 (226). Recent, Harper County, Oklahoma.

Gyraulus deflectus (Say)

Plate III, Figs. 5-7

Planorbis deflectus Say, 1824, p. 261, Pl. XV, fig. 8.

Planorbis hirsutus Gould, 1840, p. 196.

Planorbis obliquus DeKay, 1843, p. 62, Pl. IV, fig. 57a, b.

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

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

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

Gyraulus deflectus (Say), Taylor, 1960, p. 57.

Gyraulus borealis Westerlund, 1875, Malakozoologische Blätter, p. 77.

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 accompanying map 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 446527); Fairfax County, Potomac River at Mt. Vernon (USNM 572015); Potomac River at Alexandria. (UMMZ 156782).

District of Columbia: Anacostia, Poplar Point (USNM uncat.).

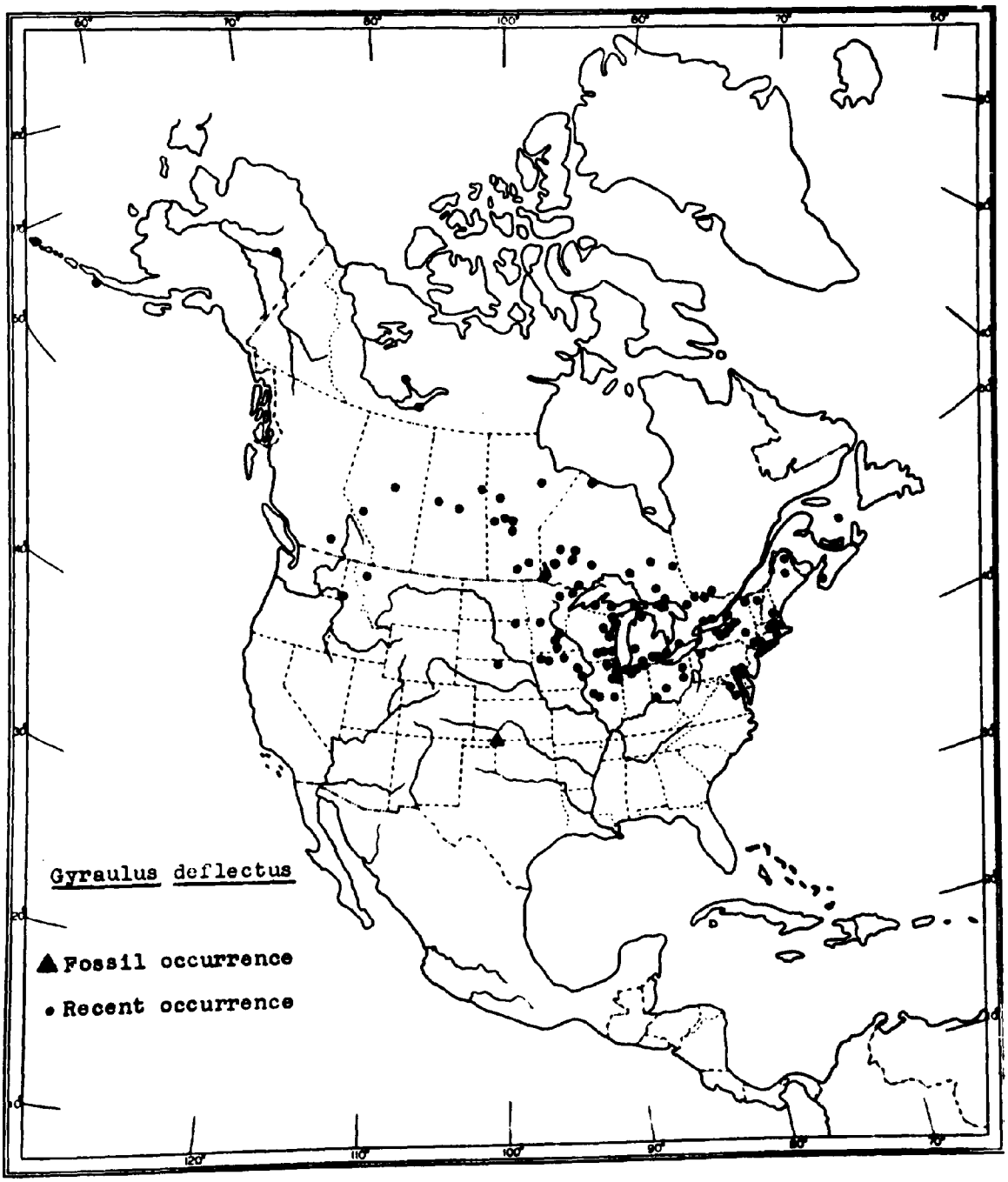


Fig. 5. Map showing distribution of Gyraulus deflectus.

Ohio: Hamilton County, Cincinnati (USNM 121165a); 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 Nebraska 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., 9 miles east of Kalispell (UMMZ 181060).

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

British Columbia: Kamloops (USNM 392125).

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, p. 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, G. hirsutus, G. deflectus borealis, and G. borealis, are all junior synonyms of Gyraulus

deflectus.

The differentiae used by DeKay (1843, p. 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, p. 372) has tried to preserve the G. obliquus form in the nomenclatoral combination 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, sub-angular 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 distributional 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 eight lots of G. albus from Europe, in the University of Michigan Museum of Zoology collection, indicate 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 spiral sculpture when present is produced by the allignment 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.

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, p. 358).

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

Material.-Berends local fauna, 208823 (700).

Helisoma anceps (Menke)

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

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

Ecology.-"...primarily a river and creek species, not

living in large lakes" (Baker, 1928a, p. 319).

Material.-Berends local fauna, 208805 (17). Doby Springs local fauna, locality 1, 213714 (32); locality 2, 185705 (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) to Recent.

Distribution.-"Atlantic Coast and Mississippi River drainage, 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, p. 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), 213757 (2). Mount Scott local fauna, locality UM-K4-53, 200622 (10); locality UM-K2-59, 213701 (49). Recent, Harper County, Oklahoma.

Promenetus exacuous 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 and Taylor, 1960, p. 107).

Ecology.-"Promenetus exacuous is found in shallow, perennial or subpermanent, quiet-water bodies, such as ponds, oxbow lakes, marshes, and sloughs or backwaters along streams. It is usually on the submerged vegetation in such habitats" (Hibbard and Taylor, 1960, p. 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.-Taylor (Hibbard and Taylor, 1960, p. 106) has stated that "Pliocene to late Pleistocene series of P. kansasensis differ consistently from P. exacuous in that all or most shells have a sculpture of riblets instead of growth lines." Defined in this manner the shells from the Mount Scott local fauna are P. exacuous, and make untenable Taylor's placement of the nomenclatoral change from P. kansasensis to P. exacuous, sometime in the Sangamon, between the time the Cragin Quarry and Jinglebob local faunas lived (Hibbard and Taylor, 1960).

Examination of the P. kansasensis-P. exacuous complex from eleven faunas occurring in beds that range in age from Upper Pliocene (Saw Rock Canyon local fauna) through Wisconsin (Jones local fauna), confirms Taylor's observation that there are no consistent differences in size, compression of whorls, or strength of carina through time. However, the strengtn of the axial sculpture, its persistence to the adult stage, and the proportion

of riblet to non-riblet individuals in a given population also appear to be inconsistent.

