STATE GEOLOGICAL SURVEY OF KANSAS

RAYMOND C. MOORE
State Geologist

BULLETIN 9

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Geology and Invertebrate Paleontology of the Comanchean and "Dakota" Formations of Kansas

BY

W. H. TWENHOFEL

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STATE BOARD OF ADMINISTRATION.

STATE GEOLOGICAL SURVEY OF KANSAS.

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The Geology and Invertebrate Paleontology of the Comanchean and "Dakota"[1] Formations of Kansas.[2]

Introduction.

THE Comanchean and "Dakota" formations of Kansas occur in two widely separated areas, one in the central and northern portions of the state and the other near the southern margin. The strata of the south are in considerable part calcareous, but they begin with a basal formation composed of sandstone and constituting from a fourth to a half of the entire sequence which without gradation gives place to shell limestones and dark shales. These strata are exposed in narrow strips over a large section of the country, but in few places do they form the uplands, generally being confined to the valley slopes. They have been variously correlated and named. The strata of the central and northern portions of the state are largely red sandstones, which have been generally known as the "Dakota" sandstones and the Mentor beds. These strata occur as isolated outliers on their eastern extensions and cover extensive areas on the western margins.

There are no known surface connections between the two areas, but it is possible that connection may exist beneath the overlapping Benton and Tertiary strata. Whether present or not, it is certain that such connection once existed and that these strata also were at one time connected with the extensive areas of strata of the same general age which are present in southern Oklahoma and across central Texas. Save, however, for an occasional outlier, the strata connecting with these southern areas have been removed.

The strata under consideration in the southern part of Kansas have been considered of Comanchean age and have been so mapped

1. The term "Dakota" as used in this report relates only to the strata of Kansas known by that name. In the writer's opinion the strata known as the Dakota formation or group are probably of considerably different ages in different portions of the West.

2. The Comanchean formations have previously been referred to the Lower Cretaceous, which in general has been correlated with the Lower Cretaceous of Europe. Applying the criteria as stated by the writer in a previous article (**78**) relating to these strata appears to necessitate their reference to the Upper Cretaceous. The validity of the term Comanchean as the name of a geologic period remains to be established. That question is not considered in this report.

NOTE.—References indicated by bold face numbers in the report are listed in the Bibliography following the text of this report. (See "Bibliography" in Table of Contents.)

by the Kansas Geological Survey (**50**). The most recent maps of the state by the Survey (**69**) have placed the Mentor beds with the "Dakota" and have assigned both to the Upper Cretaceous.

The Comanchean strata of Kansas are of interest from several points of view. They throw considerable light on the climatic conditions prevailing in this region during the times of their deposition, record forward and backward migrations of the strand line, and show many variations in both the horizontal and vertical distribution of the sediments. Coupled with the variations in sediments are variations in faunas, showing the close relationship that the animals of the time bore to their environments.

Data relating to these formations are scattered through a great number of papers, many of which are difficult of access, and descriptions of the fossils have not previously been assembled. The material presented in this report has been derived from a number of years' work, including parts of three field seasons and studies of the fossil collections carried on as other duties permitted. Each of the previously described localities of the Mentor beds has been examined and several new ones have been found. In the southern part of the state all of the well-known sections have been studied and some of them have been visited several times.

In this work assistance has been received from many persons who live near the exposures. The study was begun under Dr. Erasmus Haworth, former state geologist of Kansas, and has been continued with the cordial coöperation of the present state geologist, Dr. Raymond C. Moore.

Resume of the Literature.

SOUTHERN KANSAS.

The strata of southern Kansas here considered appear to have been first noted by Mudge, and were by him included in the Upper Cretaceous and assigned to the Benton and "Dakota" formations (**17**, pp. 47-55). Cragin assigned the calcareous and shaly portions to the Benton, but noted that the underlying sandstones are quite different from any in Kansas with which he was familiar (**22**, p. 85). In 1886 Cragin referred the lower sandy beds to the "Dakota" (**23**, p. 166). These correlations were continued by St. John (**24**, p. 143) and by Hay (**25**, p. 22). In February, 1889, Cragin (**26**, p. 33) stated the discovery of error in his earlier correlation, and in the same paper gave the first detailed geologic section of these strata, the lithologic description of each zone being accompanied by a list of fossils characteristic of that zone. The resemblance of the fossils to those of the Comanchean of Texas was also noted. Basing his conclusions on the statements made in Cragin's paper, Hill (**27**, p. 115) made the definite correlation of the basal sandstones with the Trinity of the Texas section and the overlying argillaceous and calcareous strata with the Fredericksburg of the same sequence. In a paper appearing in the latter part of 1889, Cragin (**28**, p. 65) reservedly accepted Hill's correlation for the sandstone and in the same paper suggested the formation term of Cheyenne therefor, the type locality for the formation being Cheyenne Rock on the south side of Medicine Lodge river near the village of Belvidere. The sandstone and overlying strata were more fully described by Cragin (**29**) in the following year and considerable detail relating to their distribution and characteristics was given.

In 1890 Hay (**30**, p. 49) gave brief descriptions of the geology of Kansas, in which he continued the correlation of the Cheyenne sandstone with the "Dakota," and with some doubt referred the overlying strata to the Fort Benton. In 1891 Cragin (**32**) made a very definite and positive correlation of the basal sandstones with the Trinity of Texas and a portion of the overlying strata (No. 5 of his sections) with the Fredericksburg. Williston's (**33**) small geologic map of Kansas shows the presence of Comanchean strata in southern Kansas, the area of the exposures extending from the southeastern part of Kingman county westward in an irregular line into the northeastern part of Meade county. Hay's map (**35**) shows the same area as Upper Cretaceous, but correlates the strata with the Lower Cretaceous, tentatively suggesting that the Texas names, Trinity sandstone and Comanche Peak limestone, should be retained for them.

In the following year (1894) Cragin (**38**) described the first invertebrate fossils from the strata of southern Kansas and descriptions of others together with those of vertebrate fossils from the same strata were given by him in 1895 (**42**, **43**). In the latter paper he suggested the formation name Kiowa for the calcareous and shaly beds overlying the Cheyenne sandstones. In the same year Hill (**45**) published the discovery of the presence of fossils of dicotyledonous plants in the Cheyenne sandstones and stated that the species which are present are those which have previously been considered characteristic of the "Dakota." Cragin (**28**, p. 65) had previously described a cycad from the Cheyenne sandstones. Also in 1895, in connection with sections from other localities, Hill (**46**) gave two from southern Kansas—one from near Sun City and a second from near Belvidere. In this paper he proposed that those portions of these strata above the Cheyenne sandstone be known as the Belvidere shale. The paper also gave Knowlton's list of the plants which had been found in the Cheyenne sandstone, with his conclusions that the species identified "belong to the Dakota group as it has usually been accepted, and have never been identified outside of it." The invertebrate fossils from the overlying shales were listed with identifications by Stanton; and on the basis of the evidence given by all the fossils, Hill correlated the sequence as "the modified attenuated northern extensions of the Washita division and probably a portion of the Fredericksburg division of the Comanche series of Texas." (**46**, p. 234).

In the latter part of 1895 Cragin (**47**) published his last paper on the southern Kansas section. This paper to a considerable degree is controversial, but various names were proposed for members of the Comanchean sequence, the basal lithologic unit of the "Kiowa shales" in particular being separated as the Champion shell bed and given rank equal to the Cheyenne sandstone. Thirty-six species of invertebrates were listed from the Champion shell bed, and it was stated that fifty-one species of invertebrates and nine species of vertebrates are present in the "Kiowa shale." In respect to correlation Cragin concluded that the "Kiowa shale represents a group of sediments intermediate between the Fredericksburg and the Washita."

Haworth's (**48**, pl. xxxi) "Reconnaissance Geological Map of Kansas" shows a band of Comanchean strata extending from the northwest corner of Barber county to the southeastern corner of Meade county.

The most extensive paper discussing the southern Kansas section is that of Prosser (**50**). This paper reviews all previous work relating to these strata and gives abundant facts relating to their distribution and local sequence.

Additional papers have been published by Vaughn (**53**), Gould (**55, 59**), Stanton (**64**), Twenhofel (**78**), and Berry (**79, 80, 81**).

CENTRAL AND NORTHERN KANSAS.

The central Kansas strata appear to have been observed first by Dr. John L. LeConte (**5**). While a member of a party making a survey for the extension of the Union Pacific railroad west of

Salina, he collected fossils south of Spring creek crossing, a locality near the present little village of Bavaria. He referred the strata to the "Dakota" and stated that Prof. B. F. Mudge had collected fossils near the same place. In 1872 Mudge (**6**, p. 38) published details relating to the locality where he discovered the fossils and in the same year the fossils were described without figures by Meek (**8**). Four years later Meek republished his descriptions with figures (**13**, pl. 2). In 1877 and 1878 Mudge (**16, 17**) gave further data relating to the localities from which he obtained his fossils.

Cragin was the first student who appears to have clearly recognized the relations of the fossiliferous sandstones of central Kansas to those of the Kiowa of southern Kansas. He patiently sought for exposures, and proposed for these strata the name "Mentor beds," the type locally being near the little railroad station of that name (**44**). Prosser (**50**) compiled the results of the work of earlier students and greatly added thereto through his own studies. These sandstones have also been studied by Gould (**59**), who gave a section in which the strata are shown in place, and announced the discovery of fossils of dicotyledons in the supposed unfossiliferous sandstones which are present beneath the sandstones in which the marine fossils occur. The present writer has published the general facts relating to these strata so far as they were known at the times of publication (**77, 78**).

The "Dakota" sandstone of southern and central Kansas has generally been considered the basal division of the Upper Cretaceous. In its first definition it was given as the base of the plains Cretaceous, and this assignment was restated by the sponsors, Meek and Hayden (**2**), in many subsequent papers. In his great work on the Cretaceous and Tertiary fossils of the Plains and Rocky Mountain portions of the United States, Meek (**13**, pls. xxv-xxviii) reconsidered the assignment and reached the same conclusion as in previous years. Other students have dissented from the assignment, Marcou at one time referring the division to the Triassic, at another time to the Jurassic, and when Heer identified fossil leaves from the "Dakota" as Miocene, Marcou adopted a like view. After he had studied the strata in the field, however, he reached the conclusion that the assignment of Meek and Hayden is correct. The age, origin and position of the "Dakota" was considered by Lesquereux (**9**, p. 26), who decided that the age is Upper Cretaceous and its origin marine, this view of origin being based on the occurrence of marine fossils which had been found in the rocks on the Big Sioux river and in Kansas (Mentor beds). These conclusions as to stratigraphic position have been generally accepted and quite generally embodied in all American textbooks of geology except that of Scott.

After the initial doubts as to the position of the "Dakota" had passed, it appears to have been generally accepted that it is the base of the Upper Cretaceous as that unit has been defined in North America. An occasional note of uncertainty, however, has been sounded by a few students. Among these Prof. L. F. Ward appears to have been the pioneer, as shown in his statement that "It would seem probable that a considerable portion of the deposits underlying the marine Cretaceous of the Rocky Mountain region, which have heretofore been referred to the "Dakota" group on purely stratigraphical evidence, may really be much older (**39,** p. 265).

In his paper on "Types of Sedimentary Overlap," Grabau (**66,** pp. 620-627) strongly insisted on the Comanchean age of at least a part of the "Dakota," and also maintained that the "formation" is of different ages in different parts of its distribution.

In Scott's "Introduction to Geology" (**75**) the "Dakota" is definitely placed in the Lower Cretaceous. A summary of the conclusions of American students on this subject was made by Todd (**73,** pp. 65-69), and as a result of his examination of the literature he reached the conclusion that the "Dakota" is Lower Cretaceous. In a preliminary paper the present writer (**78**) presented the evidence relating to the position of the Kansas "Dakota" and reached the conclusion that portions of it are equivalent to the Washita of the Comanche series as that group has been defined in Texas.

Distribution of the Comanchean and "Dakota" Formations.

SOUTHERN KANSAS.

The strata in southern Kansas which are here considered are those known as the Cheyenne sandstone, the Kiowa shale and Medicine beds. They make their appearance from beneath the Tertiary cover northeast of Medicine Lodge in the northeastern corner of Barber county, and as an irregular, narrow band extend in a generally westerly direction around the headwaters of Medicine Lodge river, Bluff creek canyon and other streams to the southeast corner of Meade county. In addition to this band there is an outlier in southern Comanche county and northern Oklahoma known as Avilla Hill. It is possible that small patches may occur both east and west of the limits given. The actual area of land immediately underlain by these strata is small.

The most easternmost point where fossils belonging to these horizons have been collected is 6 miles northeast of Medicine Lodge, where they were obtained by Gould (**49**, p. 119). That the strata once extended farther east is certain, for Kiowa shells have been collected in a Tertiary conglomerate near the village of Sharon—about 7 miles east of where the shells have been found in place. North of Lake City, not far to the northwest of Medicine Lodge, are yellowish-gray fine-grained soft sandstones which rest unconformably on the Permian red beds, and are about 20 feet thick. They are overlain by red concretionary sandstone of a considerable but unknown thickness. The deposits appear to be in a valley in the Permian and are considered to represent the Cheyenne.

The western limit of the exposures is on Big Sand creek at a place known as Little Basin, where Tertiary sandstone overlies 25 feet of thin-laminated black shale belonging to the Kiowa, which rests in turn on yellowish, coarse-grained friable sandstone described by Cragin as the Big Basin sandstone, of probable Permian age. Westward and southward the overlapping Tertiary rests on the Permian.

CENTRAL AND NORTHERN KANSAS.

The rocks of central and northern Kansas which are considered the equivalents of the Kiowa-Cheyenne-Medicine strata consist of: (1) red fossiliferous marine sandstones generally known as the Mentor beds; (2) the underlying strata down to the top of the Permian, some of which are of marine origin; and (3) a portion of the "Dakota" sandstone. The Mentor beds with their characteristic fossils are present over the western halves of Saline and McPherson counties and along the eastern edges of Ellsworth and Rice counties. The most eastern locality where they have been found is in western Marion county, on the road between Lehigh and Waldeck. The most northern locality is about 5 miles north and 1 mile east of Salina. The most western exposures appear to be east of a line extending about 2 miles west of Windom, in McPherson county; 6 miles west of Marquette, in the same county; and about 1 mile west of Brookville, in Saline county. Westward from these limits the Mentor strata disappear beneath the "Dakota." The exposures are in the nature of outliers, and it is certain that the strata once extended east of the limits given. Sandstones and shales similar to those below the Mentor beds have been traced as far north as Longford, in the southwestern corner of Clay county. About 3 miles south of Carlton, in eastern Dickinson county, are red sandstones of "Dakota" aspect which are underlain by 6 to 8 feet of white gypsiferous sandstone, below which are about 20 feet of bluish shales and thin gray sandstones. The strata below the red sandstones are like those below the Mentor beds. Similar strata are exposed 5½ miles south and 5 miles west of this locality, and again 5 miles north and 2½ miles west of Durham, in northern Marion county.

The "Dakota" sandstones are found over an extensive area. They enter the state from Nebraska on the northern edge of Washington county, and, extending in a southwesterly direction to Edwards and Hodgeman counties, they pass beneath the Tertiary cover, entire or extensive areas of fourteen counties having strata of this unit for the surface rock. It is probable that considerable areas along the eastern limits of the "Dakota" exposures lie below the horizon of the Mentor, but it is extremely difficult to make the differentiation where the Mentor horizon cannot be found. The distribution of the strata under consideration is shown on Plate I.

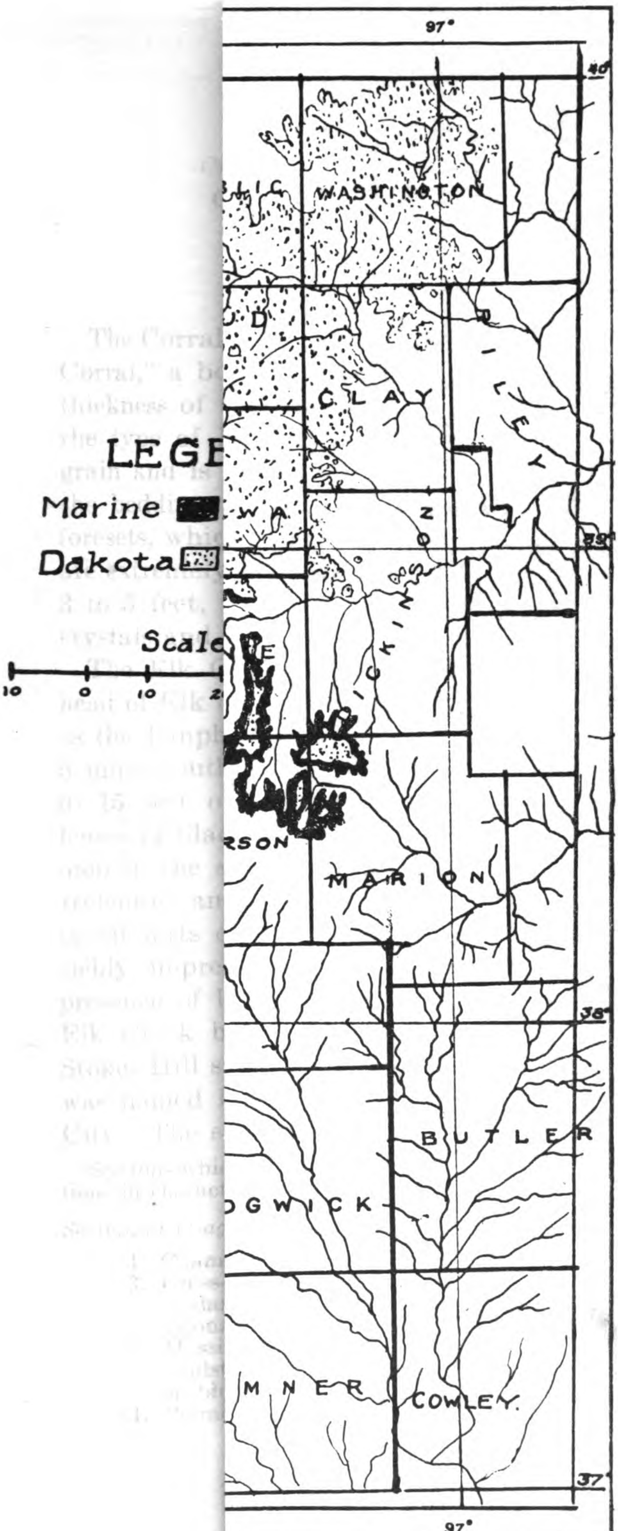
Detailed Description of the Comanchean and "Dakota" Formations.

SOUTHERN KANSAS.

The strata of southern Kansas here to be described are those which have previously been called the Cheyenne sandstone, Kiowa shale and Medicine beds, the upper member of the last-named having been usually identified as the "Dakota" sandstone. On the pages which follow these strata are designated the Cheyenne, Belvidere and "Dakota" formations, the Cheyenne without modification of previous usage, the Belvidere consisting of the lowest two members of the "Medicine beds," and the Kiowa shale, thus reviving the name proposed by Hill (**46**); and the "Dakota" including the uppermost two "Medicine" members, which are considered the attenuated southern extensions of the "Dakota" formation to the north.

Cheyenne Formation.

The Cheyenne sandstone was named by Cragin (**29,** p. 65) in 1890 from Cheyenne Rock, opposite the village of Belvidere. A year later (**31,** p. 31) he gave its distribution and characteristics, while in 1895 he added considerably more detail and divided the formation from above downward as follows (**47**):



PLATom the map of the

Cragin's Classification of the Cheyenne Sandstone.

Cheyenne sandstone.
- Elk creek beds.
  - Stokes Hill sandstone.
  - Lanphier beds.
- Corral sandstone (base).