There is a higher proportion of non-riblet to riblet individuals in the Pliocene Saw Rock Canyon local fauna than in the younger Bender local fauna population from locality UM-A1-59. The Promenetus examined from the secuence of Pleistocene faunas, which range from Nebraskan-Aftonian (Dixon and Sand Draw local faunas) through the late Illinoian (Mount Scott local fauna), seem to indicate a trend toward a decrease in the proportion of riblet to non-riblet individuals. This trend appears to be reversed in the later 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 five lots of Recent shells examined in the University of Michigan Museum of Zoology collections (UMMZ 47019; 36844; 179041; 179049; 179038) contain individuals in which all or most possess well developed axial riblets in the adults.

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

(1) The two types of sculpture may represent distinct sympatric species which have existed together since at least the Saw Rock Canyon fauna. The fluctuating proportions of riblet to non-riblet individuals in the different faunas may be

due to sampling error and/or selective environmental pressures.

(2) There may be two 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 and Taylor, 1960).

(3) The two types of sculpture may represent the extremes of variation within one very variable species, with the changes in the proportion of riblet to non-riblet 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 two species if they occur together in the same fauna. Taylor (Hibbard and Taylor, 1960, p. 104) in a discussion of the variability of P. kansasensis states 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 individuals in a population cannot be used to separate these two 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 form, the younger Cragin

Quarry local fauna, which is located approximately 50 feet 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 form is dominant.

There is the possibility that the shells possessing strong riblet sculpture in the Cragin Quarry local fauna may 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 two mammals, Notiosorex crawfordi and Dasypterus golliheri (Hibbard and 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 populations. More faunas must be studied before it can be determined whether the observed variations in the populations of the P. kansasensis-P. exacuous complex are the result of environmental or genetic differences. It seems best at this stage to recognize the two types of populations, i.e., those composed predominantly of shells with riblets, and those in which the non-riblet shells are in the majority, with the subspecific names Promenetus exacuous kansasensis and P. exacuous exacuous, respectively.

Promenetus exacuous kansasensis (Baker)

Geologic Range.-Middle Pliocene (Ogallala Formation) to Late Pleistocene (Kingsdown Formation).

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 and Taylor, 1960).

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

Material.-Berends local fauna, 208908 (449). Doby Springs local fauna, locality 1, 213715 (257); locality 4, 208911 (950); locality 5, 213771 (350).

Promenetus umbilicatellus (Cockerell)

Geologic Range.-Late Pliocene (Rexroad Formation) to recent.

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 and 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 and 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-K2-59, 213666 (5200). Locality UM-K2-60, 214187 (2).

Family Ancylidae

Ferrissia meekiana (Stimpson)

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.- "Probably the species ranges over most of the eastern United States. It is known from scattered localities in Alabama, Missouri, Virginia, the District of Columbia, and from Iowa eastward to New York" (Hibbard and Taylor, 1960, p. 113). Leonard (1959) has reported it in Kansas.

Ecology.- Leonard (1959) collected this species from three different localities in Kansas: (1) Ottawa County State Lake, where it was found living on the underside of lily pond leaves in slightly turbid water; (2) Atchison County Lake, in Typha, duckweed, and Troidea, inhabiting quiet clear water approximately 1 foot deep; and (3) Miami County State Lake, where it was found near shore in about one foot of water living on oak leaves, elm and submerged terrestrial grasses.

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.- The validity of the genus Gundlachia has long been a source of controversy among malacologists. The problem lies in determining whether the formation of a septum is a genetically fixed capability characterizing the genus Gundlachia, or is only an ecologic response that can occur in other ancylids.

Leonard (1959) following Pilsbry in the belief that the septate condition is genetically controlled, has placed the

Recent Kansas material of meekiana in Gundlachia.

Taylor (1960; Hibbard and Taylor, 1960) considered the septate forms ecologic variants, and placed meekiana in the genus Ferrissia. The writer agrees with Basch (1959a) who concluded that the validity of the genus Gundlachia was still unclear. However, for purposes of consistency in the nomenclatural treatment of the fossil material from the Meade County area, meekiana has been assigned to Ferrissia.

Laevapex fuscus (Adams)

Plate III, Fig. 4

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

Distribution.-"Massachusetts west to the Mississippi Valley, south to New Orleans" (Baker, 1928a, p. 405).

Ecology.-"This species lives on stones, reeds, logs, or the like in quiet or gently flowing shallow water" (Hibbard and Taylor, 1960, p. 114).

Material.-Doby Springs local fauna, locality 4, 208916 (27). Mount Scott local fauna, locality UM-K4-53, 200623 (17); locality UM-K1-60, 213804 (75); locality UM-K2-59, 213703 (6).

Remarks.-Basch (1959b) has found sufficient differences between the reproductive systems of Ferrissia (s.s.) and Ferrissia (Laevapex) to warrant their separation; hence in this classification Laevapex is given generic rank.

Laevapex kirklandi (Walker)

Geologic Range.-Late Pleistocene (Illinoian) to Recent. The first occurrence of this species in the southwest Kansas-northwest Oklahoma region is from the Doby Springs local fauna.

Distribution.-"Wisconsin and Michigan south to eastern Kansas and Arkansas, east to New Jersey and Virginia" (Hibbard and Taylor, 1960, p. 114).

Ecology.-Judging by the comments made by Baker (1928a) and Leonard (1959), this species appears to prefer a firm smooth substrate in clear shallow water.

Material.-Doby Springs local fauna, locality 4, 213825 (8). Mount Scott local fauna, locality UM-K1-60, 213805 (68); locality UM-K3-60, 214174 (5).

Family Physidae

Physa anatina Lea

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

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, p. 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) to Recent.

Distribution.-Probably found throughout most of North America north of Mexico. Baker (1928a, p. 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 of 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 bottom of 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, p. 454).

Material.-Berends local fauna, 208817 (97). Doby Springs

local fauna, locality 4, 208913 (300). Mount Scott local fauna, locality UM-K4-53, 208926 (270); locality UM-K1-60, 213801 (45); locality UM-K2-59, 213869 (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, XV, 3, p. 55 (non Physa fontinalis minor Moquin-Tandon, 1855, pp. 451 and 452).