The Corral sandstone was named from exposures in the "Natural Corral," a box canyon about 5 miles southeast of Belvidere. The thickness of this member was estimated at 30 to 50 feet (**32**). At the type of locality it is a white to yellow sandstone of medium grain and is not uncommonly striped with yellows and reds along the bedding and lamination planes. Cross-lamination with steep foresets, which in large part appear to have southerly inclinations, are extremely common. The average length of the foresets exceeds 3 to 5 feet, with lengths up to 50 feet not uncommon. Gypsum crystals and impregnations are of general occurrence.

The Elk Creek beds were so named from exposures about the head of Elk creek, the lower portion being differentiated by Cragin as the Lanphier beds from exposures on the Lanphier ranch about 5 miles southeast of Belvidere, where this member consists of 10 to 15 feet of poorly cemented sands in which are streaks and lenses of black to gray shale. Cross-lamination is extremely common in the sandstones. Fragments of lignite, crystals of gypsum (selenite) and limonite concretions are commonly present, the last in all sorts of shapes. Many portions of the member are locally richly impregnated with gypsum. Another characteristic is the presence of logs composed of lignite and pyrite. All parts of the Elk Creek beds contain remains of dicotyledonous plants. The Stokes Hill sandstone is a yellow, medium-grained sandstone which was named from Stokes, or Black Hill, a few miles west of Sun City. The sandstone is only a few feet thick.

Sections which are illustrative of the Cheyenne sandstone, showing its variations in character and thickness from place to place, follow:

Section at Osage Rock, three-quarters mile west of Belvidere:

	Thickness. Ft.	In.
4. Champion shell bed	..	..
3. Cross-laminated, fine-grained, soft sandstone with thin layers of dark carbonaceous shale; contains fossil leaves of dicotyledons	26	0
2. Massive, cross-laminated, fine- to medium-grained yellow sandstone, containing pebbles of chert and quartz and lenses of bluish clay	16	0
1. Permian	..	..

Section three miles south of Belvidere:

	Thickness. Ft.	In.
5. Champion shell bed	..	..
4. Gray to yellow, clayey, fine-grained sandstone	15	0
3. Massive-bedded, white to gray, cross-laminated sandstone; contains pebbles of chert and quartz	12	0
2. Black carbonaceous shale with a thin bed of sandstone	6	0
1. Brown to gray, medium-grained, cross-laminated sandstone; contains pebbles of chert and quartz	12	0

Section in Champion Draw, one-half mile south of Belvidere:

	Ft.	In.
11. Champion shell bed.		
10. Sandy gray shale with remains of fossil dicotyledons	9	0
9. Soft, fine-grained, gray and yellow sandstone with bands of shale and carbonaceous material	10	0
8. Dark sandy shale with much lignite and plant material	12	0
7. Usually soft, yellow, fine-grained, cross-laminated sandstone with lignite in lenticular masses of shale. On the west bank near the top of the bluff is a hard ledge containing the best fossil leaves of dicotyledons found in this region	20	0
6. Yellow and brown sandy shale with streaks of lignite and dark shale. Much cross-lamination, grades into zone 5	6	0
5. Soft, fine-grained, cross-laminated sandstone with lenses of dark shale, contains plants and sandstone concretions	10	0
4. Yellow sandy shale with thin bands of lignite and dark shale. The lignite and shale bands contain plant remains. Generally cross-laminated	8	0
3. Massive-bedded sandstone with many limonite concretions and pebbles of chert and quartz. Generally greatly cross-laminated and streaked with different colors along the lamination planes. Contains lenticular bands of dark laminated clay	20	0
2. Yellowish-gray shale	3	0
1. Permian red beds	50	0

Section at Stokes or Black Hill, about five miles west of Sun City and six to seven miles southeast of Belvidere:

	Ft.	In.
3. Dark-gray sandy and clay shale with occasional lenses of friable yellow sandstone. Contains pyrite concretions and gypsum crystals and impregnations. Leaf impressions of dicotyledons are common	10	0
2. Light to yellowish-gray, fine-grained friable sandstone; much cross-laminated; varies greatly in thickness	40	0
1. Permian red beds	..	..

Section at Avilla Hill, an outlier on the Oklahoma line:

	Ft.	In.
3. Kiowa shale	..	..
2. Quartzitic sandstone interbedded with soft sandstone. Colors vary from yellow to red. Contains poorly preserved pelecypods and probably is Kiowa	..	..
1. Permian red beds	..	..

Considered as a whole the Cheyenne sandstone consists of light gray to yellow quartz sandstone and subordinate shale. The bedding is extremely irregular and discontinuous and most beds are merely lenses of limited extent. The writer does not consider it possible definitely to recognize any member beyond the limits of one locality, and the divisions of Cragin to which reference has been made are considered to have no validity for more than local application; and as his three members were not differentiated in the same section it is possible that two of them may be one. At any rate, no definite continuous boundary can be pointed out to separate any two of them, and the sections show that there is wide variation in thickness. Cross-lamination is extremely common throughout, the inclinations tending to be steep and in large part appear to have southerly direction. Current ripple marks are common; wave ripple marks have not been recognized definitely. While the colors are commonly gray to yellow, and probably were originally so, iron staining, believed to be due to oxidation of pyrite or marcasite, is extremely common. Where the staining has taken place along bedding and lamination planes, the rock has been striped with almost every shade of color produced by the iron staining. The grains of the sands vary from extremely fine to the coarseness of fine gravel. In some horizons the texture is almost flourlike, while other horizons are characterized by rather well-assorted small pebbles of chert, quartz and clay, a few with diameters as large as two inches. Diagrams given on Plate VI show the assortment of typical examples. Gould reports pebbles of granite (**59**, p. 17). Interbedded with the sandstones are pockets and lenses of sandy and clay shale. Pyrite is abundant in some horizons; selenite crystals are extremely common and selenite needles occur throughout; limonite concretions, believed to result from weathering, are locally common. As a rule the sandstones are poorly cemented, but locally they are quartzitic. The degree of cementation varies with the beds, so that some of them are protective to those below and project on weathered surfaces.

The strata of the Cheyenne formation are not extensively exposed. In the canyons and along the river valleys they commonly form the lower portions of the cliffs and the valley slopes, while in areas where the Kiowa shales have been removed and the sandstones directly exposed to erosion, a bad land topography has almost invariably developed. Pillars of fantastic shapes are common in such places. (Pl. II, Fig. 2). Bad land areas are not numerous or large, the most extensive being in southeastern Kiowa county in a place locally known as "Hell's Half Acre"—an appropriate designation. Some of the better cemented portions of the Cheyenne resist erosion and are locally known as "rocks." Such is Cheyenne Rock, on Medicine Lodge river opposite Belvidere, and Osage rock, on the north side of the river just above Belvidere, the latter a place of historic interest as the site of a battle between the Cheyenne and Osage Indians.

Section three miles south of Belvidere:

		Thickness. Ft.	In.
5.	Champion shell bed	..	..
4.	Gray to yellow, clayey, fine-grained sandstone	15	0
3.	Massive-bedded, white to gray, cross-laminated sandstone; contains pebbles of chert and quartz	12	0
2.	Black carbonaceous shale with a thin bed of sandstone	6	0
1.	Brown to gray, medium-grained, cross-laminated sandstone; contains pebbles of chert and quartz	12	0

Section in Champion Draw, one-half mile south of Belvidere:

		Ft.	In.
11.	Champion shell bed.		
10.	Sandy gray shale with remains of fossil dicotyledons	9	0
9.	Soft, fine-grained, gray and yellow sandstone with bands of shale and carbonaceous material	10	0
8.	Dark sandy shale with much lignite and plant material	12	0
7.	Usually soft, yellow, fine-grained, cross-laminated sandstone with lignite in lenticular masses of shale. On the west bank near the top of the bluff is a hard ledge containing the best fossil leaves of dicotyledons found in this region	20	0
6.	Yellow and brown sandy shale with streaks of lignite and dark shale. Much cross-lamination, grades into zone 5	6	0
5.	Soft, fine-grained, cross-laminated sandstone with lenses of dark shale, contains plants and sandstone concretions	10	0
4.	Yellow sandy shale with thin bands of lignite and dark shale. The lignite and shale bands contain plant remains. Generally cross-laminated	8	0
3.	Massive-bedded sandstone with many limonite concretions and pebbles of chert and quartz. Generally greatly cross-laminated and streaked with different colors along the lamination planes. Contains lenticular bands of dark laminated clay	20	0
2.	Yellowish-gray shale	3	0
1.	Permian red beds	50	0

Section at Stokes or Black Hill, about five miles west of Sun City and six to seven miles southeast of Belvidere:

		Ft.	In.
3.	Dark-gray sandy and clay shale with occasional lenses of friable yellow sandstone. Contains pyrite concretions and gypsum crystals and impregnations. Leaf impressions of dicotyledons are common	10	0
2.	Light to yellowish-gray, fine-grained friable sandstone; much cross-laminated; varies greatly in thickness	40	0
1.	Permian red beds	..	..

Section at Avilla Hill, an outlier on the Oklahoma line:

		Ft.	In.
3.	Kiowa shale	..	..
2.	Quartzitic sandstone interbedded with soft sandstone. Colors vary from yellow to red. Contains poorly preserved pelecypods and probably is Kiowa	..	..
1.	Permian red beds	..	..

Considered as a whole the Cheyenne sandstone consists of light gray to yellow quartz sandstone and subordinate shale. The bedding is extremely irregular and discontinuous and most beds are merely lenses of limited extent. The writer does not consider it possible definitely to recognize any member beyond the limits of one locality, and the divisions of Cragin to which reference has been made are considered to have no validity for more than local application; and as his three members were not differentiated in the same section it is possible that two of them may be one. At any rate, no definite continuous boundary can be pointed out to separate any two of them, and the sections show that there is wide variation in thickness. Cross-lamination is extremely common throughout, the inclinations tending to be steep and in large part appear to have southerly direction. Current ripple marks are common; wave ripple marks have not been recognized definitely. While the colors are commonly gray to yellow, and probably were originally so, iron staining, believed to be due to oxidation of pyrite or marcasite, is extremely common. Where the staining has taken place along bedding and lamination planes, the rock has been striped with almost every shade of color produced by the iron staining. The grains of the sands vary from extremely fine to the coarseness of fine gravel. In some horizons the texture is almost flourlike, while other horizons are characterized by rather well-assorted small pebbles of chert, quartz and clay, a few with diameters as large as two inches. Diagrams given on Plate VI show the assortment of typical examples. Gould reports pebbles of granite (**59**, p. 17). Interbedded with the sandstones are pockets and lenses of sandy and clay shale. Pyrite is abundant in some horizons; selenite crystals are extremely common and selenite needles occur throughout; limonite concretions, believed to result from weathering, are locally common. As a rule the sandstones are poorly cemented, but locally they are quartzitic. The degree of cementation varies with the beds, so that some of them are protective to those below and project on weathered surfaces.

The strata of the Cheyenne formation are not extensively exposed. In the canyons and along the river valleys they commonly form the lower portions of the cliffs and the valley slopes, while in areas where the Kiowa shales have been removed and the sandstones directly exposed to erosion, a bad land topography has almost invariably developed. Pillars of fantastic shapes are common in such places. (Pl. II, Fig. 2). Bad land areas are not numerous or large, the most extensive being in southeastern Kiowa county in a place locally known as "Hell's Half Acre"—an appropriate designation. Some of the better cemented portions of the Cheyenne resist erosion and are locally known as "rocks." Such is Cheyenne Rock, on Medicine Lodge river opposite Belvidere, and Osage rock, on the north side of the river just above Belvidere, the latter a place of historic interest as the site of a battle between the Cheyenne and Osage Indians.

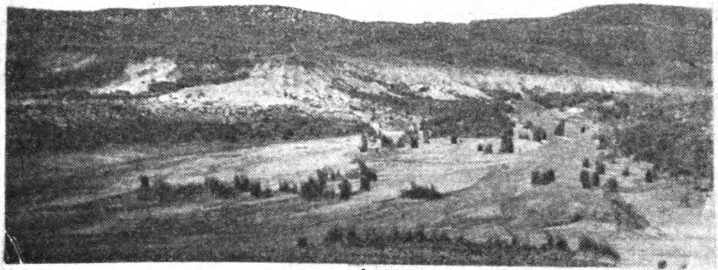
PLATE II.

VIEWS OF EROSION FEATURES ON COMANCHEAN STRATA.

FIG. 1. View looking up Champion Draw. The hills in the background are composed of the Kiowa shales. The flat surface in the middle is the aggraded floor of the draw. The white across the middle of the picture is the exposure of the Cheyenne sandstone, and to the left the dark beneath the white is the outcrop of the Permian red beds. Photograph by the author.

FIG. 2. Erosion remnant of the Cheyenne sandstone, Hell's Half Acre, Comanche county. Photograph by Victor Householder.

FIG. 3. Outcrop of the Mentor bed, Natural Corral. The fossiliferous bed is that exposed immediately below the rim of the canyon. Photograph by the author.



1

2

3

2—996

The Cheyenne sandstone appears to be confined to the eastern part of the area occupied by the Kiowa. It was not seen by the writer in the western exposures, nor has it been reported by other students. It is possibly represented in the Avilla Hill exposures by 6 feet of quartzitic sandstone containing poorly preserved pelecypods. Southward the Cheyenne disappears, for in the Oklahoma sections the Kiowa is said to rest directly on the Permian.

Fossil leaves and other vegetable matter—logs and branches, lignitized, pyritized, and as casts—are locally quite common in some horizons of the Cheyenne sandstone, particularly in the upper part. The first species of plant described from this formation is a cycad named *Cycadoidea munita* by Cragin (**28**, p. 65; **47**, p. 363), who also described foliage as belonging to *Glyptostrobus gracillimus* Lx. Large collections of fossil plants have been made from the formation by Hill and members of his field party, these having been identified by Knowlton and later described by Berry (**81**).[3] No animal remains have been collected from the formation unless the strata at Avilla Hill with the poorly preserved pelecypods are a part of the Cheyenne. It is far more probable that these beds are of Kiowa age. The flora identified from the formation is given in the following list (**81**):

Abietites ernestinæ Lesquereux.
Abietites longifolia (Fontaine) Berry.
Aralia polymorpha Newberry.
Aralia ravniana Heer.
Araliopsoides cretacea (Newberry) Berry.
Arundo grœnlandica Heer.
Asplenium dicksonianum Heer.
Carpolithus belviderensis Berry.
Cladophlebis dakotensis (Lesquereux) Berry.
Cupressinoxylon cheyennense Penhallow.
Cycadeoidea munita Cragin.
Cycadeospermum lineatum Lesquereux.
Feistmantelia oblonga Ward.
Gleichenia bohemica (Corda) Berry.
Gleichenia nordonskioldi Heer.
Sapindopsis belviderensis Berry.
Sapindopsis brevifolia Fontaine.
Sapindopsis magnifolia Fontaine.
Sapindopsis variabilis Fontaine.
Sassafras mudgii Lesquereux.
Sterculia condita Lesquereux.
Sterculia mucronata Lesquereux.
Sterculia towneri (Lesquereux) Berry.

Berry's table shows that ten of these species also occur in the "Dakota" sandstone, as that term is used by him (**81**, p. 206).

The features of the Cheyenne sandstone which throw light on the conditions of origin are the discontinuity of bedding, the cross-lamination, the assortment of the sands, the presence of land plants,

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3. In a letter (August 17, 1920) Prof. Edward W. Berry states: "I have spent some months studying the flora of the Cheyenne sandstone and that of the Woodbine formation. . . . My results may be stated thus: Nearly all of the Cheyenne sandstone plants are so-called Dakota forms but not one of them occurs in the Woodbine or in any of the Coastal Plain formations that have been commonly correlated with the Dakota (Tuscaloosa, Raritan, Magothy, etc.). The Woodbine plants are also nearly all so-called Dakota forms, but in this case nearly all occur in Coastal Plain formations that have been correlated with the Dakota. The evidence is clear that the Cheyenne is older than the Woodbine and it is equally clear that while the so-called Dakota flora has a similar general facies throughout it is not all of the same age." Berry's published conclusions (**81**) relating to the Cheyenne flora are to the same point.

and the absence of shells of marine animals. The presence of the gypsum, which is more or less scattered throughout the sandstones, must also be considered. As noted, the bedding is extremely discontinuous and the formation presents great variability in lithology and thickness, all of which implies a lack of uniformity in the depositing agencies. Cross-lamination is almost invariably present, the inclination appearing to have dominantly southerly directions. The foresets are commonly steep and long, the maximum lengths observed being those in the Champion Draw section where there are some which are at least 50 feet long at inclinations of about 20 degrees. In considerable part these cross-laminations are truncated in horizontal planes, but some have inclined truncation. This suggests wind deposition for these portions. The assortment of the sands is generally good, but occasional layers and laminæ of mixed grain are present. The assortment is shown in the graphs on Plate VI. The gypsum, which occurs quite generally throughout the formation, may have been deposited at the same time as the sands, but, on the other hand, it may have been introduced subsequently to deposition. It has appeared to the writer that the gypsum is more abundant in those places where the sandstones are still overlain by the Kiowa shales, and this suggests that it may have been brought into the sands by waters which leached it from the shales above. The fact that the overlying Kiowa shales are full of endogenous gypsum indicates that the climate of Kiowa time in this region was not humid; but, on the contrary, that more water evaporated in this gulf than was brought in by the rivers. This suggests that the climate may not have been greatly different from the present.

The relation of the Cheyenne sandstones to the overlying Kiowa shales suggests that the place of deposition of the former was not far above or far from a shore line, which indicates that the deposits are either shallow-water marine or stream, and perhaps, in part only, wind deposits of a coastal plain. Most of the bedding structures could have been developed under either condition. In shallow marine waters in which the sea bottom is near the profile of equilibrium redeposition of sediments constantly occurs, with scouring and great inequality of deposition; cross-lamination, cross-bedding and discontinuity are the rule in such an environment.

Since, however, the sandstones contain an abundance of vegetable matter in some horizons, it seems strange that this complex of material could have been deposited under marine conditions and not contain any shells of marine animals. The vegetable matter appears to have floated in, for nothing has been found suggesting that the vegetation grew where it now occurs.

On a somewhat dry coastal plain, aggrading streams would spread sands over their flood plains and deltas with a discontinuity of bedding similar to that which is now found in the Cheyenne sandstones. The wind would help to produce the assortment and give the inclined truncation to the cross-lamination, while the clays, logs and leaves could have been brought from the sources of the streams and deposited in a manner similar to that which permits the deposition of sand, mud, logs and vegetable material in the deposits now forming on the aggraded floors of some of the canyons existing in the region. Under these conditions it is extremely unlikely that any marine shells would be present, and accordingly this environment appears to be more probable than any other. Although the Kiowa shales contain remains of aquatic vertebrates, none have been found in the Cheyenne sandstones. Were these sandstones of marine origin it seems that some remains of marine animals should be entombed, and since such are not present, it would seem that the animals either were not able to reach the places of deposition or there was nothing to attract them in the cases of a few which could have gone either on land or in the shallow waters of the sea. The fact that animal remains have not been found permits the inference that they are not present, and hence that the sandstones were deposited under conditions which either prohibited or were not favorable to the presence of animals. Such would have been the environment of a coastal plain in an arid or semiarid climate, where streams from lands to the north and west spread sediments which they were unable to carry through to the sea. Goldman's study of a sample of the Cheyenne sands suggests a somewhat similar environment (**81**, 204).

Belvidere Formation.

The Belvidere formation as defined in this report includes the Kiowa shale, Spring Creek shale and Greenleaf sandstone members.

Kiowa Member. Cragin's classification of the different divisions of the Kiowa member is as follows:

Kiowa shale.
- Tucumcari shale.
- Fullington shale.
  - Blue Cut shale.
  - Black Hill shale.

Champion shell bed.