Physa skinneri Taylor, 1954. Taylor and Hibbard, 1955; Hibbard and 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 and 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 suppliments the one published in Hibbard and Taylor (1960, p. 119-120). The accompanying map 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

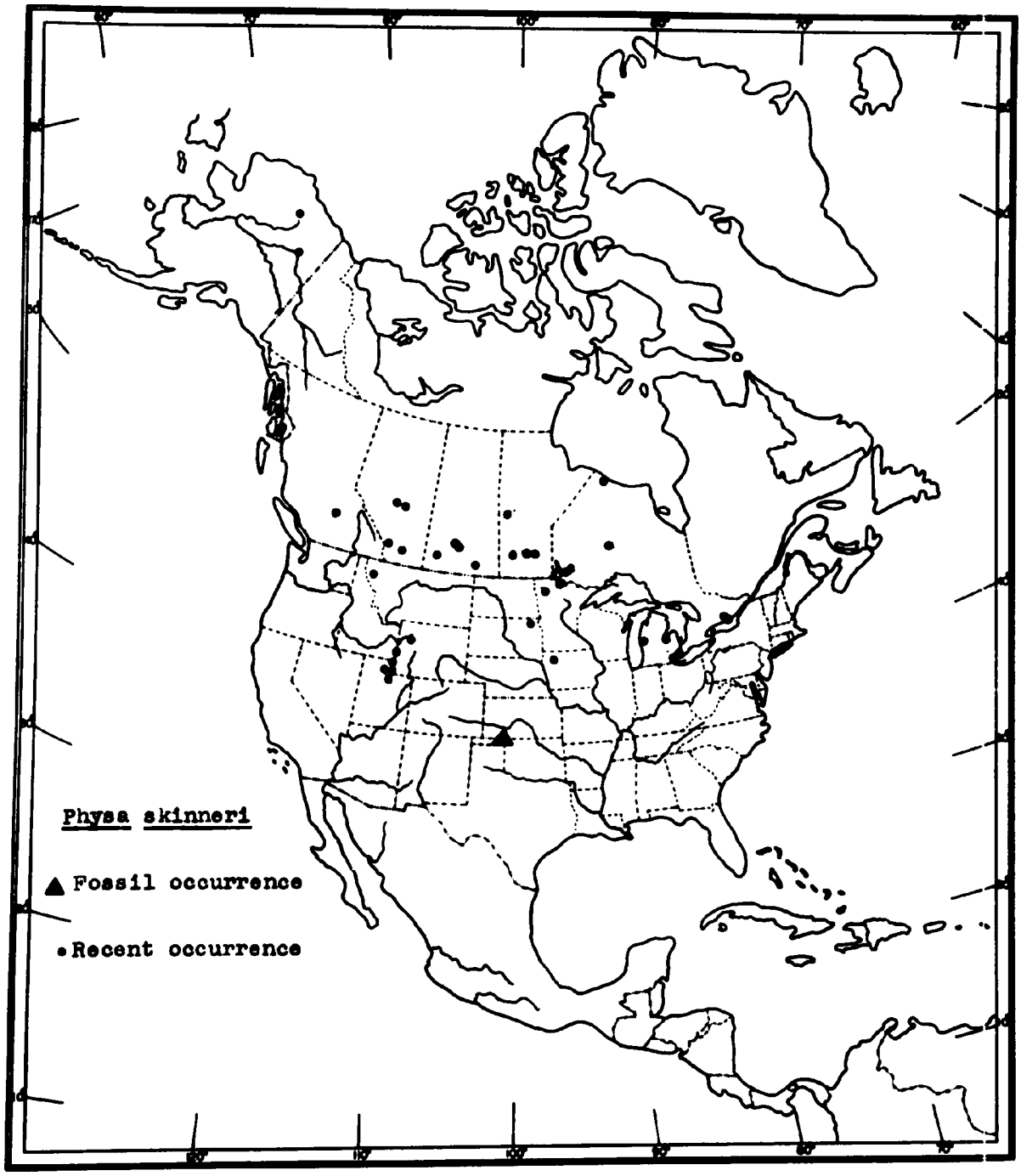


Fig. 6. Map showing distribution of Physa skinneri.

Hills (UMMZ 214556). Shore, Hastings Lake, 30 miles east of Edmonton (UMMZ 214159).

Manitoba: Pothole 9, near Minnedosa (UMMZ uncatslogued). 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).

Iowa: Palo Alto County, Elbow Lake, Ruthven (UMMZ 157548). Palo Alto County, Trumbell Lake (UMMZ 157549). Palo Alto County, 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 labels 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 and Taylor, 1960, p. 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, 208917 (97). Doby Springs local fauna, locality 1, 213722 (1,; locality 4, 208914 (21). Mount Scott local fauna, locality UM-K4-53, 208727 (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, p. 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	Width	Height of Aperture	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.(	2.25
3.12	2.12	2.5	2.25

Height	Width	Height of Aperture	Number of Whorls
3.5	2.12	2.6	2.25
3.5	2.25	2.5	2.5

Examination of this series of syntypes of P. s. 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 Gouin-Tandon, 1855. The first available name for this species is Physa skinneri Taylor.

Aplexa hypnorum (Linné)

Geologic Range.-Early Pleistocene (Aftonian) to Recent.

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.-"Aplexa hypnorum is a species of swales and intermittent streams or stagnant pools in Wisconsin, as far as present data goes. It is especially abundant in woodland pools which become dry in summer, in company with Stagnicola caperata, Physella hildrethiana, and Sphaerium occidentale" (Baker, 1928a, p. 474).

Material.-Berends local fauna, 208831 (25). Doby Springs local fauna, locality 4, 208943 (4); locality 5, 213793 (1). Mount Scott local fauna, locality UM-K4-53, 200401 (142); locality UM-K2-59, 213672 (500).

Order Stylommatophora

Family Strobilopsidae

Strobilops labyrinthica (Say)

Plate III, Figs. 8-10

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

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, p. 167).

Material.-Berends local fauna, 208799 (1). Doby Springs local fauna, locality 1, 213741 (1); locality 4, 208917 (4). Mount Scott local fauna, locality UM-K4-53, 208640 (339); 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 labyrinthica 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, are probably based on fossil shells.

Family Pupillidae

Gastrocopta armifera (Say)

Geologic Range.-Early Pliocene (Laverne Formation) to Recent.

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

Material.-Berends local fauna, 208921 (29). Doby Springs local fauna, locality 1, 213717 (3); locality 2, 195783 (1); locality 4, 208918 (27); locality 5, 213766 (97). Mount Scott local fauna, locality UM-K4-53, 208613 (1500); locality UM-K1-60, 213807 (50); locality UM-K2-59, 213779 (1150); locality UM-K3-60, 214179 (17). Locality UM-K2-60, 214189 (97). Recent, Harper and Beaver counties, Oklahoma.

Gastrocopta tappaniana (Adams)

Geologic Range.-Late Pliocene (Rexroad Formation, Saw Rock Canyon local fauna) to Recent.

Distribution.-"Ontario and Maine to Virginia and Alabama, west to South Dakota and Kansas, southwest to Arizona, but not known from the southeastern Atlantic States, Virginia to Florida" (Pilsbry, 1948, p. 899).

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, p. 177).

Material.-Berends local fauna, 208902 (96). Doby Springs local fauna, locality 1, 213729 (34); locality 2, 195794 (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) to Recent.

Distribution.-"Maryland to South Carolina and Alabama; west to South Dakota and Arizona" (Hibbard and Taylor, 1960, p. 123).

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, p. 32). Its distribution in Kansas is indicative of its ability to with stand periods of high temperatures and drought (Leonard and Goble, 1952).

Material.-Berends local fauna, 208925 (5). Doby Springs local fuana, locality 2, 195796 (1); locality 4, 208921 (110); locality 5, 213764 (15). Mount Scott local fauna, locality UM-K4-53, 200615 (2100); locality UM-K4-53, 200615 (2100); locality UM-K1-60, 213871 (19); locality UM-K3-60, 214175 (7).

Recent, Beaver and Harper counties, Oklahoma.

Gastrocopta cristata (Pilsbry and Vanatta)

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

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 (9). 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, 214186 (2). Recent, Beaver and Harper counties, Oklahoma.