In this classification the "Champion shell bed," which has a thickness not exceeding a foot and a half, is given a stratigraphic value coördinate with the Cheyenne sandstone and the remainder of the Kiowa member (**47**). This is not justified by the facts, and on the pages which follow the term Kiowa will be used with the significance given it by Cragin in his first definition (**43**); that is, including all the beds from the top of the Cheyenne to the top of the typically marine strata of the section, but excluding the Spring Creek shale and the Greenleaf sandstone of Gould. These last do not appear to have been known to Cragin at the time of his definition of the term Kiowa, or at least they were not differentiated by him.

The Kiowa shales rest conformably[1] on the Cheyenne sandstone. The contact is sharply defined and abrupt and is thought to represent the change from continental to marine conditions. The plane of contact is the strand line surface of erosion made by a transgressing sea. Bedding is well defined and regular, the units are continuous for long distances, and some are possibly continuous over the entire area of the exposures. Detailed descriptions of the units follow.

The Champion shell bed varies in thickness from 6 to 18 inches and is a fossil coquina of small *Gryphæas*, together with some other shells. The matrix is varied, in some places consisting of shell fragments and sand and in others of sand and clay. Almost everywhere there is an abundance of gypsum which locally forms the matrix for the shells and iron pyrite. The oxidation of the latter leads to the disintegration of the rock and the destruction of the shells. As the member is more resistant than the strata immediately above and below, there is a rather general development of a terrace on this horizon, as is well shown throughout the Belvidere - Sun City region and around the heads of some of the draws. This bed has not been recognized in the Ashland - Bluff creek region.

Including the species described from this bed by Cragin and those concerning whose identity it is not likely he could have been mistaken, the list of fossils from the bed contains a total of 27 species and varieties. Cragin listed 36 species:

1. There is evidence, at least locally, of an unconformity between the Cheyenne and Kiowa divisions. The upper surface of the Cheyenne just north of Belvidere is irregular, depressions in the sandstone being filled with horizontally laminated Kiowa shale.—R. C. Moore.

Anchura kiowana Cragin.
Astrocœnia nidiformis Cragin.
Cardita belviderensis Cragin.
Cardium? bisolaris Cragin.
Cardium? kansasensis Meek.
Corbula crassirostrata Cragin.
Cucullœa recedens Cragin.
Engonoceras belviderei Cragin.
Exogyra texana Roemer.
Gryphœa corrugata Say.
Gryphœa corrugata hilli Cragin.
Limopsis subimbricatus Cragin.
Margarita newberryi Cragin.
Margarita marcouana Cragin.
Neries? incognita Cragin.
Pecten fredericksburgensis Cragin.
Pholadomya? belviderensis, n. sp.
Pinna comancheana Cragin.
Protocardia texana Conrad.
Pteria belviderensis Cragin.
Salenia kansasense, n. sp.
Schlœnbachia kiowana, n. sp.
Serpula championi Cragin.
Tapes belviderensis Cragin.
Turritella seriatim-granulata belviderii Cragin.
Tylostoma elevata (Shumard).
Vanikora propinqua Cragin.

Cragin identified *Ostrea subovata* Shumard and *Holectypus planatus* Roemer, which may possibly also be present.

The Fullington shales were divided by Cragin into the Black Hill shale and the Blue Cut shale, the former being named after Black (or Stokes) Hill, near Hell's Half Acre, in Comanche county, and the latter from the Blue Cut, on the Santa Fe railroad a few miles west of Belvidere. The Black Hill shale contains few fossils and was stated by Cragin to be 15 to 20 feet thick (**47**, p. 380). The unit consists mostly of black paper shale and appears to be the equivalent of zones 2 to 6 of the Belvidere section as given in this paper. The Blue Cut shale is on the average less dark than the beds below, but consists of shale of a similar character, in which fossils are extremely common. This unit is thought to include about zones 7 to 13 of the writer's Belvidere section.

The Tucumcari shales make up the upper portion of the Kiowa. The strata in this zone are considerably more limy than are those below, and are particularly characterized by the presence of large *Gryphœas*.

While the differentiation of these units may be advisable in certain sections, it does not appear probable that the differentiation has any great validity. There are no sharp lines of separation and the units cannot be followed through the entire extent of the exposures. Considered as a whole, the Kiowa formation consists of shales and interbedded thin limestones. The shales in the lower half are commonly black and the laminæ in the lower part have a thickness as thin as coarse wrapping paper. These black shales contain few identifiable fossils, and such as are present are generally small. A few layers contain pebbles of quartz and brown chert. Limestone layers, generally thin, occur throughout, but are more common in the upper half. Most of them are fossil coquinas. Gypsum, usually in the form of a selenite, is common throughout.

The following 40 species and varieties of invertebrates have been identified from the Kiowa shales, exclusive of the Champion shell bed.

Anchura kiowana Cragin.
Anisomyon? cragini, n. sp.
Cardita belviderensis Cragin.
Cardium kansasense Meek.
Cardium? mudgeni Cragin.
Cucullæa recedens Cragin.
Cyprimeria kiowana Cragin.
Dentalium, sp.
Engonoceras belviderensis Cragin.
Exogyra texana Roemer.
Gervillia mudgeana White.
Gryphæa corrugata Say.
Gryphæa corrugata belviderensis Hill and Vaughan.
Gryphæa navia Hall.
Leptosolen otterensis Cragin.
Limopsis subimbricatus Cragin.
Lingula, sp.
Lithophagus interrogatum Cragin.
Mactra antiqua Cragin.
Margarita marcouana Cragin.
Neritoma marcouana Cragin.
Nucula catharina Cragin.
Ostrea kiowana, n. sp.
Pecten texanus Roemer.
Petersia medicinensis Cragin.
Pholadomya? belviderensis, n. sp.
Plicatula senescens Cragin.
Protocardia texana Conrad.
Pteria belviderensis Cragin.
Remodia ferresi Cragin.
Roudaria quadrans Cragin.
Schlœnbachia belknappi Marcou.
Schlœnbachia kiowana, n. sp.
Schlœnbachia peruviana von Buch.
Tapes belviderensis Cragin.
Trigonia emoryi Conrad.
Trochus texanus Roemer.
Turritella seriatim-granulata belviderii Cragin.
Tylostoma elevata Shumard.
Yoldia microdonta Meek.

There are no essential differences between the invertebrate faunas of the Champion shell bed and the overlying portion of the Kiowa shales, although Cragin considered the two faunas quite distinct. In addition to these invertebrates, fragments of insects have been collected from thin beds of sandstone immediately above the Champion bed.

The vertebrates which are listed below, compiled from several publications, have been collected from the Kiowa shales:

Cœlodus browni Cope.
Cœlodus stantoni Williston.
Cimolios annus Williston.
Hybodus clarkensis Cragin.
Hyposarus? sp. Williston.
Lamna sp. (toothlike *L. occidentalus* Leidy) Williston.
Lamna? quinquelateralis Cragin.
Lepidotus sp. Williston.
Leptotyrax bicuspidatus Williston.
Lower Cretaceous dinosaur Williston.
Mesodon? abraus Cragin.
Plesiochelys belviderensis Cragin.
Plesiosaurus mudgei Williston.
Teleost, vertebra like that of *Portheus*, Williston.
Turtle, size of *Protostegia*, Williston.
Uranoplosus arotatus Cope.
Uranoplosus flectidens Cope.

The sections which follow show in detail the character of the member throughout the extent of its exposures. The sections west of Sun City and near Belvidere are the most extensive.

Section in Champion Draw, about one-half mile south of Belvidere (Plate II, Fig. 1):

	Thickness. Ft.	In.
19. Not well exposed, appears to be largely gray shale and pink and gray *Gryphæa* shell limestone	29	0
18. Pinkish, poorly cemented limestone with a thin layer of satin spar on top. Contains many *Gryphæa corrugata*, a few *Turritella seriatim-granulata belviderii* and *Cyprimeria kiowana*	0	8

		Thickness. Ft.	In.
17.	Shale, probably very dark-blue, weathered yellow in exposures, with interbedded fine-grained sandstone and gypsum. A few poorly preserved fossils in the sandstone; shale essentially without fossils	38	0
16.	Dark-blue and yellow shale, no fossils	1	4
15.	Gray and blue shale, crowded with *Gryphœa corrugata*	0	4
14.	Shell limestone, gray with pink patches. Contains *Gryphœa corrugata* in great abundance	1	6
13.	Black paper shale	7	0
12.	Gray shell limestone with patches of pink. Contains many small colored quartz pebbles, of which the diameter of the largest observed is about one-half inch. *Cyprimeria kiowana* very abundant	0	6
11.	Black paper shale	4	0
10.	Mottled gray and pink shell limestone. Contains some gypsum; many *Cyprimeria kiowana*	0	8
9.	Black paper shale	5	0
8.	Pink and gray shell limestone containing thin layers of satin spar. Contains an abundance of *Gryphœa corrugata, Cyprimeria kiowana, Cardium kansasensis* and *Turritella seriatim-granulata belviderii*	0	6
7.	Black paper shale	11	0
6.	Fine-grained gray quartz sandstone. Contains a few shell fragments and impressions	0	4
5.	Black paper shale	4	0
4.	Alternating thin bands of black and yellow shale, and thin, fine-grained gray quartz sandstone. The shale contains small concretions and quartz pebbles, the former containing fossils	2	0
3.	Black paper shale	14	0
2.	Fine-grained, friable gray sandstone filled with needles of selenite. Contains poor impressions of pelecypods, among which *Tapes belviderensis* occurs rarely[4] ....1 in. to	0	6
1.	Champion shell bed. A highly gypsiferous shell bed, made up almost wholly of the shells of *Gryphœa corrugata hilli.* It is locally much iron-stained and contains a great deal of iron pyrite and gypsum, each in a few places serving as a matrix for the shells. The iron oxide is known to have been partly derived from the oxidation of the pyrite. Where the pyrite and the gypsum are most abundant the zone is thinnest and the shells most poorly preserved, largely because the oxidation of the pyrite has led to their decomposition. In many places the surface is covered with efflorescences of salt, gypsum, lime carbonate and sulphur. The zone is splendidly exposed about the head of the draw, where it forms the floor of a well-defined terrace with inclination in a southwesterly direction. Base of the Kiowa ....4 in. to	1	6

Section at Black or Stokes Hill, about 5 miles west of Sun City:

		Ft.	In.
16.	Covered slope to top of hill. Float on the top of the hill from the Kiowa	16	0
15.	Covered slope with Kiowa float of fine-grained yellow sandstone and pinkish limestone, the latter containing an abundance of *Gryphœa corrugata,* and an occasional *Turritella seriatim-granulata belviderii* and *Cyprimeria kiowana*	32	0
14.	Gray and yellow shale with an abundance of *Gryphœa corrugata*	2	0

4. Gould obtained remains of insects from a horizon not more than a foot above the Champion shell bed. They probably came from zone 3, but may have been derived from zone 2 (**59**, p. 24).

		Thickness. Ft.	In.
13.	Black paper shale	4	0
12.	Gray shaly limestone in which there is an abundance of *Cyprimeria kiowana*	1	0
11.	Black paper shale	4	0
10.	Yellow shales and pinkish and gray shell limestone with an abundance of *Gryphœa corrugata, Cyprimeria kiowana* and *Turritella seriatim-granulata belviderii*	1	0
9.	Black paper shale	5	0
8.	Yellow and brown shale with an abundance of *Gryphœa corrugata*	1	0
7.	Black and yellowish shale, the latter sandy and containing small pebbles of quartz	8	0
6.	Alternating layers of yellowish-gray sandy shales and black clay shale, with lenses of limestone up to about 2 inches thick,	2	0
5.	Black paper shale	4	0
4.	Interbedded gray, black and yellow shale, some beds sandy. Contains small black chert pebbles and small concretions in some of which fossils occur. These are commonly fish teeth..	1	6
3.	Black paper shale. A few poorly preserved fossils in basal portion	16	0
2.	White clayey sandstone	0	6
1.	Champion shell bed, characters as in the Champion Draw section	1	0

Avilla Hill Section, (after Vaughan, **53**, p. 46):

		Ft.	In.
6.	Capping of the Plains Tertiary gravel	..	..
5.	Yellow limy flagstone and shale with a layer about 10 feet and another about 20 feet from the top filled with *Gryphœa*	70	0
4.	Yellow clay shale with a few layers of sandstone	35	0
3.	Gray shell limestone containing many *Gryphœa, Turritella, Cyprimeria* and other fossils	5	0
2.	Black paper shale with a 1-foot bed of brown sandstone about 10 feet above the base	45	0
1.	Yellowish clay shale	5	0

Bluff Creek Canyon section:

		Ft.	In.
17.	White Tertiary marl	15	0
16.	Covered slope	5	0
15.	Fine-grained yellow sandstone	0	6
14.	Sandy yellow shale with fragments of *Gryphœa corrugata*	2	0
13.	Black shale	4	0
12.	Compact, mottled pink and gray shell limestone with a thin layer of satin spar on top. Contains many *Gryphœa corrugata*. Correlated with zone 18 of the Champion Draw section,	0	10
11.	Covered slope with sandstone and limestone float. Probably mostly shale	26	0
10.	Thin-bedded gray sandstone	2	0
9.	Covered slope	6	0
8.	Sandy gray shells	10	0
7.	Thin-bedded yellow sandstone and gray shale	1	0
6.	Thin-laminated black shale	40	0
5.	Gray and pink shell limestone with a thin layer of satin spar on top. Make up largely of shells of *Gryphœa corrugata* and *Trigonia emoryi*	0	4
4.	Black paper shale	2	0
3.	Sandy shale and fine-grained gray sandstone	1	0

	Thickness. Ft.	In.
2. Black paper shale	5	0
1. Friable, fine-grained white sandstone. May be the equivalent of the Cheyenne, but is conformable on the red beds, and is probably Permian	12	0

Little Basin section, western part of Clark county (after Prosser, **50**, p. 171):

3. Tertiary sandstone	..	..
2. Yellowish shale with Kiowa fossils	15	0
1. Thin-laminated black shale, base of Kiowa	13	0

This section shows the thinning of the Kiowa westward.

In the Kiowa section shown in Champion Draw, probably the most complete known, there are six repetitions of lithology, four of which consist of alterations of black paper shale and shell limestone, the former relatively thick, the latter quite thin and in the upper part, two of alternations of lighter-colored shale and limestone as below. In this statement the calcareous shale filled with shells, as illustrated by zone 15, is included with the limestone. These alternations represent six rhythms or cycles of sedimentation, the immediate cause of which is patent. The limestones were deposited when the deposition of black mud was not going on, the shale when the bottoms were not favorable for the existence of shelled animals. The explanation of this which appears most reasonable to the writer is that the transgressing Kiowa sea was intermittent in its advance, so that the sequence of events was somewhat as follows. For a period the sea moved northward rapidly over the Cheyenne sands, and the shallow-water life followed, the shell limestones representing the rock made by them. A quiescent period followed the advance, and mud deposits extended outward into the shallow waters, which may have been without open connection with the ocean to the south, due to the presence of Permian hills, then islands or peninsulas. The black muds were probably in considerable part the accumulations of vegetable matter from plants of low rank with habits similar to those of the plants which are now forming the black muds of the east Baltic region.[5] The black-mud deposition was terminated by another advance of the sea, and again the shallow-water life peopled the bottom, and was again repelled by a new extension outward of the black-mud environment. This repetition of events is assumed to have continued to the end. At the time of farthest advance the region of southern Kansas was beyond the area of black-mud deposition, so that yellow and blue

5. Twenhofel, W. H., Notes on Black Shales in the Making. Am. Jour. Sci., 4th ser., vol. XL, pp. 271-280; 1915.

muds were deposited, creating an environment in which shell life could make a home on the bottom. Farther south, in Texas, where there was more intimate connection with the open sea, black muds of the type present in the Kiowa shales did not generally appear.

If one could ascertain the length of time involved in the deposition of one of the laminations of the black paper shales, a fairly reliable estimate could be made of the minimum time involved in the deposition of that part of the Kiowa sequence which still remains. In some of the zones the thickness of the individual laminations approximate a millimeter, and the hypothesis that each lamination represents one season's deposition seems for the present the most reasonable assumption. On this basis it would have required 2,100 years to deposit the shale of zone 3 of the Belvidere section, or 150 years to one foot. If the limestone was accumulated at the rate of one foot in 1,000 years, the Champion shell bed required from 1,000 to 1,500 years for its development. Since oyster-like shells accumulate with great rapidity, it is probable that 1,000 years for the accumulation of one foot is too low a rate of deposition. As there are about 100 feet of shale in the Champion Draw section—not all of this is black paper shale—the rate of 150 years for a foot would give 15,000 years as the time required for the deposition of the shale. The limestones which are present in the section add roughly another 10,000 years to this figure, giving a total of 25,000 years as the approximate time required for the deposition of the strata present in the Champion Draw section. As there were probably many times when no deposition was going on, due to the bottoms having been built up to the profile of the equilibrium, this figure should probably be greatly increased.

Spring Creek Member. The upper two members of this formation were defined by Gould, and with the overlying strata were described as the Medicine beds (**55**). The sequence given by him is shown below, the origin and character of the organic content being also given:

Reeder sandstone................	"Dakota" flora	Continental
Kirby clays.....................	"Dakota" flora	Continental
Greenleaf sandstone.............	Kiowa fauna	Marine
Spring Creek clays..............	Kiowa fauna	Marine

The writer is not certain to what extent the differentiation of the Spring Creek and Greenleaf members as distinct from the Kiowa is justified, but since it has been done, and there are differences in the character of the sediments, it is considered best to continue the usage of these terms.

The Spring Creek member, named from a creek west of Belvidere, consists of bluish, greenish and yellowish clays and shale in which there are concretions of impure limonite. Its contact with the underlying Kiowa is not sharply defined. The thickness is around 50 feet for the maximum. The member contains the fossils listed below (**59**, p. 26):

Cardium cf. *kansasensis* Meek.
Corbula sp.
Cyprimeria cf. *kiowana* Cragin.
Gryphæa corrugata Say.
Lingula sp.
Nucula or *Leda* sp.
Mactra sp.
Ostrea quadriplicata Shumard.
Pholadomya? cf. *belviderensis*, n. sp.
Plicatula sp.
Protocardia cf. *texana* Conrad.
Tellina sp.
Shark teeth and fish scales.

Greenleaf Member. The immediately succeeding Greenleaf member (the name derived from Greenleaf ranch, near the village of Belvidere) consists of light-gray to light-brown, massive-bedded, commonly cross-laminated sandstone. Nodules of clayey limonite are extremely common in some layers. The maximum thickness is around 50 feet, but there are not many places where this thickness occurs. The member is probably of marine origin as suggested by the poorly preserved fossils which are present. Those which have been identified are given in the list which follows (**59**, p. 26):

Cyprimeria cf. *kiowana* Cragin.
Lingula sp.
Pholadomya cf. *belviderensis*, n. sp.
Turritella sp.
Shark teeth.

"Dakota" Formation.

The strata of the "Dakota" formation consist of clay and sandstone. As a result of post-"Dakota" erosion the formation is not everywhere present above the Belvidere formation. Portions of these strata were identified as the "Dakota" by Cragin (**43**, p. 381) and designated the Reeder sandstone. Their relation to the marine strata was worked out by Gould, and to him is due the name of the underlying Kirby member. These strata are overlain by the plains Tertiary, the contact being one of erosion.

The Kirby member, so named from the Kirby ranch near Belvidere, consists of yellow and reddish clay and shale in which are interbedded thin layers of yellow, fine-grained sandstone. The thickness may attain 50 feet, but is generally much less. The member appears to be conformable on the Greenleaf sandstone. It is believed to be of continental origin, and the only organic remains which are said to have been found consist of fragments of dicotyledons.

The Reeder sandstone has the characteristics of the "Dakota" of the central part of the state. It was named from an occurrence near Reeder post office on Medicine Lodge river. The rock consists of dark-brown massive sandstones which are commonly cross-laminated, contain many pebbles of chert and quartz and are locally characterized by large nodular concretions. The maximum thickness is around 20 feet, but in most sections very little of this is present. The plants given in the list which follows were collected by Gould (**59,** p. 30) from this horizon, identifications made by Ward:

Proterides daphnogenoides Heer.
Embrothrites daphneoides Lx.
Laurus plutonia Heer.
Eucalyptus geinitzi Heer.
Eucalyptus gouldi Ward.
Eucalyptus sp.

Sections which are typical of "Dakota" and Belvidere beds are given below:

Section on Spring Creek, about 12 miles west of Belvidere (after Gould, **55**):

	Thickness. Ft.	In.
6. Covered slope underlain by the plains Tertiary	..	..
"Dakota" sandstone.		
5. Reeder sandstone. Dark-brown, massive-bedded sandstone, generally cross-laminated and containing many pebbles and nodular concretions, the latter up to 3 feet in diameter. No fossils observed	20	0
4. Kirby clay. Yellowish to reddish clay, more or less sandy and containing beds of light-yellow sandstone. Contains nodules of clay ironstone	20	0
Belvidere formation.		
3. Greenleaf sandstone. Light-gray to yellow sandstone, generally much cross-laminated and containing nodules of dark-brown to black clay ironstone	55	0
2. Spring Creek clay.		
(*a*) Blue to yellow clay, containing bands and concretionary masses of impure limonite. Outcrop of a reddish color	20	0
(*b*) Dark-brown clay ironstone, bedding undulatory and cross-laminated. Not everywhere present. Weathers into odd forms	5	0
(*c*) Green to yellow clay with 1 to 8 in. beds of gray shaley sandstone. Contains numerous iron concretions; many of these are geodic, but contain clay	15	0
1. Kiowa shale. Black paper shale	15	0

On the western part of the Comanchean outcrop the Kirby clay unit is not present, as is shown in the section which follows (modified after Gould, **59**, p. 25):

Chatman Creek section, about 12 miles northwest of Ashland:

	Thickness. Ft.	In.
"Dakota" sandstone.		
4. Reeder sandstone. Light to very dark-brown sandstone, more or less massive-bedded and locally cross-laminated. Contains pebbles and large limonite concretions	15	0

	Thickness. Ft.	In.
Belvidere formation.		
3. Greenleaf sandstone. Massive-bedded, yellow to dark-brown sandstone, locally cross-laminated	25	0
2. Spring Creek clay. Yellowish to blue clay containing nodules of clay iron-stone	25	0
1. Kiowa shale.		

Cheyenne, Belvidere and "Dakota" Strata Beneath Younger Formations (Southern Kansas).

What lies beneath the Tertiary cover to the north of the Cheyenne, Belvidere and "Dakota" exposures is not known, and the data in the possession of the writer are rather scanty. It is possible that none of the formations under consideration is present and that these rocks were all removed during the Tertiary erosion. A well drilled on the Tertiary near Minneola, about 10 miles west of the most northern exposures of Bluff creek canyon, gave the record which follows:

Record of well near Minneola, Clark county.

Formations.	Feet.
8. Soil	5
7. Yellow clay	75
6. Gray sandstone	41
5. Yellow gypsum	4
4. Red rock	4
3. Soft blue shale	143
2. Hard white limestone	2
1. Soft blue shale	10

The white limestone shown in this record is probably the Day Creek dolomite of the Permian. The blue shale above, with the overlying red rock and the yellow gypsum, is probably also Permian. It is possible that the gray sandstone is Cheyenne, but it is more likely a part of the gray sandy marls at the base of the Tertiary. On this interpretation neither Comanchean or "Dakota" strata are present.

CENTRAL AND NORTHERN KANSAS.

The red and other sandstones and shales lying beneath the Benton shales have generally been known as the Dakota, and with this division were formerly included all the strata to the top of the Permian. The division as thus limited was known to contain marine fossils in at least one horizon. The discovery that some of these marine forms also occur in the Comanchean series of Texas was made by Cragin, and he found that there are two horizons in which such marine forms are present. A thin limestone member near the base, containing fossils identical with those of the Kiowa to the south, he called the Kiowa shale (**26**, p. 37, **29**, p. 80). A shell-bearing horizon some 50 feet above this horizon was named the Mentor beds (**44**, pp. 162-165), the type locality being near the little railroad station of that name in Saline county. Many years before, Meek had collected marine fossils in the "Dakota" of northeast Nebraska and southeast South Dakota (**13**, pp. 171-174), and Mudge, long before Cragin, had found fossils in the red sandstones later named the Mentor beds (**6**, p. 394).

Belvidere Formation.

It is proposed in this paper to include all of the strata from the top of the Mentor horizon down to the Permian in the Belvidere formation and those above the Mentor in the "Dakota." It will not be possible to determine everywhere to which formation certain beds belong, because of inability to prove the stratigraphic position; and as the Mentor drops out northward, it is not possible at the present time to state the distribution of the Belvidere formation in the northern part of the state.[6]

The term Mentor is used with the significance given it by Cragin in his first definition. The thin marine limestones near the base of the sequence it is proposed to call the Windom member, from the extensive occurrence of these strata northeast of the village of that name. Zones 5 to 10 of the Natural Corral section are designated the Marquette member, while to the strata below the Windom member the name Natural Corral member is applied. It is not to be understood that these terms are given any significance other than that they conveniently serve to designate the occurrence of fossils and the stratigraphic position of exposures.

These different divisions are shown in few natural exposures. Thus the type locality of the Mentor beds has nothing other than float plowed up in a road ditch. Places where exposures have been found showing the strata in sequence are in the upland country forming the divide between Smoky Hill and Little Arkansas rivers between the village of Marquette on the north and Conway and Windom on the south, and on Spring creek, near the village of Brookville. The best exposures are in the vicinity of Natural Corral a box canyon about 5 miles southwest of Marquette (N. W. ¼, sec. 5, T. 18 S., R. 5 W.), McPherson county. At that locality the

6. In the writer's judgment, the Kansas "Dakota," as at present defined, includes nonmarine strata which are the equivalent of the Belvidere formation, strata deposited on the retirement of the Belvidere sea and strata which were deposited immediately antecedent to the Benton invasion. The differentiation of these three groups of strata has not yet been attempted. If continental deposition continued in this region from the Mentor to the Benton, it will not be possible to find a structural plane of separation in these sandstones and shales, and any dividing plane selected will have to be based on paleobotanic criteria.

Mentor sandstone can be followed about the shoulders of the canyon and neighboring hills and its variations easily observed. Float from the Mentor beds, in most cases very close to the stratigraphic position, is extremely common over parts of Saline and McPherson counties. This float generally occurs in road ditches and plowed fields.

The section at the Natural Corral is composite, having been made from the many exposures in the canyon (Pl. II, Fig. 3), as follows:

Section at the Natural Corral, McPherson county:	Thickness. Ft.	In.
12. Covered slope with Tertiary at the top, but float indicates the presence of red sandstone of the "Dakota"	50	0
11. Cross-laminated, highly ferruginous and concretionary coarse red sandstone. The concretions are similar to those characteristic of the "Dakota." About 4 to 6 feet from the top is a horizon containing the typical Mentor fauna. Fossils may be present in other parts of this zone but they have not been observed. There are many places in the immediate vicinity where the zone appears to contain no fossils whatever. This in part may be due to original absence, but in some cases it appears probable that it is due to the development of limonite concretionary structures whose presence in places has so completely modified the rock that all original features have been obliterated. This zone forms the rim of the canyon and the shoulders of the bluffs in the immediate vicinity	8	0
10. Cross-laminated, medium-grained, friable yellow sandstone; no fossils	2	0
9. Friable, fine-grained, yellowish sandstone with a somewhat compact 6-inch band near the middle and another similar 2-inch band about 7 feet from the top. Locally the zone contains a little shale. It forms the upper portion of the cliff above the spring at the head of the east arm of the Corral, where it is thinner and more compact than indicated above. No fossils	17	6
8. Compact yellowish-white sandstone; no fossils....... 7 ft. to	8	0
7. Blue paper shale; no observed fossils	10	0
6. Pale yellow sandstone, containing dicotyledonous leaves	2	0
5. Blue gypsiferous shale	14	0
4. Two 6-inch layers of gray shell limestone separated by gray shale. The limestone consists almost wholly of shells. The most common species being *Ostrea kiowana, Cyprimeria kiowana, Cardium kansasensis* and *Turritella seriatim-granulata belviderii*	3	0
3. Dark-blue gypsiferous shale containing many crystals of yellow selenite, nodules of pyrite and a layer of cone-in-cone limestone. The cone-in-cone layer, or one very similar, has been found in a number of localities in Saline and McPherson counties where no fossiliferous strata are present	16	0
2. Concealed, believed to be shale and sandstone	14	0
1. Permian. Red, blue and yellow shales of the Wellington formation	25	0

The only other place where a section of the marine strata is known to occur in Saline county is along the banks of Spring creek, near the village of Brookville. The section here is as follows:

Section on Spring creek, near Brookville, Saline county:

	Thickness. Ft.	In.
4. Yellow and gray sandstone overlain by reddish sandstone containing limonite concretions	10	0
3. Thin laminated blue shale which locally carries limonite concretions. The largest of these have horizontal diameters up to a foot and a thickness up to 6 inches	16	0
2. Friable, thick-bedded yellow sandstone, nearly one solid bed, containing poorly preserved Comanchean fossils	6	0
1. Thin laminated black shales, to creek bed	9	0

A section showing the character of the nonmarine strata which are believed to hold the stratigraphic position of the strata below the Mentor member is exposed on the south bank of Solomon river and an adjacent hillside one mile south of Bennington. This section is as follows:

Section on south side of Solomon river, one mile south of Bennington:

	Thickness. Ft.	In.
9. Mottled red, brown and yellow coarse-grained sandstone in which are mud pebbles. The rock is concretionary in spots. Exposed at the base to the extent of 6 feet, upper portion exposed only in spots. About two miles to the south on a horizon which seems to fall within this zone is a layer of cone-in-cone limestone like that of zone 3 of the Natural Corral section	50	0
8. Friable white sandstone of medium grain	12	0
7. Concealed	3	0
6. Medium-grained, friable white sandstone in which are occasional harder bands	6	0
5. Dark blue shale	4	0
4. Fine-grained, friable yellow sandstone	2	9
3. Blue shale	2	0
2. Medium-grained, friable yellow sandstone	8	8
1. Concealed to river level, probably of weak materials	9	0

While these sections serve to show the sequence of strata in the central portion of the state, not one of them occurs in the localities where the strata are most fossiliferous. The best place at which to collect Mentor fossils is in the road ditches and plowed fields about five miles west of the little village of Smolan, in Saline county. Here the rock is simply a mass of fossils—all molds—no shell matter being preserved. The best place to collect fossils from the Windom member is about 3 miles northeast of Windom village.

The sands of the Marquette member show every indication in some horizons of having been deposited by the wind. Mechanical analyses of some of these and other sands are shown on Plate VI.

The fauna of the Mentor beds is relatively large and extremely prolific in individuals of some species, varying greatly, however, with locality. Descriptions of thirty-one species are given on subsequent pages, and in addition there is considerable material too imperfect for description. The species are as follows:

Anchura kiowana Cragin.
Anisomyon? cragini, n. sp.
Arcopagella mactroides Meek.
Barbatia parallela Meek.
Cardium kansasense Meek.
Corbicula elongata, n. sp.
Corbicula nucalis Meek.
Crassatellina oblonga Meek.
Cucullæa? gigantea, n. sp.
Cucullæa? recedens Cragin.
Cyprimeria kiowana Cragin.
Engonoceras belviderensis Cragin.
Gervillia mudgeana White.
Leda acuminata, n. sp.
Leptosolen conradi Meek.
Linearia kansasense, n. sp.
Mactra siouxensis smolanensis, n. var.
Margarita ornamentata, n. sp.
Margarita mudgeana Meek.
Natrea? smolanensis, n. sp.
Nerita semipleura, n. sp.
Ostrea kiowana, n. sp.
Ostrea quadriplicata Shumard.
Protocardia texana Conrad.
Pteria salinaensis White.
Siliqua mentorensis, n. sp.
Tellina subscitula Meek.
Trigonia emoryi Conrad.
Trigonarca salinaensis Meek.
Turritella kansasense Meek.
Yoldia microdonta Meek.

The fauna of the Windom member is not large in species, but of some species it contains an abundance of individuals, particularly of *Turritella and Ostrea.* The species listed below have been identified:

Anchura kiowana Cragin.
Cardium kansasense Meek.
Cyprimeria kiowana Cragin.
Engonoceras belviderii Cragin.
Neritoma marcouana Cragin.
Ostrea kiowana, n. sp.
Turritella seriatim-granulata belviderii Cragin.

"Dakota" Formation.

The sequence of strata given by Logan (**51**) for the Kansas "Dakota" is as follows:

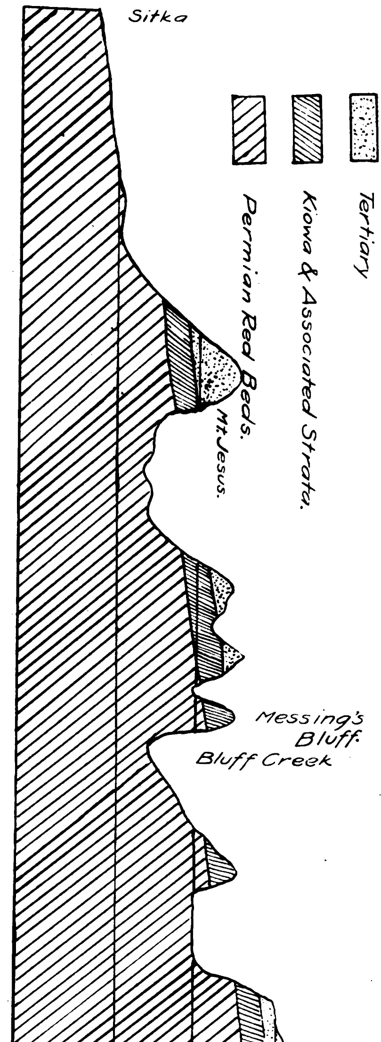
Upper "Dakota":

(*a*) Gypsiferous dark shale	10 to 20 ft.
(*b*) Saliferous shale with thin sandstone layers containing marine fossils	15 to 30 ft.
(*c*) Shell bed	6 in.
(*d*) Shales like those above	5 to 10 ft.
(*e*) Lignite zone	6 to 26 in.

To what extent this section is correct is not known to the present writer. According to Logan (**82,** p. 259), letter to Stanton, T. W., 1905, the Mentor beds have been included and assigned to the upper Dakota. This makes it desirable that the Kansas "Dakota" section be carefully restudied. It will probably be found far more complex than suspected.

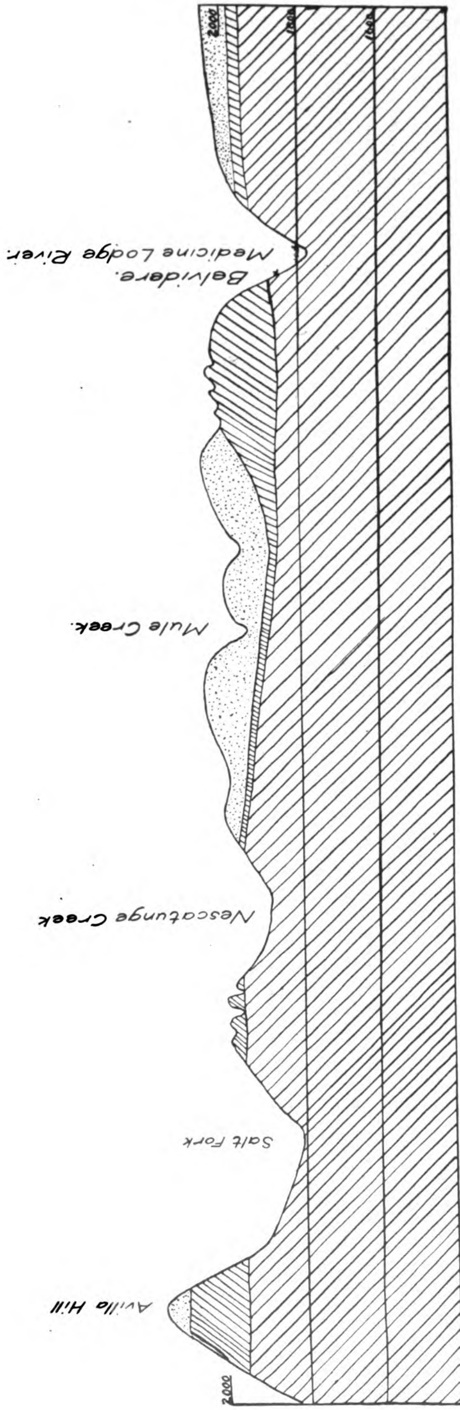
The Base and Summit of the Comanchean.

In southern Kansas the Comanchean strata rest unconformably on the red beds of the Permian, the surface on which the strata were deposited having been developed by deep erosion. The relief



Sitka North to Ford County Line.

PLATE III.—Cross section from Sitka to the Ford county line, modified from Gould.



Avilla Hill to Northeast of Belvidere.

PLATE IV.—Cross section from Avilla Hill to northeast of Belvidere, modified after Gould.