Gastrocopta pellucida hordeacella (Pilsbry)

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

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 and Taylor, 1960, p. 123-124). "The northward extension along the Atlantic Coast

is very narrow, discontinuous so far as is known, and perhaps mainly confined to the coastal islands" (Pilsbry, 1948, p. 194).

Ecology.-"Uncertain. From the geographic distribution, frequent occurrence in the 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 grass roots, perhaps sometimes even on exposed slopes. So far as known, the snail has not been collected alive in the Plains" (Hibbard and Taylor, 1960, p. 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) to Recent.

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 and Taylor, 1960).

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

Material.-Doby Springs local fauna, locality 4, 208919 (1). Mount Scott local fauna, locality UM-K4-53, 213611 (930); locality UM-K1-60, 213808 (11); locality UM-K2-59, 213676 (735).

Gastrocopta holzingeri (Sterki)

Geologic Range.-Late Pliocene (Rexroad Formation, Saw Rock Canyon local fauna) to Recent.

Distribution.-"Ontario and western New York to Helena, Montana, south to Illinois, Kansas, and Albuquerque and Vesilla, New Mexico" (Pilsbry, 1948, p. 893).

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 summertime. G. holzingeri is not one of the predominating species of the fauna of Kansas. According to its general distribution in North America, it prefers decidedly cooler climates" (Franzen and Leonard, 1947, p. 334-335).

Material.-Berends local fauna, 208909 (29). Doby Springs local fauna, locality [illegible], 208940 (1); locality 5, 213749 (1). Mount Scott local fauna, locality UM-M4-53, 206413 (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 into 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 and Leonard, 1947, p. 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, 208654 (1280); locality UM-K1-60, 213814 (85); locality UM-K2-59, 213682 (5900); locality UM-K3-[illegible], 214176 (2). Recent, Beaver and Harper counties, Oklahoma.

Vertigo milium (Gould)

Geologic Range.-Late Pliocene (Rexroad Formation, Saw Rock Canyon local fauna) to Recent.

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, p. 945).

Ecology.-"Found in numbers under sticks, stones and leaves in moist situations along flood-plains and wooded stream borders" (Leonard, 1959, p. 195). 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, 208653 (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, p. 956, figs. 514; 515, number 6.

Vertigo elatior, Franzen and Leonard, 1947, p. 357, Pl. XX, fig. 2.

Vertigo gouldi, Hibbard and Taylor, 1960, p. 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 accompanying map is based on material examined in the collections of the University Museum of Zoology, United States National Museum, and published records. The following is a list of peripheral localities:

British Columbia: Field, Pilsbry, 1948, p. 956.

Alberta: Laggan, Pilsbry, 1948, p. 956.

Manitoba: Ilford (UMMZ 180135).

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

Colorado: Lake George, Henderson, 1924, p. 136.

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

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

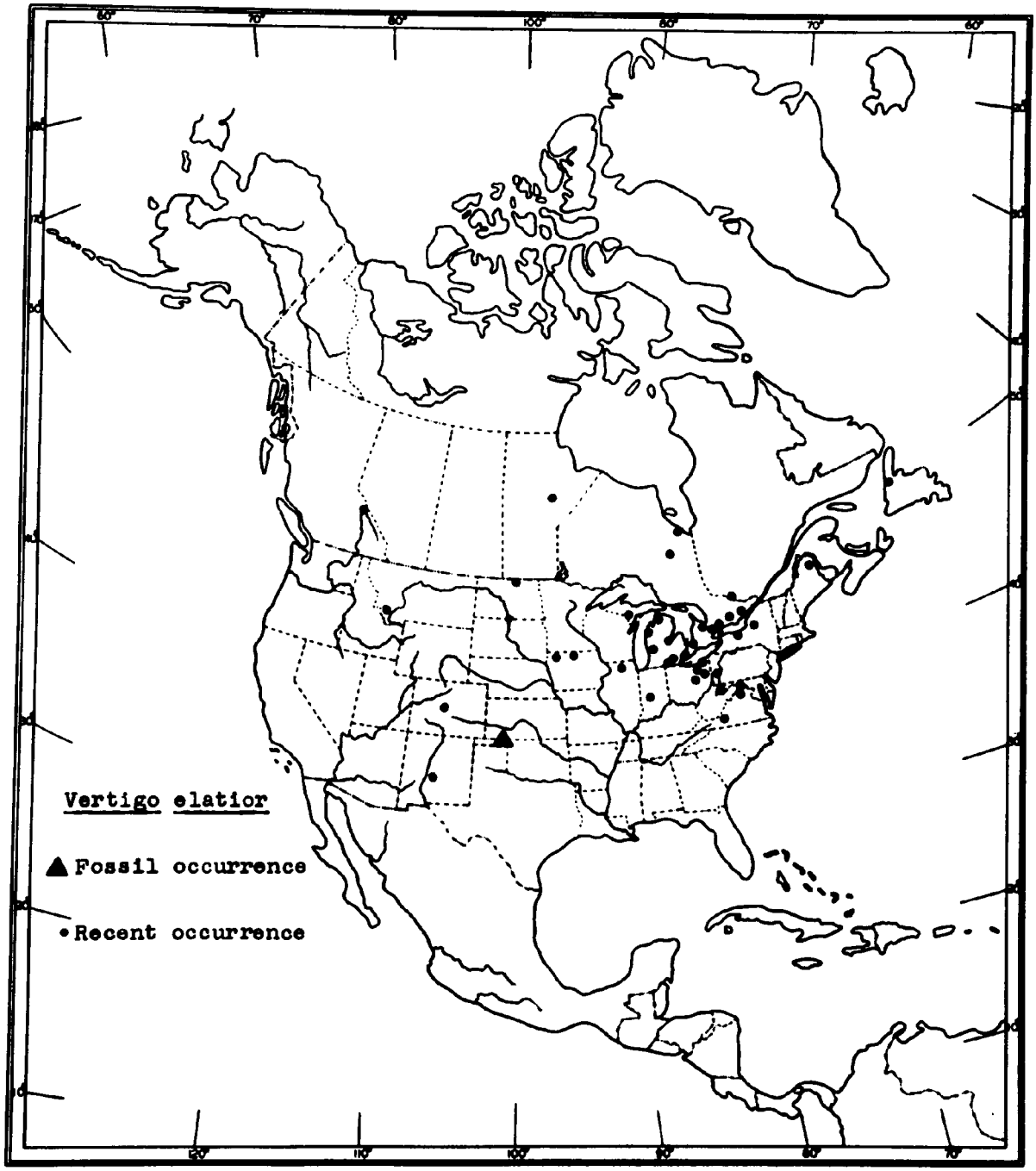


Fig. 7. Map showing distribution of Vertigo elatior.

(UMMZ 180150).

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

Newfoundland: Bonne Bay, Brooks and Brooks, 1940, p. 72.

Maine: Aroostok County, Caribou (USNM 160160).

New York: Staten Island (USNM 47497a).

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

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

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

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

Illinois: Winnebago County, Baker, 1939, p. 106.

Iowa: Cerrogordo County, Mason City, dredged in Big Slough (USNM 508437); West Lake Okoboji; drift on north shore of Miller's Bay (USNM 476262).