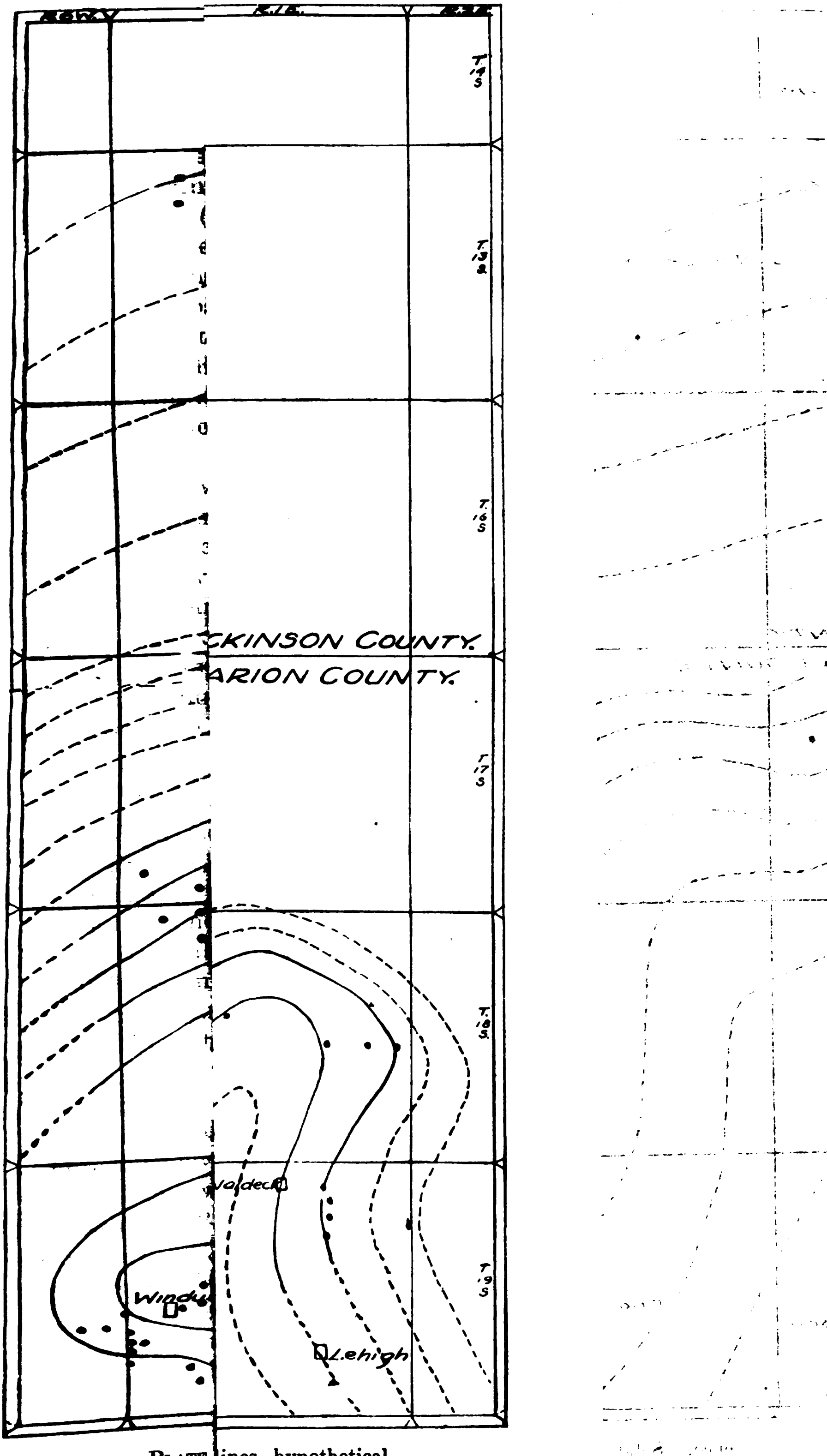
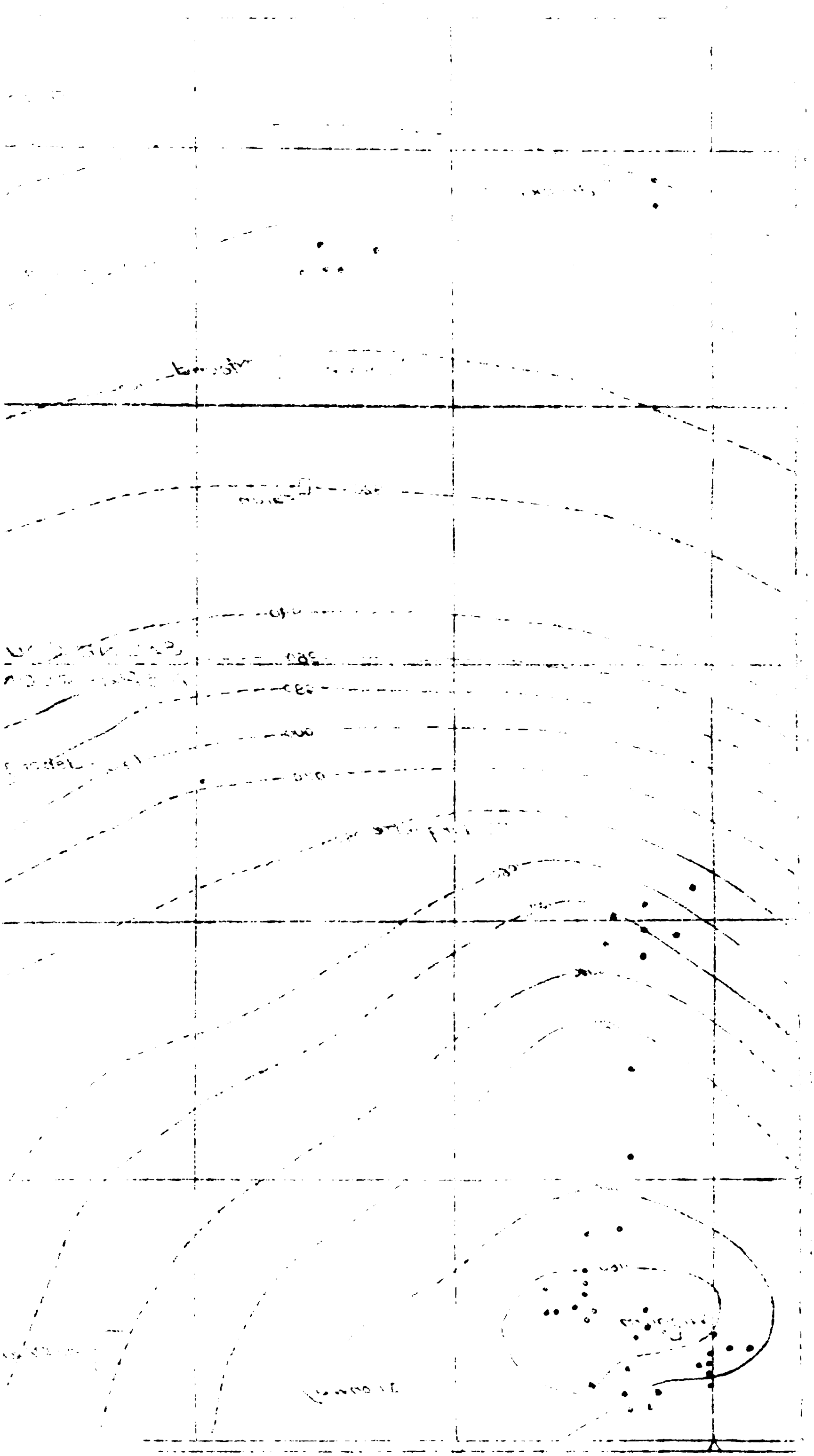


PLATE lines hypothetical



does not appear to have been great, but it is probable that hills composed of Permian rock were not completely covered by the Comanchean strata (**50, 53**). The surface on which deposition occurred probably sloped to the south, and such a slope still obtains over the western extension, though now modified by a slope to the east. In the east part of the Comanchean area the base slopes to the north and east.

In central Kansas the Comanchean rests on strata which in McPherson county are either Cimarron red beds or the Wellington shale. In the vicinity of Salina the underlying strata appear to belong to the Marion formation. The surface of the Permian here appears to have had considerable relief.

The upper surface of the Comanchean-"Dakota" in central Kansas is extremely irregular as a consequence of late Cretaceous or early Tertiary erosion. In places the "Dakota" has been completely taken away and the Tertiary rests on the Mentor beds. Elsewhere erosion has extended to the base of the Comanchean strata and the Tertiary rests on the Permian. Information in the possession of the writer does not permit a statement as to where the top of the strata described as Comanchean should be drawn.

Structure of the Marine Portions of the Comanchean Strata.

Southern Kansas. The geologic sections which follow, modified after Prosser, show the different structural relations of the Comanchean in southern Kansas. Throughout the western extension of the Comanchean strata in Clark county the elevation of the base varies from about 2,100 to 2,250 feet and the summit from 2,220 to 2,350 feet. In the eastern extensions around Belvidere the elevation of the base varies around 1,900 feet, thus indicating a dip to the east of 6 or 7 feet to a mile. From Avilla Hill to Belvidere the strata dip to the north, the base falling from about 1,950 feet at the former place to 1,850 or 1,900 feet at the latter. In the west Prosser gives a section extending from Mt. Jesus, about 4 miles north of Sitka, where the elevation of the base is about 2,100 feet, to the Clark-Ford county line, where the most northern exposure of the base has an elevation of 2,250 feet. It is known that there are local variations in inclination, but detail is wanting. One reversal of dip was noted by Prosser (**50,** p. 175) on the high prairie north of Ashland, making a small anticline with a broad base. (See plates III and IV.)

Central Kansas. The structure of the marine portion of the Comanchean beds in central Kansas was determined by stadia and telescopic alidade survey. The actual work was done by Messrs. E. M. and M. L. Stryker, using the Mentor and the Windom members as key horizons. It is quite probable that some errors of detail occur in the results, but they can hardly be great. The results indicate that the strata are inclined to the north, east, south and west from a point situated about three miles northeast of Windom between section 15 and 22, T. 19 S., R. 5 W. The measured descent to the east is 190 feet in a little over 30 miles, or about 6 feet to the mile; that to the north is about 300 feet, or about 11 feet to a mile; to the west the inclination is a little more than 5 feet to a mile for 5 miles, and 21 feet to the south in 4 miles. These figures are based on ledge measurements. These facts are shown on the structural map of the Mentor and Windom distribution in central Kansas. (Plate V; the round dots are places where exposures occur.)

Lithology and Interpretation of Sediments.

The descriptions which have been given show that four general types of sediment are present, namely: (1) shell limestone and calcareous shale in which are many ostreoid shells and which also contain more or less pyrite and gypsum, both usually being present; (2) dark pyritiferous shale with crystals of gypsum, fossils being generally absent, and where present, of small size; (3) yellow and gray sandstone with streaks and lenses of shale, the sandstone as a rule being highly impregnated with gypsum and other salts, and locally and horizontally containing much pyrite, and locally also having leaves and unrecognizable plant matter; and (4) red and brown highly ferruginous sandstones, of which some are of marine and others of continental origin.

The shell beds and calcareous shales are certainly the deposits of marine waters. The sands, which in many instances form parts of the matrix inclosing the shells, are generally poorly rounded and assorted. In most instances the shells are not in the positions in which they were when inhabited by the animals which formed them. In essentially every occurrence there are many broken and eroded shells, proving transportation after the deaths of the owners. Some of the *Gryphœa* and *Ostrea* are as they grew, but in a majority of the cases there was considerable transportation. This is considered to prove a water of such shallowness that the bottom was within the limits of wave and current action.

The gypsum which is generally present suggests that the saltiness of the water was above normal, but it may have resulted in the reaction of lime carbonate in solution and sulphuric acid produced from hydrogen sulphide. The fact that the shells are of normal size does not favor the view that the waters were very acid, as such would have been unfavorable to life, while an excess of saltiness would not necessarily have been so. It is possible that the oxidation of the pyrite in these strata and also in the black shales may have produced the sulphuric acid, which filtering through the limestone strata formed the gypsum. This view is not favored, because in many instances the gypsum lies interbedded in thin sheets with the limestone, the contact being sharp, arguing for deposition in sequence with other sediments. An occasional vein which occurs locally is no doubt of epigenetic origin.

The black shales are considered to have been deposited in quiet, shallow bays and sounds, such as at present exist on the east shore of the Baltic.[7] These abound in hydrogen sulphide, which probably is produced by sulphate-reducing bacteria. If sulphur and sulphuric-acid bacteria are also present, calcium sulphate may be precipitated. The fauna of these black shale bays is small, and the organisms which are buried in the shale are not representative of the waters in which they were deposited, but are the young and planktonic forms which float in or are washed in during occasional storms. As the black shales of the Kiowa duplicate what would result were the black muds of the east Baltic formed into shales, it is considered probable that the former were deposited under somewhat the same conditions as the latter. It has been shown that black muds may be deposited in deep waters beyond the sands,[8] but the evidence of shallow-water conditions in some of the shales and in the associated deposits opposes any assumption that the Kiowa black shales are the deposits of deep water.

The yellow and gray sandstones are without fossils, and in their general characteristics suggest that they are not of marine origin. To this statement must be excepted the occasional thin sandstones in the marine sequence. Most of the sandstones appear to be either of fluvial origin on a broad sand-covered coastal plain under conditions tending toward aridity or the deposits of a broad sand beach over which the marine waters transgressed on rare occasions. The deposits locally contain leaves of dicotyledons which did not grow where they are found, but were carried to the places of deposition. The fact that most of the cross-lamination is inclined in a southerly

7. **Twenhofel, W. H.**, Notes on Black Shales in the Making: Am. Jour. Sci., 4th ser., vol. XL, pp. 271-280; 1915.
8. **Ruedemann, R.**, Bull. Geol. Soc. Am., vol. 22, pp. 234; 1911.

direction shows that the depositing currents came from a northerly direction.

The red sandstones in part may have been red from the beginning, but at least a part of the coloring matter was introduced subsequent to deposition. The Mentor beds with the numerous marine fossils were at first composed of calcareous shells and sand and the change to iron oxide was certainly subsequent. Some of the other red sandstones may be marine, but the major portions contain no marine fossils and locally do contain vegetable matter, and these portions are best interpreted as fluvial deposits on a coastal plain.

Such is thought to be the origin of the greater portion of the sandstones and shales known as the "Dakota." As the climatic conditions appear to have tended toward dryness, it is possible that some of the deposition was by wind.

In a few places portions of the sandy strata have been cemented to form a quartzitelike sandstone. This is known to have occurred about the southwest corner of sec. 16, T. 20 S., R. 6 W., where the Windom member is a quartzitic coquina. The sandstones of the "Dakota" form a compact quartzitelike rock on the hills south of Roxbury, and a similar occurrence is on a hill one and a half miles west and a little south of Waldeck. This is considered to have been brought about by ground-water action, but intrusions of igneous rocks may lie beneath these occurrences, as has been found to be the case in other parts of Kansas.

General Conditions of Origin of the Comanchean of Kansas.

It is obvious that the strata of the two areas here described were once connected—connection may still obtain beneath the Tertiary cover—and that they were deposited under conditions which permitted marine and continental environments to contend with each other for the places of deposition. For a time marine conditions prevailed, to be succeeded later by conditions of continental deposition, this occurring at least twice in the central part of the state. Conditions such as these were brought about by migrations of the strand line north and south over the sites of deposition; north when marine deposits pressed northward, south when continental deposition advanced southward. These to-and-fro migrations could have been brought about by oscillation of sea level through cyclic upward and downward movements of varying extent, or through intermittent and differential downward movement, with building outward of the shore line by terrestrial sediments during the times of relative stability, and invasions northward of the sea during the times of rapid downward movement, the thickness and character of the deposits being consequent to the extent of movement and the duration of the times of stability. Whether the movement was upward and downward or altogether downward, the writer does not know, but it appeals to him as more probable that the major movement was downward rather than oscillatory, with uplift toward the close of deposition, and consequent extension of continental deposition as far southward as Texas, where the Woodbine formation of the "Dakota" was deposited. However the effects were accomplished, there resulted a dovetailing of marine and continental deposits, the former everywhere containing a Belvidere fauna, the latter in some cases a "Dakota" flora.

The facts indicate that parts of the "Dakota" sandstone of Kansas and the marine strata known as the Kiowa-Mentor were deposited during the same general interval of time, the former being the continental equivalent of the latter. It is possible, and considered probable, that portions of the "Dakota" are channel fillings in and below the Mentor, so that later strata lie on a lower stratigraphic level than older strata. It may be that a disconformity and stratigraphic break occurs in the "Dakota," but on this point the writer has no information. On the other hand, continental deposition may have continued without break from the top of the Belvidere to the base of the Benton, so that no important break in sedimentation occurred. That a change in marine life occurred between the retirement of the marine fauna of the Belvidere and the appearance of the Benton is certain so far as this region is concerned.

SUMMARIZING THE CONCLUSIONS.

A shallow sea invaded the Kansas region, which was then a dry or semiarid land of little relief. This sea was narrowly connected with the ocean to the south, and appears to have been dotted with islands and parted by peninsulas, which weakened the force of the waves. The Wichita and Arbuckle islands or peninsulas narrowed ingress from the southern seas, so that tidal action was probably insignificant. Streams from the bordering lands built their deltas into the bay. These formed lagoons, and in these and the basins made by the islands and peninsulas the black shales were deposited. Ultimately the rivers extended their deposits over the marine and drove back the sea. For a time the sea retreated, but depression again permitted northward progress.

The general dryness of the climate resulted in the feeding of insufficient water to the Gulf during parts of the year, thus failing to balance the loss by evaporation. Consequently there was a current into the basin from the sea, through a connection which was apparently too small to permit sufficiently free circulation to maintain uniform conditions. During such times of abnormal salinity, precipitation of calcium sulphate is assumed to have occurred.

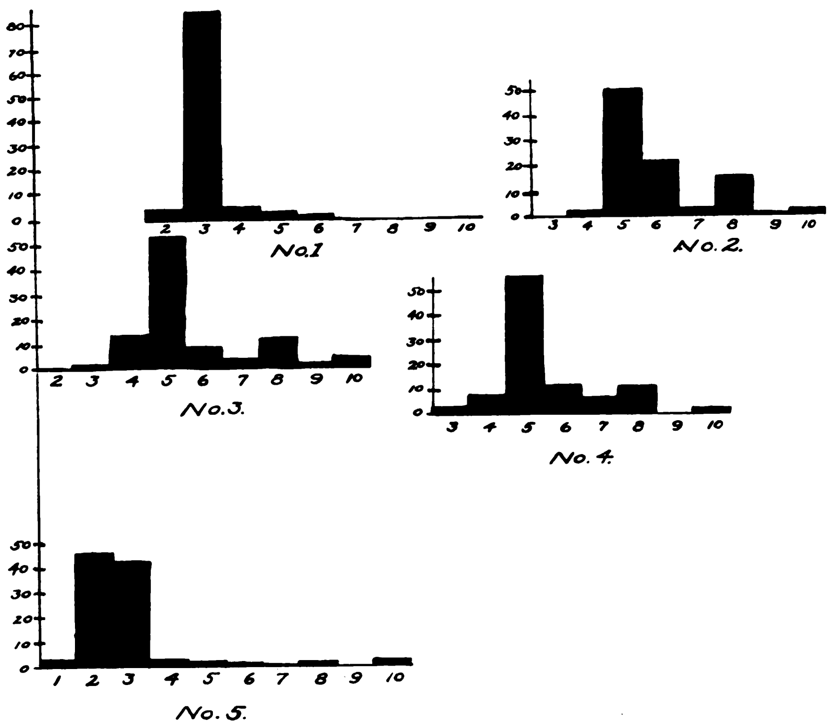


PLATE VI.—Mechanical analyses of Comanchean sands.

Mechanical Analyses of Sands.

1. White Cheyenne sandstone, Champion Draw section, 20 feet below top (see Plate VI, Fig. 1):

Standard mesh.	Size of openings (in mm.).	Per cent retained.
48	0.295	4.80
65	.208	85.50
80	.175	5.70
100	.147	1.71
115	.124	1.50
150	.104	0.04
170	.088	0.20
200	.074	0.04
200*a*	Pan	0.26
Total		100.75

Remarks. This material is wholly quartz, with the exception that all fractions below 48-mesh contain small percentages of gypsum. All meshes to 115 have most of the grains polished, and about 10 per cent being spherical. The 150-, 170- and 200-mesh samples contain a large percentage of the grains sharply angular, although there are few spherical grains and some polishing and rounding. In the 200*a*-mesh material all the grains are sharply angular. The dimensions extend to microscopic sizes.

Conclusions. This sand is considered to be of stream production and of wind or stream deposition. The cross-lamination, inclined truncation and degree of assortment are believed to harmonize better with the view of wind deposition.

2. Cross-laminated white sandstone from lower portion of the 17½-foot zone of the Natural Corral section (see Plate VI, Fig. 2):

Standard mesh.	Size of openings (in mm.).	Per cent retained.
65	0.208	0.40
80	.175	2.00
100	.147	51.00
115	.124	22.40
150	.104	2.50
170	.088	16.60
200	.074	1.30
200*a*	Pan	3.50
Total		99.70

Remarks. The material is quartz and gypsum, the latter consisting of a few flakes in all fractions except the 200*a*-mesh, in which there is much finely divided gypsum. The fraction of the 150-mesh contains an occasional highly polished black grain which is not magnetic. There is essentially no rounding or polishing in any of the fractions.

3. Cross-laminated yellow sandstone from zone below the 17½-foot zone of the Natural Corral section (see Plate VI, Fig. 3):

Standard mesh.	Size of openings (in mm.).	Per cent retained.
48	0.295	0.03
65	.208	2.27
80	.175	14.40
100	.147	56.12
115	.124	8.81
150	.104	3.13
170	.088	11.34
200	.074	1.04
200*a*	Pan	3.38
Total		100.52

Remarks. The material is wholly quartz with flakes of selenite, which in the 65 and smaller-mesh fractions rise to as much as 3 per cent. The fraction from the 65-mesh screen contains a few granules of opaque material with rusty exteriors which may be pyrite. The 48-mesh screen contains about 10 grains of elliptical or spherical shapes; all others are sharply angular. In all other meshes essentially every grain is sharply angular. The 200-mesh has the grains decreasing to microscopic sizes.

4. Cross-laminated white sandstone, zone below the 17½-foot zone, the main layer of the spring (see Plate VI, Fig. 4):

Standard mesh.	Size of openings (in mm.)	Per cent retained.
65	0.208	3.5
80	.175	7.7
100	.147	56.2
115	.124	12.6
150	.104	6.2
170	.088	11.4
200	.074	0.7
200*a*	Pan	1.6
Total		99.9

Remarks. The material is almost wholly quartz, with an occasional flake of gypsum in every fraction. The fraction on 200*a*-mesh contains a small percentage of limonite in finely divided form. The grains of every fraction are sharply angular, but the fractions of the larger meshes contain an occasional spherical grain.

The sand and its structures have the characteristics of wind deposition, but the sand does not appear to be of wind production and may have been deposited by streams.

5. Red cross-laminated Cheyenne sandstone, Champion Draw section, Belvidere, Kan., from near the top, stained and cemented with limonite (see Plate VI, Fig. 5):

Standard mesh.	Size of openings (in mm.)	Per cent retained.
35	0.417	2.31
48	.295	46.42
65	.208	43.86
80	.175	2.12
100	.147	1.70
115	.124	0.76
150	.104	0.11
170	.088	0.77
200	.074	0.08
200*a*	Pan	1.89
Total		100.02

Remarks. The materials consist throughout of quartz with an occasional grain of limonite, which in the 150-mesh comprises about 2 to 3 per cent of fraction. The 150-mesh also contains an occasional flake of selenite. The 35-, 48-, and 65-mesh contain grains quite well polished and with corners rounded off, but there are few spheres. The 80-, 100- and 115-mesh fractions have about 75 per cent of the grains polished and about 25 per cent sharply angular. In 150-mesh the percentage of angular grains rises to about 50 per cent, and in the 170-mesh about 75 per cent. The 200-mesh material shows very little rounding, and smaller dimensions show no rounding whatever. The sand of the 200*a*-mesh screen decreases to microscopic dimensions.

Correlation of the Kansas Comanchean.

In the preceding discussion it has been tacitly assumed that the marine beds of the Kansas sequence are the thinned northern extension of the Washita of the Texas sequence. This appears to be the most reasonable conclusion in the light of present information. It is true that there are some things in the fauna which are of Fredericksburg aspect, but the species for the most part are more like those of the Washita. This correlation makes parts of the "Dakota" of Washita age, thus taking these portions from the Upper and placing them in the Lower Cretaceous as these two divisions have been defined in the United States. The Cheyenne lies beneath the Washita, and is therefore older. It contains a flora of dicotyledons which has led to its being correlated with the "Dakota," but which Berry states is little allied to, and older than, the flora of the Woodbine (**80**, pp. 399-390; **81**). That the Cheyenne is older than much of the "Dakota" is also evident, but it is probable that it is of the same age as some of the strata of north Kansas which have been referred to that division. The "Dakota" appears to be a kind of wastebasket into which have been placed all mid-Cretaceous sandy strata containing a dicotyledonous flora or consisting of red sandstones. A part is probably of the age of the Cheyenne, another portion the continental equivalent of the Belvidere, and there is an upper portion younger than any of the marine strata.

In the Black Hills of South Dakota, Darton (**60,** pp. 526-532) found that the lower portion of what previously had been called the "Dakota" consists of four formations or members, to which he gave, from below upward, the names of Lakota, Minnewaste limestone, Fuson, and Dakota, the last being limited to those strata containing the dicotyledonous leaves generally considered as constituting the "Dakota" flora. No marine fossils were discovered in any of the formations, so that it is assumed that none is present. That the uppermost member correlates in a general way with the beds containing the "Dakota" flora of Kansas is considered probable, and it is possible that there is a partial equivalence between the lower strata and some portions of the Belvidere formation and the Cheyenne sandstone.

Strata which are the equivalent of the Washita were identified about fifteen years ago in Colorado near the base of sandstones which had previously been referred to the "Dakota" (**64,** pp. 661-668). The discovery was made by Stanton and Lee on Purgatoire river in a section which was ultimately divided and correlated as follows:

5. Benton shale.	
4. Dakota sandstone	100 ft.
3. Dark shale and shaly sandstones with a Washita fauna	50 to 100 ft.
2. Coarse, gray, cross-laminated sandstone	15 to 60 ft.
1. Morrison shales.	

It is possible that zone 2 is the equivalent of the Cheyenne, but correlation of terrestrial, or, for that matter, any kind of sediments on the basis of the lithology, has nearly all possible chances of being incorrect. Zone 3 contains species which are also in the Kiowa, and this zone is probably contemporaneous with some part of the Kiowa of Kansas.

In the description of the geology of the Apishapa quadrangle Stose (**72,** pp. 3-5) differentiated the strata containing marine fossils of Washita affinity as the Purgatoire formation. In his description of the Colorado Springs quadrangle Findlay (**73**) divided the Purgatoire formation into the Lytle sandstone member below and the Glencairn shale above. In the shales there are few fossils and none in the Lytle sandstone, but the correlation with the Purgatoire formation is considered established.

Sequence of Events During the Deposition of the Cheyenne, Belvidere and "Dakota" Formations.

The sequence of events for Kansas from the first appearance of the Comanchean in the state is something as follows:

1. Continental deposition by streams and winds on a coastal plain in a dry or semiarid climate—the Cheyenne sandstone.
2. Kiowa—"Dakota" deposition.
   a. Shallow sea waters advanced northward to about the city of Salina, Kan.—Kiowa deposition.
   b. Retreat of the shore line toward southern Kansas, with continental deposition over the central and northern part of the state.
   c. Northward advance of the shore line to a position a little north of Salina—Mentor deposition.
   d. Retreat of the shore line southward with continental deposition over the central part of the state—post-Mentor continental deposition.

The Base of the Upper Cretaceous.

Where shall the base of the Upper Cretaceous be drawn? Some have insisted that the Comanche series of this continent has the value of a system and the Upper Cretaceous of another, the former to be called the Comanchean, the latter the Cretaceous. There was most certainly a broad retirement of the sea at the close of Washita time and a considerable change between the faunas of the Washita and those of the Benton, and it would appear that the place in central Kansas at which to draw the plane between the Upper and Lower Cretaceous should be above the last appearance of the Washita fauna. Many European students have correlated the Washita with the Cenomanian of the Upper or Neocretaceous of Europe (**65**, p. 1408, **67**, **68**, p. 513). The general drift of American opinion also appears to have been toward correlation of the Washita, at least the upper part of it, with the Cenomanian (**71**, p. 584, **81**, p. 201, etc.). In Europe the Cenomanian witnessed a great transgression of the sea, which extended beyond the limits of the Lower Cretaceous sea, so that the European strata of the Cenomanian hold the same position with respect to invasion that is held by the Benton of the Plains (**74**, p. 412; **67**, p. 168).

This brings forward the question as to what should constitute the boundary of a larger time unit. On the basis of diastrophism, the boundary of these two time units for Kansas and adjacent states should be placed at the top of the Washita and its equivalents. In Europe it apparently should be placed at the base of the Cenomanian, considered by many students as the equivalent of the Washita. Thus the diastrophic principle places the break on one continent at one level and on another continent at a different level. There ought to be nothing strange about this—it seems that such should be more normal than anything different—and the writer is inclined to the opinion that this ultimately will be found to be true for several of the larger time units just as soon as we can get away from the view that the order of events on this continent was the same as in the Old World. The writer would go still further and insist that such is quite likely to be found to be the case for some of the larger time units on the same continent, thus agreeing with Willis that "each region has experienced an individual history of diastrophism, in which the law of periodicity is expressed in cycles of movement and quiescence peculiar to the region," and "the periods of diastrophic activity" have been, "as regards the whole surface of the earth, in general, not contemporaneous."

The theory of universal time breaks for all the continents grew up within the last century, on the assumption that either all the continents or the oceans moved as a whole at the same time, and received tremendous support from the views of Suess, with his postulate of the sinking of the ocean basin to account for the lowering of the strand line and the rising of the land. Chamberlin and Salisbury gave it further support when they asserted that "deformation movements begin with a depression of the bottom of the ocean basins, by which their capacity is increased," withdrawing the water from the epicontinental seas, thus bringing about a general raising of the strand line because of the probable connection of all the oceanic basins with each other (**67**, p. 192). The writer wishes that this theory of universal depression or elevation of the strand line could be established, as it would immensely simplify the problems of intercontinental stratigraphy and those of opposite sides of the same continent, but he considers the wish essentially impossible of realization. That some withdrawals of the sea were of this general character is possible, and such might constitute the chief division points of the geologic time scale—perhaps the boundaries between eras—but the view that local regional elevation and depression takes place on the continents irrespective of what the ocean and other continents are doing seems to him to rest on a firmer basis of fact. That the separation of the geologic time table into periods is based on such local withdrawals of the sea seems far more probable than that such planes of division are due to general withdrawals of the sea over all the continents.

If the bounding planes between divisions of the geologic column of periodic rank are determined by local regional withdrawals of the sea, how is it to be decided for each continent as to what constitutes a period? In order for nomenclature relating to the geologic time scale to be of value to geologists and students in general, the larger time units, as nearly as possible, should have the same limitations on one continent as on another, and if the above postulate be valid it means that after the boundaries of a system have been determined on one continent they will have to be arbitrarily fixed for other continents on a basis of paleontologic criteria, irrespective of where the diastrophic breaks may be. If done otherwise, a term given to a period will mean one thing on one continent and something else on another. This would mean that as the boundary between the Lower and Upper Cretaceous has been determined in Europe, the limitations of these divisions in North America will have to be determined on paleontologic criteria. The application of this principle makes it necessary to place the strata under consideration in the Upper Cretaceous.

The writer would compare the divisions of geologic history of one continent, in their relations to the geologic history of another, to the divisions of the history of man. The great divisions of American and European history have been based on great events in the history of the white race, and ultimately these high points may become the basis for the division of the history of all people, the histories of other peoples being made to conform to the divisions in the histories of American and European peoples. Did one study Chinese history, the high points would be at other times. They might coincide in some instances; in most they would not. It may ultimately come to pass that another civilization with different antecedents may supplant the existing one, and to this civilization the high points of the present civilization may have no significance. So the high points in European geologic history may have no relation to the high points in American geologic history; and as the limitations of many of our geologic time divisions were established in the former country, those of the latter should be drawn on paleontologic criteria to agree with the former, irrespective of where the diastrophic breaks occur.

Invertebrate Paleontology and Faunal Summary.

In the descriptions which follow, a total of seventy-eight species and varieties is described. These embrace species described by Meek, Cragin, White and others, and new species described by the writer. An effort was made to see the material on which Cragin worked, but it could not be found. He listed many species which are doubtfully present, and he listed species by one name which he subsequently described under another. As he was far removed from large libraries and collections, it is obvious that he labored under extreme difficulties. It has been extremely difficult at times to decide what forms Cragin had in mind; but so far as the writer has been able, he has retained all names given by Cragin. Some of the names have been omitted as obviously in error. The fauna described by Meek from the "Dakota" sandstone has been included.

All the types of the species described in this article for the first time are in the museum of the University of Kansas. The writer has cotypes of all species of which material is abundant.

In their distribution the species are intimately related to the type of sediment in which they occur. Not a great many species are common to both the limy shales and limestones of the Kiowa shales and the sandstones of the Mentor beds. A few forms like *Trigonia emoryi, Protocardia texana, Cardium kansasensis* and *Turritella* occur in both the sandstone and the limy beds. On the other hand, no *Gryphæas* have been collected from the sandstones and no *Mactra siouxensis smolanensis* have been found in the shales. The sandstones have thirty species, of which five occur in the calcareous strata, while there are forty-seven species in the latter which do not occur in the sandstones. In the Mentor beds there is much variation with respect to species distribution.

In addition to the species which have been described by name, there are others of which the material is not sufficiently well preserved to warrant generic or specific designation. The number of such approximates about a dozen.

The character of the fauna is dominantly molluscan. There is a total of forty-eight species and varieties of pelecypods in the Mentor and other marine strata of central and northern Kansas. There are an additional six species of pelecypods which were described by Meek from the "Dakota" of southeastern South Dakota. There are fourteen species of gastropods in the Kiowa and Mentor strata. All other groups are represented by but few species. The cephalopods have four species; the annelids have two species; there is a single echinoid and a single coral. Brachiopods are exceedingly rare, only a few fragments of a *Lingula* having been collected. Several fragments of a *Dentalium* have been found.

The fauna of the Kiowa shale is essentially the same at all localities, but differs somewhat in different beds. The organisms in the Mentor beds vary in number and components with every locality, as is to be expected. The organisms found in most of the beds of the Kiowa shale probably did not live a great distance from where the shells now occur, but the shells in the Mentor bed in most instances appear to have undergone considerable transportation.

CŒLENTERATA.

Astrocœnia nidiformis Cragin.

(Plate X, figure 4.)

1895. *Astrocœnia nidiformis* Cragin. Colorado Coll. Studies, 5th Ann. Publication, p. 50.

Cragin's description (in part). Stock massive, broad and low, its breadth increasing more or less from the base upward; its summit excavated, the prominent, narrowly rounded border region of the summit being irregularly lobed; cells united by rather thick walls, calyces small, irregularly polygonal or slightly rounded-polygonal; columella short; septa rather stout, their free margins apparently a little uneven, their summits moderately depressed below the level of the calyx borders, the primary and secondary septa six each, short septa of the third order also appearing.

The above description was based on two specimens. The writer has collected an additional one (a colony), upon which the statements which follow are based.

The colony began its growth on fragments of shells and ultimately overgrew a portion of the surrounding sands. It is not over a centimeter thick. Each calyx is about ¾ mm. in diameter and the intercalicular substance is about ½ mm. wide. The calyces are about ¼ mm. deep. The septa in the writer's specimen are in two sets, the larger reaching the center, the shorter consisting of well-defined ridges. There are twelve septa in each set. Cragin noted a columella which has not been observed by the writer. Neither tabulæ nor dissepiments appear to have been preserved.

Horizon and locality. Cragin's two specimens came from the Champion shell bed in Champion Draw. The writer's specimen came from the same horizon and locality.

ANNELIDA.

Neries? incognita Cragin.

(Plate VII, figure 4.)

1894. (*?Neries*) *incognita* Cragin. Am. Geol., vol. XIV, p. 2, pl. I, figs. 20, 21.

Cragin's description. The specific name, *incognita,* is proposed as a convenient designation for the large, apparently neried worm that inhabited the sandy beach of the Comanchean sea of southern Kansas, and the casts of whose burrows (part of one of which is shown natural size from above and in cross section in figures 21 and 22 of Plate I) occur commonly in Kiowa county in No. 5 of my Belvidere section, and occasionally at least in Clark county, in the earthy and saccharoidal sandstone which constitutes No. 4 of my Bluff Creek section.

The burrows form boldly sweeping, tortuous curves which lie in a slightly warped surface and occasionally cross themselves in a sigmoid or "figure 8" path. The transverse section of the cast is lenticular, averaging about 10 mm. and 6 mm. in major and minor diameters.

The writer has seen markings in the sandstones which were interpreted as seaweed impressions. It is possible that these are the forms described under the above name.

Serpula cragini, n. sp.

(Plate VII, figure 1.)

1889. *Serpula intrica* White, Cragin. Bull. Washburn College Lab. Nat. Hist., vol. II, No. 9, p. 35 (not described). *Ibid.*, No. 11, 1890, p. 75 (not described).
1895. *Serpula championi* Cragin. Am. Geol., vol. XVI, p. 369 (not described).

The tubes are of varying diameters up to 2 mm. Slow increase in diameter, with the smallest less than 1 mm. Each tube very long and intricately tortuous. Surface without any observed ornamentation. Not certain that either end of a tube has been seen. The walls of some of the largest examples are about a third of a millimeter thick, and in some specimens each wall is composed of three layers. In other specimens only one layer has been observed.

The tubes were first identified by Cragin as *S. intrica* White, a species from the Upper Cretaceous of Utah. It differs from that species in greater diameter of the tubes.

Horizon and locality. Occurs in abundance in the Champion shell bed; not seen elsewhere.

ECHINODERMATA.

Salenia kansasense, n. sp.

(Plate VII, figure 7.)

The test is small, 18 mm. in diameter (which may be a little too great, as there is some distortion), 8 mm. thick. The actinal surface appears to have been slightly concave in the vicinity of the mouth opening.

The ambulacral areas are narrow, about 2¾ mm. where widest, increasing from the abactinal end to the peripheral margin, and thence continuing to the mouth with parallel sides. Plates simple, arranged in alternation. Two rows of tubercles in alternating position are along the middle, at least 20 in each row (there may possibly be one or two more, as a small portion of the test is broken away around the peristome). The tubercles are mammillated and the surrounding areas apparently are granulated. Pores uniserial, the outer row situated on the ambulacral plates and two of this row to each plate. Every alternate pore of the inner row is in the central portion of the plate. Each intermediate pore of this row is divided into two parts by the planes separating the plates. Pore couplets slightly inclined.

Interambulacral areas 7 to 7½ mm. wide at the widest portion, narrowing in both directions, formed of two rows of broad plates which are about 3½ mm. in each direction, rectangular and not in alternation. Each with a large crenulated tubercle in the center; these increase rapidly in size from the peristome and are surrounded by mammillated granules of different sizes. An imperforate mamelon is situated within the crenulated margin of the large tubercle.

The apical disk is large, convex, nearly-circular, 10 mm. in diameter. Small grooves extend from one plate to those adjacent. Each groove has a small pore in the middle which is shared by each plate. The subanal plate occupies the center of the disk. The anal opening appears to be nearly round, but may be flattened anteriorly-posteriorly. Oculars exsert.

Peristome apparently round; margin broken away so that the original width not determinable. The opening so made is 7½ mm. in diameter.

The shell is about the size of that of *S. texana* Credner, but differs markedly in the sculpturing of the apical disk and the number of pores to one of the ambulacral plates.

Horizon and Locality. A single specimen from the Champion shell bed, Champion Draw, Belvidere, Kan.

BRACHIOPODA.

Lingula sp.

Fragments of a *Lingula* are not uncommon in the Kiowa shales and also to a less extent in the Mentor bed, but in no instance has an entire shell been collected. The shell is small, the maximum length probably not exceeding five-eighths inch. The present color of the fragments is black, and such was probably the original color.

GASTROPODA.

Anchura kiowana Cragin.

(Plate IX, figures 2 and 3.)

1890. *Anchura* sp. Cragin. Bull. Washburn Coll. Lab. Nat. Hist., vol. II, No. 11, p. 75 (not described).
1894. *Anchura kiowana* Cragin. Colorado Coll. Studies, 5th Ann. Publication, pp. 66, 67.
1895. *Anchura kiowana* Stanton. In Hill, Am. Jour. Sci., vol. L, p. 217 (not described).

Cragin's description. Shell small, consisting of six convex whorls; spire elevated; suture impressed; wing of moderate size, consisting of a proximate flangelike part, continued posteriorly across half or more of the first spire whorl, and a carinated falciform process; carina gradually arising at the base of the falciform process and traversing the latter to the extremity; falciform process much shorter and less upturned distally than that of the somewhat similar species, *A. ruida* White, not rising to the lowest level of the suture between the body whorl and the first spire whorl, but having its point directed outward and somewhat upward, so as to make a large angle with the axis of the spire; exteroinferior outline of wing rounded and the border between this and the canal sinuous; margin of upper (flange) part of wing describing a slightly concave to sigmoid outline and more or less thickened and reflexed; inner lip provided with a moderately broad and prominent callous; canal short and obliquely truncated; spire whorls and posterior half to two-thirds of body whorl ornamented with narrow, curved, subvertical ribs, or folds, of which there are about twenty-four on the first spire whorl, and with numerous revolving striæ, the latter ornamentation gradually becoming prominent and superseding the ribs on the lower third to half of the body "whorl." The height of a full-grown shell is about 22 mm. The apical angle is about 30 degrees.

This species appears to be closely related to *A. mudgeana* White from the Paw Paw beds of the Texas section, a fact previously noted by Stanton. Cragin stated a resemblance to *A. ruida* White from the Cretaceous of Utah, but the relationship does not appear to be close. The entire wing has not been preserved in any specimen which the present writer has observed. *A. mudgeana* and *A. kiowana* are about the same size, but in the latter the ribs are concave toward the aperture instead of straight as they appear to be in the former.