North Dakota: Polette County, Upsilon Lake, Winslow, 1921, p. 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 and Leonard, 1947, p. 357).

Material.-Doby Springs local fauna, locality 1, 213730 (30); locality 4, 209938 (145); locality 5, 213779 (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 apparently 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 columelar wall: and a subvertical, columelar 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, 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.

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

The description and illustration of V. gouldi in Franzen and Leonard (1947, p. 358, Pl. XX, fig. 3) suggest that this 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 and Leonard for Vertigo gouldi (The Cudahy Mine, sec. 2, T. 31 S., R. 29 W., Meade County, Kansas), tends to support this conclusion.

Pupoides albilabris (Adams)

Geologic Range.-Early Pliocene (Laverne Formation) to Recent.

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, p. 191).

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 and Leonard, 1947, p. 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, 213913 (36); 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 and Taylor, 1960, p. 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 and Taylor, 1960, p. 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 and Taylor, 1960, p. 131).

Material.-Doby Springs local fauna, locality 5, 213772 (21). Mount Scott local fauna, locality UM-K4-53, 208638 (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 mm. (height) x 1.60 mm. (width), to 3.5 mm. (height) x 1.75 mm. (width).

Pupilla muscorum (Linné)

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

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, p. 934).

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

Material.-Doby Springs local fauna, locality 1, 213727 (105); locality 4, 208939 (59); locality 5, 213773 (190).

Family Valloniidae

Vallonia gracilicosta Reinhardt

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

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 a cottonwood grove.

Material.-Berends local fauna, 208806 (7). Doby Springs local fauna, locality 1, 213725 (1650); locality 2, 185797 (12); locality 4, 208926 (720); locality 5, 213774 (1120). Mount Scott local fauna, locality UM-K4-53, 200650 (300); locality UM-K1-60, 213815 (2); locality UM-K2-59, 213697 (110); locality UM-K3-60, 214166 (32). Locality UM-K2-[illegible], 214193 (900).

Vallonia parvula Sterki

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

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

Ecology.-"Vallonia parvula inhabits wooded areas in both upland and floodplain 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, p. 189). In Meade County, it has been collected from leaf litter in a cottonwood grove near the west end of Lake Laribee.

Material.-Berends local fauna, 208910 (23). Doby Springs local fauna, locality 4, 208927 (4). Mount Scott local fauna, locality UM-K4-53, 208651 (561); locality UM-K1-60, 213816 (8); locality UM-K2-59, 213696 (145); locality UM-K3-60, 214168 (4). Recent, Harper County, Oklahoma.

Family Succineidae

Oxyloma retusa (Lea)

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

Distribution.-"Ohio west to Montana, south to Kansas" (Hibbard and Taylor, 1960, p. 141).

Ecology.-Oxyloma retusa has been collected in Kansas from roadside ditches, "...dead vegetation on the ground and from the wet banks near water" (Miles, 1958, p. 152). Taylor (1960) has reported this species from north-central Nebraska, where it was always found close to perennial water, crawling about on dead wood or among riparian vegetation.

Material.-Berends local fauna, 208910 (18). Doby Springs local fauna, locality 1, 213720 (2); locality 4, 208929 (12). Mount Scott local fauna, locality UM-K4-53, 208624 (143); locality UM-K2-59, 213697 (20).

cf. Succinea

Material.-Berends local fauna, 208934 (6). Doby Springs

local fauna, locality 1, 213719 (1[illegible]); locality 2, 185793 (13); locality 4, 208928 (1[illegible]); locality 5, 213780 (5). Mount Scott local fauna, locality UM-K4-53, 200741 (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 succinids cannot be satisfactorily placed to genus or species, on the basis of shell characteristics (Miles, 1958; Taylor, 1960). In the present study, Oxyloma retusa has been the only succinid that it has been possible to identify to species with reasonable confidence. All the remaining succinid material has been referred to cf. Succinea.

Family Endodontidae

Discus cronkhitei (Newcomb)

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

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 and 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, p. 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 laevi, and Gastrocopta tappaniana.

Material.-Doby Springs local fauna, locality 1, 213724 (132); locality 2, 185776 (14), 208930 (104). Mount Scott local fauna, locality UM-K3-54, 200605 (2); locality UM-K1-60, 213818 (10); locality UM-K2-59, 213791 (1); locality UM-K3-60, 214132 (1).

Helicodiscus parallelus (Say)

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

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

Ecology.-"It lives on decaying wood in shady or humid places, also on damp leaves" (Pilsbry, 1948, p. 627). "In eastern Kansas the species may occur in grassy fields, on sparsely timbered slopes, and on rocky ledges as well as in more moist places. In the more arid parts of the state, however, H. parallelus is limited to woodland cover, and usually occurs around decaying timber" (Leonard and Goble, 1952, p. 1039).

Material.-Berends local fauna, 208912 (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 (2??); 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.

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

Ecology.-This species has apparently never been taken alive in the High Plains (Hibbard and Taylor, 1960). The occurrence of fresh shells among the fossil bearing matrix that has been washed from various localities in the southwest Kansas-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, Harper County, Oklahoma.

Family Limacidae

Deroceras aenigma Leonard

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

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

Material.-Berends local fauna, 208927 (24). Doby Springs local fauna, locality 1, 213710 (9); locality 4, 208932 (42), 213779 (51). Mount Scott local fauna, locality UM-K4-53, 200604 (200); locality UM-K1-60, 213822 (17); locality UM-A2-59, 213690 (250).

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

Family Zonitidae

Euconulus fulvus (Müller)

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

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

Ecology.-"E. fulvus lives among leaves in well-shaded places and may usually be obtained by sifting where its presence would otherwise be unsuspected" (Pilsbry, 1946, p. 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, 208915 (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 (24); locality UM-K1-60, 213823 (3); locality UM-K2-59, 213824 (6).

Hawaiia minuscula (Binney)

Geologic range.-Late Pliocene (Rexroad Formation, Saw Rock Canyon local fauna) to Recent.

Distribution.-"North America from Alaska and Maine to Costa Rica...It is generally spread over every eastern and mid-western 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, 1948, pp. 421-423).

Ecology.-"Hawaiia minuscula is found under logs, sticks, stones and in clumps of grass in both floodplains and upland situations" (Leonard, 1959, p. 121). 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 Laribee, in Meade County State Park.

Material.-Berends local fauna, 213822 (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, 213698 (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.

Distribution.-North America from northern Canada south to Banana River, Costa Rica (Pilsbry, 1946). Its northern limit is placed by Dall (1905) at 71° 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, 1948, p. 492).