Horizon and locality. This shell occurs in abundance in the calcareous beds of the Kiowa shales, making its appearance in the Champion shell bed and extending to the top of the section. It is also locally abundant in the Windom member in McPherson county, particularly at the Natural Corral and the exposures to the northwest of Conway. A single well-preserved mold of the exterior was collected in the Mentor sandstone to the west of Smolan, and four fragments from the Mentor sandstone at the Natural Corral.

Anisomyon cragini, n. sp.

(Plate VII, figure 3.)

Three specimens of patelloid shells have been found in the collections made by the writer. The largest of these has a diameter of about 4 mm. and a height of 1 to 1½ mm. The specimens in two cases have the shell absent; a single specimen from the Champion Draw section has portions of the shell still present. The surface is shown by all three specimens to have been ornamented by irregular concentric undulations. The apex is central and there is a little variation in the apical angle, the specimen from the Champion Draw section being of smaller angle than the others. This may be of a different species. In no one of the specimens is the shell entirely preserved, but there appears to have been no twisting of any kind.

Horizon and locality. Mentor bed, 5 miles west of Smolan, 2 specimens; one specimen from zone 12 of the Champion Draw section.

Margarita (Solarella) newberryi Cragin.

1894. *Margarita (Solarella) newberryi* Cragin. Am. Geol., vol. XIV, pp. 10, 11.

Cragin's description. Shell thin, low-turbinate, consisting of about four rapidly enlarging whorls; spire small and low, the sutures rather deeply impressed, the body whorl very large and ventricose; surface of each whorl ornamented with coarse, unevenly elevated revolving lines or granuliferous ridges, the intervals between which are marked with usually two similar but much finer revolving lines, the whorls being also obliquely crossed by a system of rather remote, narrow, raised lines which proceed from the apex down the slopes of the shell with a somewhat sigmoid, or sicklelike, curvature, and produce more or less distinct eminences at their intersection with the revolving ridges. Of the primary revolving lines or ridges there are six or seven on the flank and shoulder of the body whorl. Measurements: Height of shell, 13 mm.; breadth of body whorl, 15 mm.; divergence of slopes, 104 degrees.

Horizon and locality. Cragin founded this species on a single specimen of the Champion Draw section, which he collected from the Champion shell bed. No other specimen is known to have been collected.

Margarita marcouana Cragin.

(Plate VIII, figure 7.)

1894. Margarita Marcouana Cragin. Am. Geol., vol. XIV, p. 9.

Cragin's description. Shell turbinate, spire moderately prominent; whorls, four and a half, convex, increasing rapidly in size, the large body whorl obliquely flattened below and above; aperture subcircular, apparently as high as wide; no umbilicus; columella flattened below; whorls marked with prominent, oblique growth lines, and ornamented with three strong, equidistant. coarsely but regularly beaded carinæ, above which, on the body whorl, is a fourth smaller one close to the suture. Measurements: Height, 15 mm.; breadth, 14.5 mm.; divergence of slopes, 85 degrees.

The writer has collected only a single specimen of this shell, which shows a portion with the ornamentation. The shell is 8 mm. high and 10 mm. wide. The lower portion of the body-whorl below the lowest carina is ornamented with fine, somewhat nodular lines, of which there are about four per millimeter. In the depression between the lowest two carinæ is a low ridge which appears to be wanting between higher carinæ. This shell may be identical with *M. mudgeana* Meek, but it is smaller and no nodes are stated to be present on the carinæ of that shell. With the discovery of better specimens of Meek's species these may be found to be present. For the present it is deemed best to consider the two shells distinct.

Horizon and locality. Cragin's specimens, two in number, were derived from the Champion shell bed and his zone 3, which embraces zones 8, 10 and 12 of the writer's section. The specimen described by the writer came from zone 10.

Margarita mudgeana Meek.

(Plate VIII, figures 8, 9.)

1871. *Margarita mudgeanus* Meek. Hayden's Rept. U. S. Geol. Surv. Territories, p. 3131.
1876. *Margarita mudgeana* Meek. Rept. U. S. Geol. Surv. Territories, vol. IX, p. 300, pl. 2, figs. 9*a*-*b*.
1893. *Margarita mudgeana* Boyle. Bull. 102, U. S. Geol. Surv., p. 177 (not described).

Meek's description. Shell rather large, turbinate, about as high as wide; spire moderately prominent; volutions, four and a half to five, increasing rather rapidly in size, convex, last one somewhat obliquely flattened below and above, and laterally compressed or flattened around the middle of the outer side, at the base of which it is angular; suture more or less channeled; aperture circular; outer lip thin and oblique; columella arched and flattened below; axis imperforate; surface ornamented by strong, raised, oblique lines of growth, which are crossed by four equidistant rather sharp, revolving carinæ, only three of which are seen on the volutions of the spire. Height, 0.66 in.; breadth, about 0.64 in.; divergence of slopes of the spire, about 75 degrees.

Horizon and locality. Meek's specimens came from the Mentor beds, about 12 miles southwest of Salina, Kan. It probably also occurs near Smolan. The shell has not been found in any of the writer's collections.

Margarita ornata, n. sp.

(Plate VIII, figure 6.)

Shell small; apical angle, 88 degrees; 12 mm. high; 11 mm. wide; at least three and a half whorls, sutures impressed, ornamented by spiral lines (these observed only on the lowest whorl). On the body whorl near the suture is a well-defined rounded ridge about 1 mm. wide, which appears to have a shallow groove on its apex. This ridge is succeeded below by a round-bottomed depression in which are two low, rounded, spiral ridges. The depression is bordered below by a well-defined ridge, below which for a short distance the surface is vertical. Below this spiral are six others, of which the topmost is the smallest and the other five are of nearly equal size. The body whorl is 8 mm. high. Aperture unknown.

Horizon and locality. Mentor beds, 5 miles west of Smolan, Saline county. Not common.

Natica? smolanense, n. sp.

(Plate VII, figure 6.)

Shell small; largest 13 mm. high, 13 mm. wide. About three and a half whorls; body whorl about 11 mm. high, other whorls small and not rising more than 3 mm. above body whorl. No ornamentation other than small ridges of growth. Specimen preserved as fillings of interior. Aperture wholly unknown.

Horizon and locality. Mentor beds, 5 miles west of Smolan, Saline county; common. Two specimens from the type locality of the Mentor beds at Mentor.

Nerita? semipleura, n. sp.

(Plate VII, figure 2.)

This shell is represented by two molds of the exterior, neither of which shows the shape of the aperature. It is low-spired, the body whorl constituting nearly the whole of the shell, and it probably did not grow to much larger dimensions than those given below. The best specimen has about two and a half whorls, the apical whorl being not more than 0.5 to 0.75 mm. above the body whorl. About 8 mm. wide; 5 to 6 mm. high. Surface ornamented with transverse ribs, which trend backward from the suture so as to be convex toward the aperture. These are more prominent on the upper half of the whorl, and on the lower half they are crossed by low spiral ridges which give to this portion of the shell a slightly nodular appearance. These transverse lines are about 1 mm. distant from each other.

Horizon and locality. The specimens came from the Mentor beds, about 5 miles west of Smolan, Saline county.

Neritoma marcouana Cragin.

1894. *Neritoma marcouana* Cragin. Colorado Coll. Studies, 5th Ann. Publication, pp. 62, 63.

Cragin's description. Shell small, of moderate thickness, depressed-subglobose, oblique, consisting of apparently three and a half whorls; spire sublateral, small, eroded; body whorl large, ventricose, evenly rounded, nearly smooth, its upper part with feebly elevated costellæ, extending obliquely upward (that is, toward the suture and at the same time somewhat toward the aperture), and separated by the round-bottomed, groovelike intervals of about the same breadth, that begin, in part abruptly, at or just above the periphery; periphery and base of body whorl smooth, or marked only by ordinary growth lines; aperture obliquely and rather narrowly ovate; inner lip with a callous, strongly flattened and without teeth; outer lip with a moderate, shallow, broadly rounded excavation just below the peripheral line. No umbilicus. The uneroded portion of the spire rises but little above the body whorl. Measurements: Height, 10 mm.; breadth, 10.5 mm. Costellæ of body whorl about 3 in., 2 mm.

Horizon and locality. Cragin's specimens came from the Kiowa shales above the Champion shell bed, and he obtained a specimen very similar in the Windom member near Windom, in McPherson county.

Trochus texanus Roemer.

(Plate IX, figure 4.)

1888. *Trochus texanus* Roemer. Paleont. Abhandl., vierter Band, heft 4, p. 15, taf. I (XXXI), fig. 13; Berlin.
1894. *Trochus texanus* Cragin. Am. Geol., vol. XIV, p. 11 (not described).
1895. *Trochus texanus* Stanton. In Hill, Am. Jour. Sci., vol. L, p. 217 (not described).

Shell small, 12 mm. high, about 11 mm. broad, apical angle 73 degrees; base rounded convex, not flat, meeting side slopes at rounded angles, ornamented with granulated ridges which are finer than those of the slopes, ½ mm. apart. As the shell grows larger these successively migrate over the margin angle and come up on the slopes, resulting in that the spiral lines of granules progressively increase from the apex to the base. The lower whorl in each specimen showing the ornamentation has six rows of spirals, the whorl above has five rows suggesting that the increase in the number of spirals is one for each whorl. In every one of the specimens many of the granules have a small hole in or near the apex. The spirals on the slopes are about 1 mm. apart; the separating depressions are narrower than the ridges, and round-bottomed.

This pretty shell is not common in any of the exposures. According to both Stanton and Cragin, it is somewhat smaller than the Texas form, but otherwise similar.

Horizon and locality. Zones 8 to 14, and of the Champion Draw section; not seen elsewhere. Roemer's specimens were collected about two miles above the mouth of Barton creek, near Austin, Tex. This is probably from the Fredericksburg.

Turritella kansasensis Meek.

(Plate VIII, figures 3-5.)

1871. *Turritella kansasensis* Meek. Hayden's 4th Ann. Rept. Geol. Surv. Territories, pp. 312, 313.
1876. *Mesalia? kansasensis* Meek. U. S. Geol. Surv. Territories, vol. IX, p. 333, 334, pl. 2, figs. 7a-b.
1897. *Turritella kansasensis* Cragin. Science, n. ser., vol. VI, p. 134.
1893. *Turritella kansasensis* Boyle. Bull. 102, U. S. Geol. Surv., p. 294 (not described). Also listed as *Mesalia? kansasensis*, p. 183.

Meek's description. Shell elongate-conical, or gradually and regularly tapering from below to the apex, with the lateral slopes of spire straight; volutions eight to ten, increasing regularly in size, flattened, or only very slightly convex; last one rounded below; suture nearly linear; aperture ovate; surface with small, threadlike, revolving lines, varying much in their arrangement and distinctness, but usually more strongly defined on the lower half of the last turn; lines of growth very fine, obscure, and strongly arched or sigmoid, so as to indicate a deep sinuosity in the outer lip above the middle. Length of a large specimen, 1.10 in.; breadth, 0.34 in.; divergence of slopes of spire, about 22 degrees.

This shell reaches a considerably larger size than given by Meek. One specimen, which was measured, has a length of 35 mm. and a width at the apertural end of 9.5 mm. Another specimen 12 mm. wide at the aperture has a length of 40 mm. The apical angle is around 14 to 15 degrees, the variation being from 14 to 15. As noted by Meek there is also a variation in the number and development of the spiral striations, and these appear to be altogether wanting in ornamentation, no nodes of any kind having been observed on a single one of the hundreds of specimens examined.

The essential difference between this species and *T. belviderii* Cragin appears to be in the presence of nodes on the spirals of the latter.

Horizon and locality. In great abundance in the Mentor beds and present in every locality where these strata have been seen. Occurs in great abundance at Smolan, Mentor, Brookville, Natural Corral, Lehigh, etc.

Turritella seriatim-granulata var. *belviderii* Cragin.

Plate VIII, figures 1-2.

1893. *Turritella seriatim-granulata* Cragin (*partim*). 4th Ann. Rept. Texas Geol. Surv., pt. 2, p. 231.
1893. *Turritella ventrovoluta* Cragin. *Ibid.*, p. 232.
1893. *Turritella flagellta* Cragin. *Ibid.*, p. 232.
1897. *Turritella ventrovoluta* Cragin. Science, n. ser., vol. VI, p. 134.
1897. *Turritella belviderii* Cragin. Science, *ibid.*, p. 134.
1889. *Turritella marnochii* White, Cragin. Bull. Wash. Lab. Nat. Hist., vol. II, No. 9, p. 35.
1890. *Turritella marnochii* typ. Cragin. *Ibid.*, vol. II, No. 11, p. 75.
1890. *Turritella marnochii* var. *belviderii* Cragin. *Ibid.*, p. 75.
1895. *Turritella* sp. Stanton. In Hill, Am. Jour. Sci. vol. L, p. 217.

Cragin's Description. Shell of medium size in the genus, consisting of ten or more flattened or somewhat convex whorls; suture feebly impressed; aperture round-rhombic, slightly elevated; whorls ornamented with about six subequal to unequal, abruptly elevated revolving ribs whose summits are beaded, each bearing rather closely set or oblique to transverse prominent granules; the intercostal intervals square-bottomed, those of the upper spire whorls and of the lower part of the body whorl and the first spire whorl respectively less than and about equal to the ribs; upper rib tubercles of each whorl usually coarser than the others, especially so in the case of the body whorl, in which the large tubercles are sometimes distinctly arcuate (concave on the side away from the aperture), an attenuated rib, or raised line (sometimes two) developed just above it, about on the suture, the second rib above this being also sometimes smaller than the average.

Shells of this form are present in great abundance in the Kiowa shales at every occurrence where these strata have been seen. The largest specimen seen has twelve whorls. The whorls nearest the apex are flat or only slightly convex and the sutures are only faintly indicated. The whorls nearest the aperture show the sutures more plainly and the convexity of the whorls is greater. Each whorl has six to seven spirals, which on the large whorls are ornamented with small knobs or beads. These may be conical or elongated parallel to the spirals, both types being present on the same specimen. The highest spiral is generally the most prominent and has the largest nodes. The apical whorl has the spiral nodes or beads very obscure, and in many instances they appear to be wanting. There is considerable variation in the development of the spirals on different whorls and on different specimens.

The shells reach a large size, the largest specimen measured being 76 mm. long and 18 mm. wide at the aperture end, with the possibility that a part of this end has been broken away. The apical angle is around 15 degrees.

This shell is related to *T. seriatim-granulata,* and it is possible that it is not deserving of varietal differentiation from it, but until the "Comanche" *Turritellas* have been monographed it appears best to consider the Kiowa form distinct. It appears to differ in the development and ornamentation of the spirals.

Horizon and locality. This shell has been collected at every locality where the Kiowa shales have been studied. It is extremely abundant around Belvidere, Bluff creek, 6 miles west of Marquette, Natural Corral between Windom and Conway, etc.

Tylostoma elevata (Shumard).

(Plate XVI, figure 5; Plate XXII, figure 3.)

1854. *Globoconcha? elevata* Shumard. Exploration of the Red River of Louisiana in 1852, R. B. Marcy, p. 196, pl. 4, fig. 3.

Shumard's description. Shell ovate, spire produced, whorls six, regularly convex, body whorl shorter than spire. Length, 1.5 in.; breadth, 1 in.

Shumard's figure shows an apical angle of about 65 degrees. A shell apparently identical with this species occurs in the Kiowa member. A nearly perfect specimen from the Champion shell bed has a height of 45 mm., a width of 25 mm., and an apical angle of 65 degrees. Except for minute growth lines, the surface is without ornamentation. The same shell in somewhat smaller size has also been collected in higher beds.

Horizon and locality. Kiowa shales, Champion shell bed to zone 14 of the Belvidere section. Not seen at other localities. Shumard's specimens came from the Western Cross Timbers of Texas and were probably derived from Fredericksburg strata. Shells from the Fredericksburg of Benbrook, Tex., are like those of the Kiowa. Small forms which appear to be the young of this species occur in the Mentor beds at Smolan and the Natural Corral.

Vanikora propinqua Cragin.

1894. *Vanikora propinqua* Cragin. Colorado Coll. Studies, 5th Ann. Publication, p. 65.

Cragin's description. Shell rather small, depressed-subglobose, thin or of moderate thickness; whorls four, convex, those of the spire not prominently so; body whorl greatly enlarged, rounded, somewhat narrower and more elevated than in *V. ambigua* M. & H.; spire rather low, proportioned almost exactly as in *V. ambigua;* suture not deeply impressed; axis (?perforate); aperture rhomboidal-ovate, angular above, obtuse below; ornamentation unknown. Dimensions: Somewhat smaller than *V. ambigua* M. & H., the exact dimensions not measurable owing to the imperfections of the labial region. Angle of slopes of spire a little less than 90 degrees.

Cragin obtained but one specimen.

Horizon and locality. Cragin's specimen came from zones above the Champion shell bed. It is not known to have been recognized in other collections.

Petersia medicinensis Cragin.

1894. *Petersia medicinensis* Cragin. Am. Geol., vol. XIV, pp. 11, 12.

Cragin's description. Shell of medium size, consisting of five or more (? six or seven) whorls; spire rather short, acute, equalling about or a little less than half the height of the shell; whorls shouldered and ornamented with rather closely spaced, raised, revolving lines and with prominent but rather narrow vertical ribs or folds, of which latter there are about 14 on each of the lower whorls; aperture elongate, subquadrilateral, bent slightly backward below to form a very short or rudimentary notchlike canal, and with a somewhat similar rounded, everted notch at the upper (posterior) corner; spindle short; inner lip, within, bearing, opposite the middle of the aperture, two oblique, parallel, narrow, sharply raised folds which do not extend outward to its slightly thickened and everted border; outer lip with a sharp, slightly crenulated edge, back of which the newest fold (in the stage of growth shown in the younger, but more perfect, of the two type specimens) forms a riblike thickening. Measurements: Height 21 mm.; breadth of body whorl, 11.5 mm.; divergence of slopes, 52 degrees; these being the measurements of a young shell. An imperfect specimen, which perhaps represents nearly the adult size, indicates a height of nearly 50 mm.

Horizon and locality. Cragin obtained his specimens from zone 3 of his section, corresponding to zones 8 to 12 or 14 of the writer's section. The species has not been observed in any of the collections seen by the writer.

SCAPHOPODA.

Dentalium sp.

Fragments of cylindrical shells which are referred to the genus *Dentalium* are present in both the sandy and limy strata of the Kiowa shale and the Mentor beds. The fragments are of small size and not sufficiently well shown in characteristics to warrant specific designation.

Horizon and locality. Limy bands of the Kiowa shale near Belvidere and Sun City and the Mentor beds near Smolan.

PELECYPODA.

Arcopagella? macrodonta Meek.

(Plate XIX, figure 3.)

1876. *Arcopagella? macrodonta* Meek. U. S. Geol. Surv. Territories, vol. IX, pp. 202, 203, pl. 1, fig. 2.

1893. *Arcopagella? macrodonta* Boyle. Bull. 102, U. S. Geol. Surv., p. 50 (not described).

Meek's description. Shell trigonal, compressed, with height equaling about three-fourths the length; dorsal margin sloping rather abruptly, and nearly equal from the beaks in front and posteriorly, the anterior margin being straight and the posterior a little convex in outline; basal margin forming a regular semielliptic curve; extremities subangular; surface unknown; lateral teeth of hinge long, linear and compressed. Length, 0.93 in.; height, 0.70 in.

The specimen on which Meek founded his description consisted of an imperfect mold of the interior of a right valve. The pallial line was not preserved, and if cardinal teeth were present they had not been preserved. Impressions which he considered indicative of the lateral teeth were present both in front and posterior to the beak, and as these were similar to what they are in the genus *Arcopagella,* he referred the shell to that genus.