Material.-Doby Springs local fauna, locality 1, 213796 (25); locality 2, 185796 (2); locality 4, 208935 (146). Mount Scott local fauna, locality UM-K4-53, 208655 (150); locality UM-K1-60, 213796 (17); locality UM-K2-59, 213695 (131), 213699 (13); 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 is based on published records, and material examined in the University of Michigan Museum of Zoology (UMMZ), and the

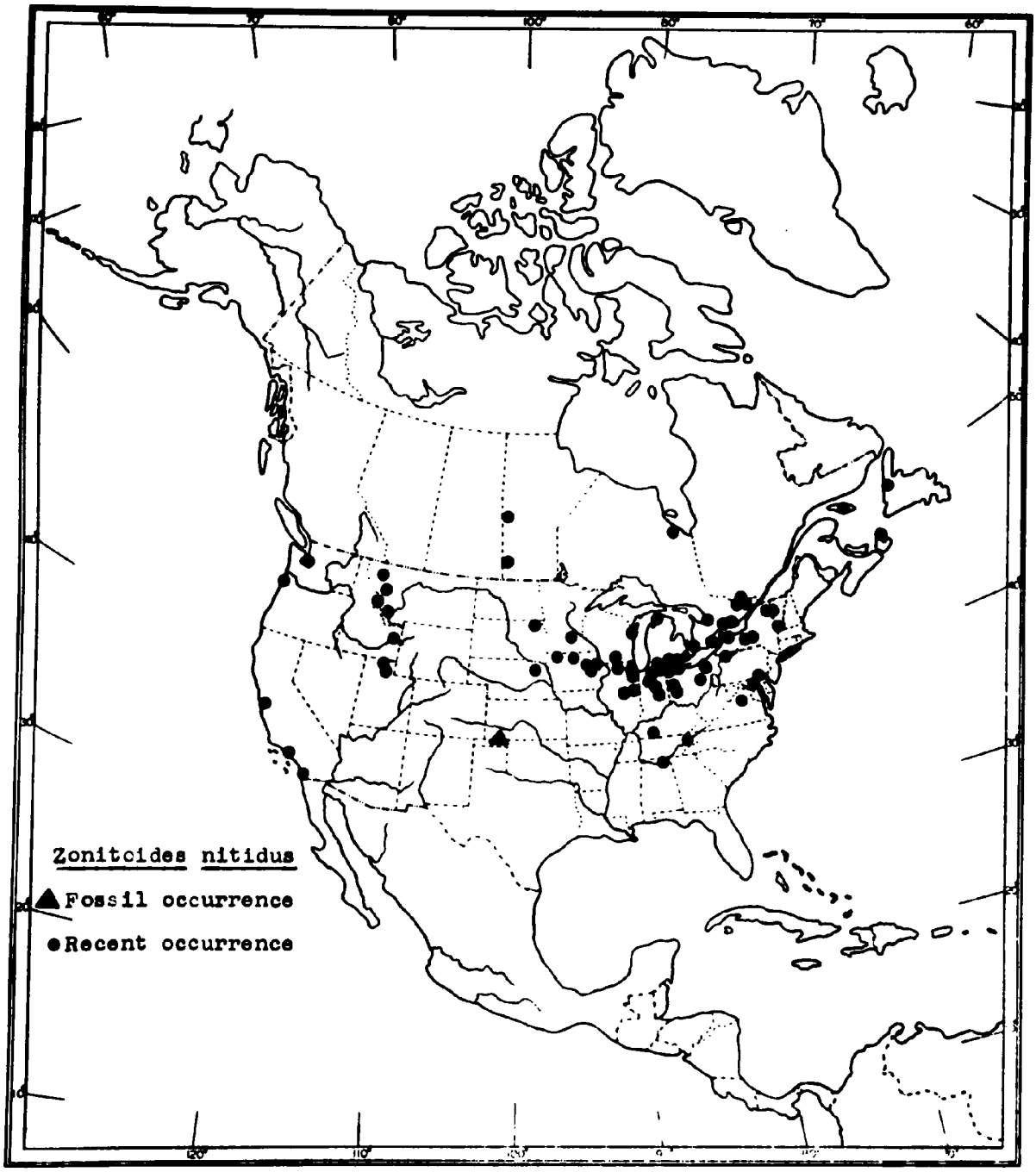


Fig. 8. Map showing distribution of Zonitoides nitidus.

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 and Brooks, 1943, p. 71.

Quebec: Anticosti Island, Pilsbry, 1948, p. 477.

Nova Scotia: Victoria County, MacMillan, 1953-54, p. 399.

Virginia: Orange County, Orange, UMMZ 115397.

Kentucky: Warren County, USNM 568444.

Tennessee: Knox County, Knoxville, USNM 38881.

Alabama: Jackson County, USNM 114596.

Iowa: Linn County, Cedar Rapids, USNM 507725; Dubuque County, Dubuque, USNM 507744; Bremer County, Waverly, USNM 507820; Cerro Gordo County, Clear Lake, USNM 507724; Dickinson County, West Lake Okoboji, USNM 525197.

Nebraska: Cuming County, Beemer, USNM 506141.

Utah: Morgan County, 3 miles east of Morgan, UMMZ 167031; Cache County, Logan, Blacksmith Fork of Bear River, UMMZ 167029.

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

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

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

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

Ecology.-"In Illinois Gastrodes 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, p. 79).

Goodrich (1932, p. 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, 213-789 (89); locality UM-K4-59, 21378' (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.

Retinella electrina (Gould)

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

Distribution.-"North America north of about latitude 33°, southward in the Rocky Mountains to Arizona and New Mexico" (Hibbard and Taylor, 1960, p. 143).

Ecology.-*Retinella 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 and Goble, 1952).

Leonard (1950, p. 37) reports that R. electrina is a common snail in the forested areas of eastern Kansas, "...where the annual rainfall is generally more than 35 inches, but it declines in frequency of occurrence toward the more arid Plains Border Province and is unknown in the Plains Province even where timber is locally available." 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, p. 19).

Material.-Doby Springs local fauna, locality 1, 213734 (15); locality 4, 213934 (5); locality 5, 213777 (31). Mount Scott local fauna, locality UM-A4-53, 213939 (107); locality UM-A2-59, 213699 (22).

Punctum minutissimum (Lea)

Plate II, Figs. 7-8

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, p. 645).

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

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

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, 1948, p. 679).

Ecology.-"S. monodon is a snail of damp places near the water..." (Pilsbry, 1940, p. 678). Baker (1939, p. 60) states that "...the habitat of Polygyra monodon is in lowlands, usually on the floodplains of rivers and creeks or the margins of lakes, in woodlands of oak, hickory, elm and willow."

Material.-Ferends local fauna, 200804 (73). Doby Springs local fauna, locality 4, 213793 (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.

Family Cionellidae

Cionella lubrica (Müller)

Plate I, Fig. 3

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

Distribution.-Holarctic. "Point Barrow, Alaska, and Queen Charlotte Islands to Labrador and Newfoundland, south in the East to Washington, D. C. and southern Missouri; in all the Western and Mountain States except California; to the Mexican boundary in Arizona; in the Sierra Madre of western Chihuahua" (Pilsbry, 1948, p. 1048).

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

Material.-Doby Springs local fauna, locality 4, 209914 (1); locality 5, 213781 (1). Mount Scott local fauna, locality UM-K3-60, 214171 (1).

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PLATE I

Sphaerium sulcatum (Lamarck), Mount Scott locality UM-K2-59.

Figs. 1, 2. Inner and outer views of right valve. X5, UMMZ 208885a.

Anodonta grandis Say, Doby Springs locality 4. Fig. 3. Outer view of right valve. X1, UMMZ 213832.

Pisidium obtusale Pfeiffer, Mount Scott locality UM-K2-59.

Figs. 4, 5. Inner and outer views of left valve. X10. UMMZ 208872a.

Pisidium subtruncatum Malm.

Fig. 6. Mount Scott locality UM-K4-53. Outer view of right valve. X10, UMMZ 200632.

Fig. 7. Jones Sink, lower level. Inner view of right valve. X10, UMMZ 195840a.

Cionella lubrica (Müller), Doby Springs locality 4.

Fig. 8. Aperteral view. X10, UMMZ 208994.

Sphaerium occidentale Prime, Mount Scott locality UM-K2-59.

Figs. 9, 10. Inner and outer views. X10, UMMZ 208880a.

Vertigo elatior Sterki, Doby Springs locality 5.

Fig. 11. Aperteral view. X10, UMMZ 213770a.

Oxyloma retusa (Lea), Mount Scott locality UM-K2-59.

Fig. 12. Aperteral view. X10, UMMZ 213967a.

Plate I



PLATE II

Sphaerium rhomboideum (Say), Doby Springs locality 1.

Figs. 1, 2. Inner and outer views of right valve. X5, UMMZ 213739a.

Uniomerus tetralasmus (Say), Doby Springs locality 4.

Figs. 3, 4. Inner and outer views of right valve. X1, UMMZ 208937a.

Fig. 5. Outer view of left valve showing umbonal sculpture. X5, UMMZ 208937b.

Punctum minutissimum (Lea), Mount Scott locality UM-K4-53.

Figs. 6-8. Apical, aperteral and basal views. X20, UMMZ 200236a.

Pisidium walkeri Sterki, Mount Scott locality UM-K1-60.

Figs. 9, 14. Inner and outer views of right valve. X10, UMMZ 208873a.

Pisidium variabile Prime, Mount Scott locality UM-K2-59.

Figs. 10, 11. Inner and outer views of left valve, X10, UMMZ 208887a.

Sphaerium securis Prime, Berends local fauna.

Figs. 12, 13. Inner and outer views of left valve. X10, UMMZ 208840a.

Sphaerium lacustre (Müller), Mount Scott locality UM-K4-53.

Fig. 15. Outer view of right valve. X5, UMMZ 200642a.



PLATE III

Zonitoides nitidus (Müller), Mount Scott locality UM-K4-53.

Figs. 1-3. Aperteral, basal and apical views. X10, UMMZ 213789a.

Laevapex fuscus (Adams), Doby Springs locality 4.

Fig. 4. Apical view. X10, UMMZ 208916a.

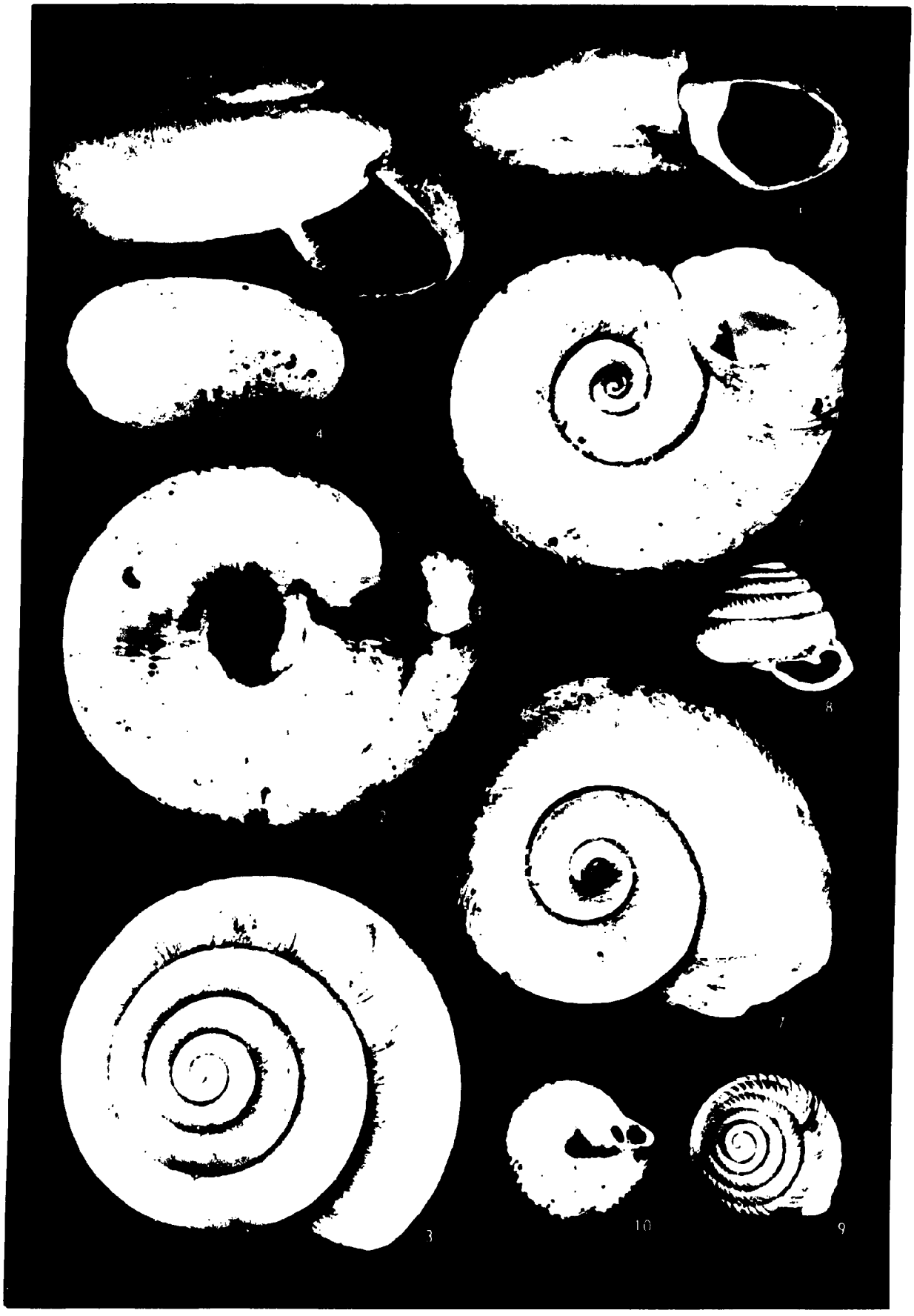
Gyraulus deflectus (Say), Doby Springs locality 1.

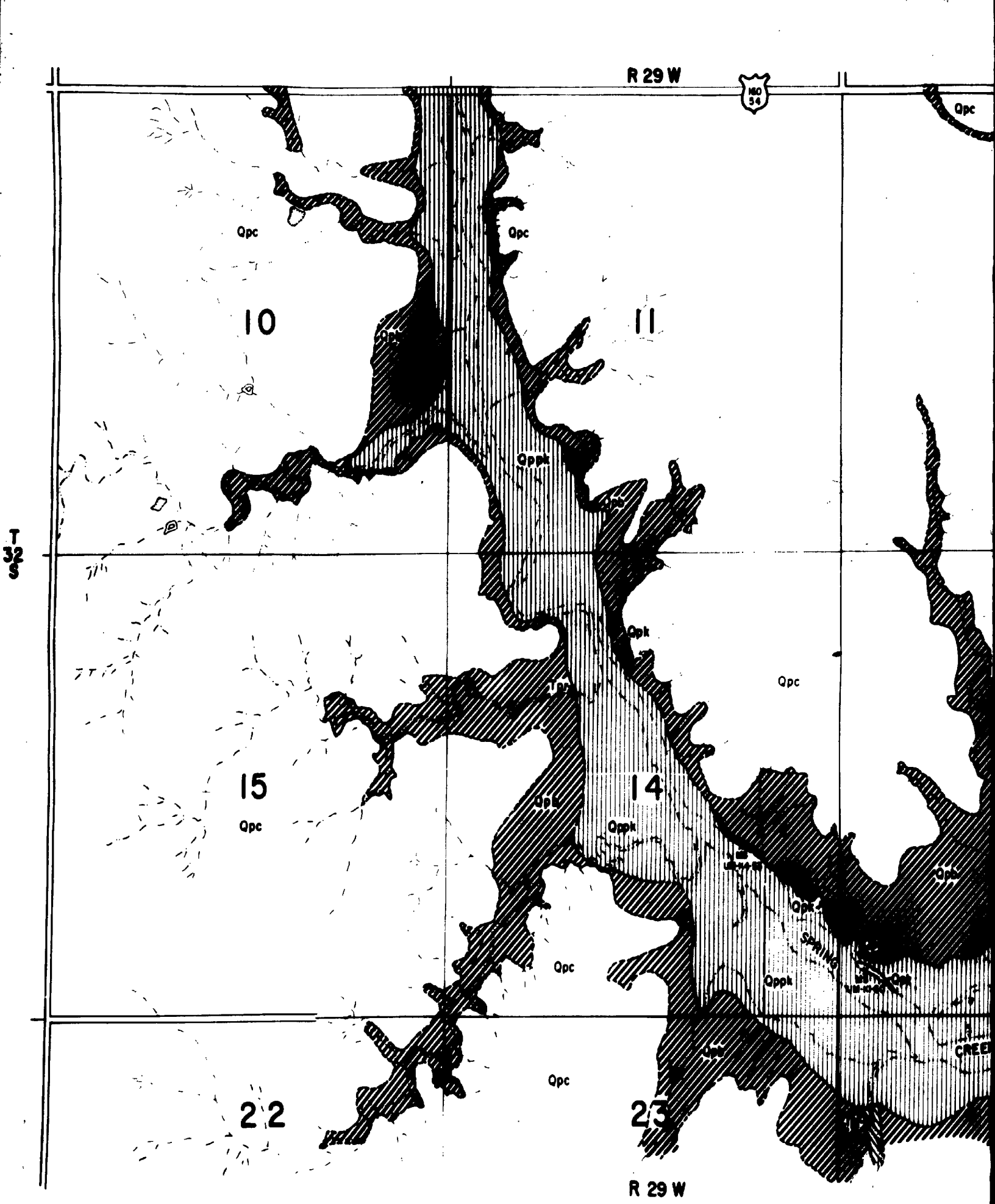
Figs. 5-7. Aperteral, basal and apical views. X10, UMMZ 213705a.

Strobilops labyrinthica (Say), Mount Scott locality UM-K4-53.

Figs. 8-10. Aperteral, apical and basal views. X10, UMMZ 200640a.

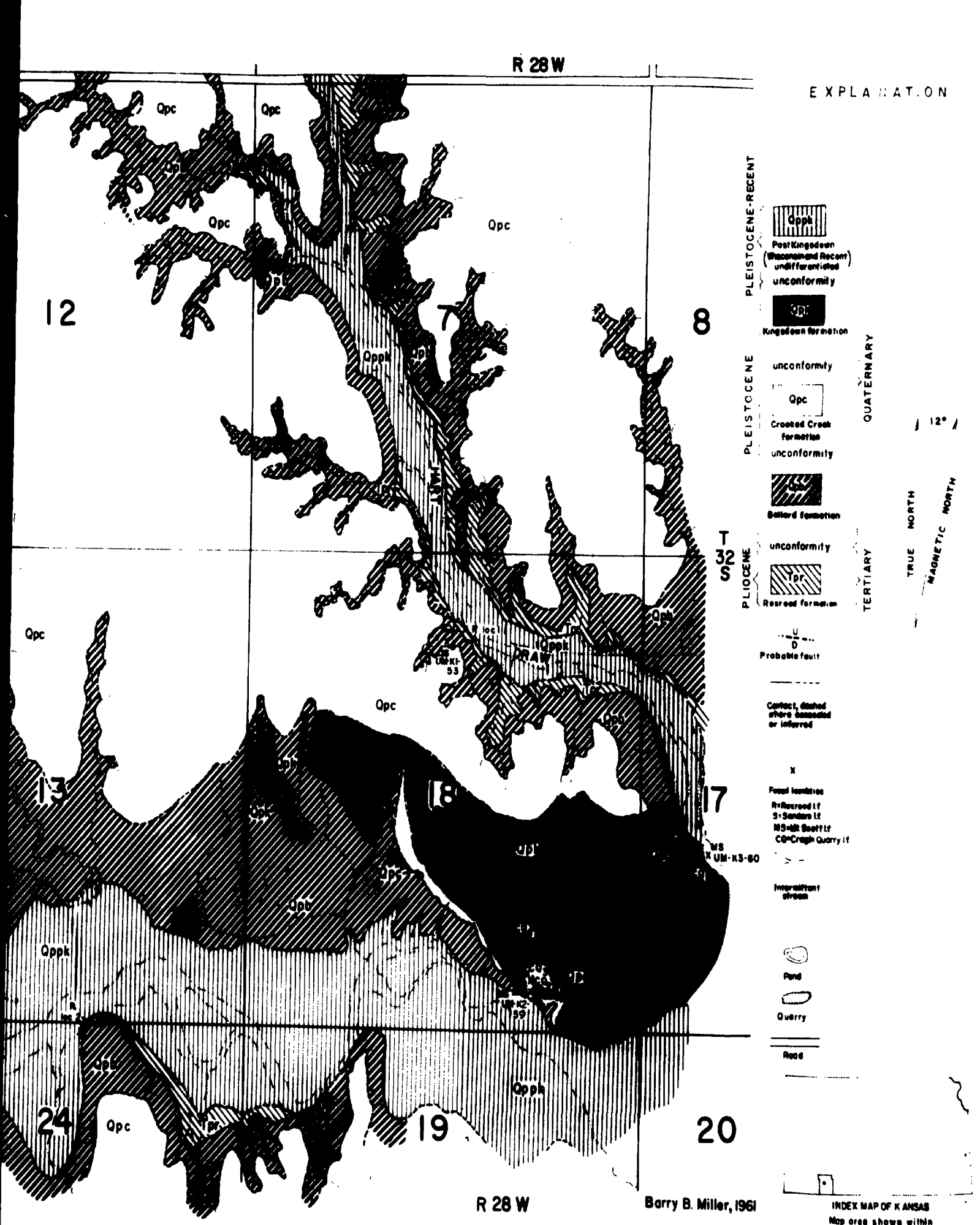
Plate III





Base map from aerial photographs

GEOLOGIC MAP OF THE BIG SPRINGS RANCH



AREA, MEADE COUNTY, KANSAS