Horizon and locality. Meek's specimen was derived from a horizon in the "Dakota" sandstone three miles above the mouth of Big Sioux river in South Dakota. Logan identified the species from thin sandstone layers in the Saliferous shales of the Upper "Dakota" of Kansas.

Arcopagella mactroides Meek.

(Plate XII, figures 4-8.)

1871. *Arcopagella mactroides* Meek. Hayden's Second Ann. Rept. U. S. Geol. Surv. Territories, p. 309, wood cuts A and B.

1878. *Arcopagella mactroides* Meek. U. S. Geol. Surv. Territories, vol. IX, p. 202, pl. 2, figs. 4*a-d*.

1893. *Arcopagella mactroides* Boyle. Bull. 102, U. S. Geol. Surv., p. 50 (not described).

Meek's description. Shell longitudinally ovate; width and height about two-thirds the length, rather compressed and moderately convex; pallial margin forming a regular semielliptic curve from end to end; anterior margin narrowly rounded, with the more prominent part near the middle; posterior border more narrowly rounded than the anterior, particularly below, where there seems to be the faintest possible tendency to form a flexure or fold; beaks moderately prominent, located very nearly centrally; dorsal outline sloping almost equally before and behind the beaks, but with the anterior slope slightly concave in outline above, and the posterior a little convex; muscular impressions faintly marked and rather narrow-subovate; pallial line with its rather shallow, broadly rounded sinus directed very obliquely forward and upward. Surface apparently with only fine lines of growth. Length of one of the larger specimens, 0.78 in.; height, 0.53 in.; convexity, about 0.26 in.

Meek states that this shell is proportionately smaller and of a different general outline from *A? macrodonta.*

Horizon and locality. Mentor beds. Meek's locality is stated to have been twelve miles southwest of Salina, Kan. The shell is common in the Mentor beds five miles west of Smolan, in Saline county.

Barbatia parallela Meek.

(Plate XIV, figure 5.)

1872. *Arca? parallela* Meek. Hayden's Second Ann. Rept. U. S. Geol. Surv. Territories, p. 3.

1876. *Barbatia* (*Polyema?*) *parallela* Meek. U. S. Geol. Surv. Territories, vol. IX, pp. 80, 81, pl. 2, fig. 10.

1893. *Barbatia* (*Polynema?*) *parallela* Boyle. Bull. 102, U. S. Geol. Surv., p. 69 (not described).

Meek's description. Shell small, longitudinally oblong, being about twice and a half as long as high, moderately convex, cardinal and pallial margins straight and nearly parallel; anterior side short, rounding up regularly from below, and intersecting the cardinal margin at an obtuse angle above; posterior side long, a little wider than the other, with its margin compressed and obliquely truncated above, but rounded below; beaks depressed, somewhat flattened, incurved, not very remote, and placed about one-fifth the length of the valves from the anterior margin; cardinal area very narrow, and apparently smooth, only marked with one or two longitudinal cartilage furrows; muscular and pallial impressions very obscure, hinge with denticles longest posteriorly, where they are directed upward and backward at an angle of about 45 degrees to the cardinal margin; from the posterior side they diminish rather rapidly in size and length forward, so as to become very minute and crowded between the beaks, which is as far forward as they have been traced in the specimens examined. Surface showing very fine, crowded, radiating striæ, with strong marks of growth. Denticles were also believed by Meek to be present in front of the beak. Length, 0.95 in.; height, 0.37 in.; convexity, 0.27 in.

Horizon and locality. Meek's specimens came from 12 miles to the southwest of Salina and were collected from a red sandstone, which is probably the Mentor bed. No specimens of this species have been found in the collections of the writer.

Cardita belviderensis Cragin.

(Plate XIII, figures 4-6.)

1894. *Cardita belviderensis* Cragin. Am. Geol., vol. IV, p. 5, pl. 1, figs. 9-11.
1895. *C. belviderensis* Hill. Am. Jour. Sci., vol. L, p. 214 *et al.* (not described).
1900. *C. belviderensis* Stanton. In Gould, Am. Geol., vol. XXV, p. 37 (not described).

Cragin's description (in part). Shell of small to medium size, triangular or cordiform, moderately to rather strongly ventricose; beaks placed near the anterior side and directed strongly forward; exterior of either valve ornamented with about 26 ribs, of which 19 or 20 are narrow, prominent, spiniferous, and separated by valleys about twice as wide as themselves, the other 6 or thereabout being low, plainer, and crowded; spines of the larger ribs much more closely set than the ribs themselves, short, erect, subtruncated (commonly appearing as little more than coarse granules owing to the weathering of the shell); margin of valves deeply notched.

A large specimen is about 28 mm. high, 27 mm. wide, and about 8 mm. deep for one valve. Most specimens are from one-half to two-thirds these dimensions.

Horizon and locality. This shell is quite abundant in the Champion shell bed. It is rarely present in zones 8 to 12 of the Champion Draw sections. It has also been collected in the basal zones of the Bluff Creek section.

Cardium? bisolaris Cragin.

(Plate XIV, figure 16.)

1894. *Cardium (Nemocardium) bisolaris* Cragin. Am. Geol., vol. XIV, pp. 6, 7, pl. I, fig. 16.

Cragin's description. Shell small, quadrilaterally or subtriangularly rotund, of moderate convexity; beaks subcentral, slightly in advance of the middle; posterior fourth (or less than fourth) part of outer surface ornamented with thirty or more slender, radial costellæ, the anterior three-fourths being devoid of concentric costellæ and marked with extremely delicate and crowded radial striæ; inner part of free margin delicately notched or crenulated. The costellæ of the posterior part are not visibly echinate in the types. Measurements: Height, 23 mm.; length, 21 mm.; breadth, 15 mm.

The writer has not found any specimens which correspond with this description so far as the differentiation of the radiate striæ are concerned. It is possible that Cragin had variants of *Cardium kansasense.*

Horizon and locality. Cragin states that the shell is moderately common in his zone 5, which corresponds with the Champion shell bed. The writer has not seen the shell if it be distinct from *C. kansasense.*

Cardium kansasense Meek.

(Plate XV, figures 1-8.)

1871. *Cardium kansasense* Meek. Hayden's Second Ann. Rept. U. S. Geol. Surv. Territories, pp. 307, 308.
1876. *Cardium? kansasense* Meek. Rept. U. S. Geol. Surv. Territories, vol. IX, pp. 170, 171, pl. 2, figs. 14*a-d.*
1889. *Cardium kansasense* Cragin. Bull. Wash. Coll. Lab. Nat. Hist., vol. II, No. 10, p. 67 (not described).
1890. *Cardium kansasense* and *C. belviderei* Cragin. *Ibid.,* No. 11, pp. 75, 76, 77 (not described).
1891. *Cardium kansasense* and *C. belviderei* Cragin. Am. Geol., vol. VII, pp. 26, 27 (not described).
1893. *Cardium kansasense* Boyle. Bull. 102, U. S. Geol. Surv., p. 78 (not described).
1895. *Cardium kansasense* Cragin. Am. Geol., vol. XVI, p. 165 (not described).
1900. *Cardium kansasense* Gould. Am. Geol., vol. XXV, p. 37 (not described).

Meek's description. Shell rather small, oval-suborbicular, being generally slightly higher than the anteroposterior diameter, and rather gibbous, with the greatest convexity usually above the middle; pallial margin rounded, or subsemicircular in outline, being in most cases most prominent behind the middle; anterior margin more or less regularly rounded; posterior outline rounded, or very faintly subtruncated; dorsal outline sloping abruptly from the beaks before and behind; beaks elevated, gibbous, incurved and subcentral, or a little in advance of the middle, and but slightly oblique; posterior dorsal slopes somewhat flattened; surface marked by numerous regular, simple, radiating striæ, or small costæ, that are sometimes interrupted by marks of growth. Hinge strong, with cardinal and anterior lateral teeth stout; posterior lateral remote and less prominent. Anterior muscular scar rather deep; posterior shallow. Scar of pedal muscle (?) small, very deep, and situated on the inner anterior side, and near the points of the beaks, almost opposite the cardinal teeth, as shown (p of fig. 14*d*).* Length, 0.94 in.; height, 1 in.; convexity, about 0.63 in.

Meek further states that no "traces of nodes or projecting points of any kind exist on the costæ of this species." In this statement he was in error, as such are shown in well-preserved molds of the exterior.

Horizon and locality. This is one of the most common shells of the Mentor beds and it has been seen at every occurrence. It is also present in abundance in the Windom member. In the Kiowa shales it is extremely abundant in zones 8, 10 and 12, but is present from the Champion shell bed to the top. The forms in the Champion shell bed are small. It has about the same distribution in other exposures.

(*?Cardium*) *mudgei* Cragin.

1895. (*?Cardium*) *mudgei* Cragin. Am. Geol., vol. XIV, p. 6.

Cragin's description. Size apparently about that of *Cardita belviderensis;* shell ornamented with heavy, narrowly interspaced, round-topped, radial ribs, and with numerous freely projecting, concentric, lamellar borders, which are relatively more prominent in crossing the ribs than elsewhere, forming there-

* This reference is to Meek's plate.

upon strong hood-like imbrications. Within a space of 9 millimeters on the ventral margin of the type specimen there are 5 ribs, and on the largest one of the ribs there are, on the distal 7 millimeters of its length, 9 of the hood-like imbrications.

Cragin states that only a single valve of this shell was found by him. From this he could not definitely determine the generic place of the shell. He compares the ornamentation to that of *Axinœa subimbricata* Meek and Hayden. As this ornamentation is quite different from that of *Cardium kansasense,* it precludes the possibility that he had a valve of the latter. No shell of this species has been seen by the writer.

Horizon and locality. Cragin collected his shells from his zone 3 of the Belvidere section, which includes the limestone zones of the writer's section numbered 8 to 12 or 14. The shell was not seen elsewhere.

Corbicula? subtrigonalis Meek.

(Plate XIV, figure 8.)

1872. *Corbicula? subtrigonalis* Meek. Hayden's Second Ann. Rept. U. S. Geol. Surv. Territories, p. 305.

1876. *Corbicula? subtrigonalis* Meek. U. S. Geol. Surv. Territories, vol. IX, pp. 164, 165, pl. 2, fig. 6.

1893. *Corbicula? subtrigonalis* Boyle. Bull. 102, U. S. Geol. Surv., pp. 93 (not described).

Meek's description. Shell oval-subtrigonal, about one-fourth longer than wide, rather gibbous, the greatest convexity being above the middle; basal outline forming a semielliptic curve; extremities rather narrowly and very nearly equally rounded; beaks somewhat depressed and very nearly central; dorsal outline sloping before and behind the beaks, the latter slope being convex and the former nearly straight. Surface only showing fine lines of growth. Pallial line with a small, obtusely subangular sinus. Length, 1.16 in.; height, 0.90 in.; convexity, about 0.66 in.

Meek saw but one mold of the hinge of this species, and this showed lateral teeth similar to *C? nucalis.* The other teeth were so poorly preserved as to be rather indeterminate. The form is said to differ from *C? nucalis* in having a more depressed and transverse outline, its lateral extremities more nearly equal and more narrowly rounded and the posterior margin not truncated.

Horizon and locality. Mentor beds. Meek's specimens came from 12 miles to the southwest of Salina, which is somewhere in the vicinity of Smolan. The species has not been seen in the writer's collection.

Corbicula? elongata, n. sp.

(Plate XX, figure 8.)

Shell small, elongate-oval, posterior extremity narrowed, beak in front of the middle; maximum length, 9 to 10 mm.; height about 6 mm.; thickness for both valves, 4 mm. Hinge structures not well preserved, but appear to be corbiculoid. Surface concentrically striated by fine lines. Both anterior and posterior muscle scars well developed, elevated above surface with the anterior edge of the anterior scar projecting. Pallial sinus small, merely a circular indentation.

Horizon and locality. Mentor beds, 5 miles west of Smolan, and at Mentor.

Corbicula? nucalis Meek.

(Plate XIV, figures 6, 7.)

1872. *Corbicula? nucalis* Meek. Hayden's Second Ann. Rept. U. S. Geol. Surv. Territories, p. 394.
1876. *Corbicula? nucalis* Meek. U. S. Geol. Surv. Territories, vol. IX, p. 163-164, pl. 2, figs. 5*a-c*.
1893. *Corbicula? nucalis* Boyle. Bull. 102, U. S. Geol. Surv., p. 92 (not described).

Meek's description. Shell small, trigonoid-suborbicular, gibbous, the greatest convexity being a little above the middle; basal margin forming nearly a semielliptic curve; posterior subtruncated or rounded; anterior margin rather narrowly rounded, its most prominent part being below the middle; dorsal outline sloping rather abruptly, and nearly equally in both directions, with slight convexity of outline near the beaks behind, and about the same concavity in front; beaks nearly or quite central, incurved, with slight forward obliquity; posterior dorsal surface sometimes very slightly furrowed immediately behind the umbonal slope in internal casts; muscular impressions shallow, comparatively rather large, and arcuate-subovate in form; pallial line with a shallow, obtuse sinus. External surface unknown; that of cast smooth. Length, 0.47 in.; height, 0.42 in.; convexity, 0.26 in.

Meek observed the presence in the mold of the right valve of "long transversally striated double lateral teeth." He thought that he observed the presence of the cardinal teeth, the anterior cardinal tooth of the left valve being directed almost horizontally forward, much compressed from above and below, very prominent, and curved upward. "The corresponding tooth of the other valve is much smaller and overlaps that of the right valve. I think I have seen two other diverging and emarginate cardinal teeth, with pits for two corresponding diverging teeth in the right valve."

Horizon and locality. Mentor bed, 12 miles southwest of Salina, probably the locality to the west of Smolan. The writer has not seen the species in any of his collections.

Corbula crassicostata Cragin.

(Plate XV, figure 10.)

1894. *Corbula crassicostata* Cragin. Colorado Coll. Studies, 5th Ann. Publication, p. 61.

Cragin's description. Shell triangular-ovate, gibbous, nearly as broad as high, short; gaping posteriorly by a short, conically inflated, gently truncated rostrum, which is placed above the base of the shell; umbones placed in advance of the middle, that of the right valve only moderately high arched, its summit obtuse; surface ornamented with very coarse, flattish-topped, concentric ribs, separated by abrupt, deep, narrow intervals. There are seven or eight of the ribs on the basal half of a right valve the same number of millimeters high. Measurements: Height, 7.5 mm.; length, breadth, about 7 mm.

There is about one of the concentric ridges to a millimeter. The separating depressions are round-bottomed. The tops of the ridges appear to be slightly depressed along their middle. This, however, is not positive. There are also indications that both ridges and the separating depressions are ornamented by concentric striæ. The hinge structure is not known.

Horizon and locality. Cragin obtained his specimens in the limestone bands of the Kiowa shales. He also identified the species in the Denison beds at Denison, Tex. It appears to be rather common in the Champion shell bed and less commonly in higher strata of the Kiowa shales.

Crassatellina oblonga Meek.

(Plate XIII, figures 7-12.)

1871. *Crassatellina oblonga* Meek. Hayden's Second Ann. Rept. U. S. Geol. Surv. Territories, p. 201, wood cuts A and B.
1876. *Crassatellina oblonga* Meek. U. S. Geol. Surv. Territories, pp. 120, 121, pl. 2, figs. 3*a-e*.
1893. *Crassatellina oblonga* Boyle. U. S. Geol. Surv., Bull. 102, p. 103 (not described.)

Meek's description. Shell small, short oblong-subtrapezoidal in outline, less than twice as long as high; valves rather distinctly convex, with flattened sides; anterior margin rounded; pallial margin nearly straight, or sometimes slightly sinuous along the middle; posterior obliquely truncated above and narrowly rounded below; dorsal outline sloping rather abruptly in front of the beaks, and less indistinctly so behind; beaks moderately prominent, and placed a little in advance of the middle; posterior umbonal slopes prominently rounded from the beaks to posterior basal extremity; posterior dorsal region above the umbonal prominences flattened; flanks sometimes a little concave toward the pallial margin. Surface with rather distinct lines of growth. Length, 0.73 in.; height, 0.32 in.; convexity, 0.30 in.

Horizon and locality. The specimens studied by Meek came from the Mentor beds and were collected from exposures twelve miles southwest of Salina. The writer's specimens came from 5 miles west of Smolan and the Natural Corral.

Cucullœa? gigantea, n. sp.

(Plate XVIII, figure 8.)

This species is represented by several molds of interiors, but the specimens are so large in comparison with *C. recedens* that they have been considered to merit differentiation as new forms. The largest of the specimens is 90 mm. long, 70 mm. high and 60 mm. thick. With the shell present the dimensions must have been considerably greater. The shape appears to be essentially that of *C. recedens,* except that the beak is relatively farther back from the anterior end of the shell.

It is possible that these specimens ought not be referred to the genus *Cucullœa,* as no portion of the hinge area is shown, but the shape is so like that of *C. recedens* that it is confidently referred to the same genus.

Horizon and locality. The specimens were collected in the Mentor beds at the Natural Corral, McPherson county.

Cucullœa recedens Cragin.

(Plate XV, figure 14; Plate XVI, figures 1-3; Plate XVII, figures 3, 4.)

1890. *Idonearca vulgaris* Conrad, Cragin. Bull. Washburn Coll. Lab. Nat. Hist., vol. I, No. 11, pp. 75-79 (not described).
1891. *Idonearca vulgaris* Cragin. Am. Geol., vol. VII, p. 26 (not described). Also identified as *Idonearca? tippiana.*
1891. *Idonearca? tippiana* Conrad Cragin. *Ibid.,* p. 76 (not described).
1893. *Cucullœa terminalis* (*partim*) Cragin. Fourth Ann. Rept., Geol. Surv. Tex., p. 174.
1894. *Cucullœa terminalis recedens* Cragin. Am. Geol., vol. XIV, pp. 3, 4, pl. I, fig. 19.

The shape is triangular, ovate, beak and umbo prominent, the former slightly projecting over the hinge area and situated from one-fourth to one-fifth the length of the shell from the anterior margin and nearly in the middle of the hinge line. Ventral margin quite uniformly curved, joining with the anterior end of the hinge line at about a right angle. Trending backward from the beak is a strong rounded ridge where the main portion of the surface meets that posterior to the ridge at an angle of 110 to 120 degrees. This posterior portion is gently concave to the margin. The hinge line in an average example is 30 to 35 mm. long. The area is marked by ridges radiating from the beak. The dentition is taxodont, the ridges and grooves chevron-shaped—except middle portion, where straight—with the angle directed toward the axis of the shell. An average example is about 7 mm. long, 45 to 50 mm. high and 40 mm. thick for both valves. The surface ornamentation consists of strong concentric growth lines.

The shell differs from *C. terminalis,* with which it has been identified, in having the beaks not nearly so terminal.

Horizon and locality. Extremely abundant and large in the Champion shell bed at Champion Draw. Occurs rarely in higher strata and is somewhat smaller in the limy beds of zones 8 to 14. One specimen with radiating lines on one portion of the mold of the interior was collected in the Mentor beds at the locality 5 miles west of Smolan, and smaller specimens with the lines less marked have been collected at the Natural Corral.

Cyprimeria kiowana Cragin.

(Plate X, figure 1; Plate XIII, figure 13.)

1890. *Cyprimeria crassa* Cragin. Bull. Washburn Coll. Lab. Nat. Hist., vol. 2, No. 9, p. 35 (not described).
1890. *C. gradata* Cragin. *Ibid.,* p. 36 (not described).
1890. *C. crassa* Cragin. *Ibid.,* No. 11, p. 75 (not described).
1890. *C. gradata* Cragin. *Ibid.,* p. 75 (not described).
1892. *C. crassa* Cragin (in part). Fourth Ann. Rept. Tex. Geol. Surv., p. 176.
1894. *C. texana* Cragin. Colorado Coll. Studies, No. 5, p. 67 (not described).
1895. *C. texana* var. *kiowana* Cragin. Am. Geol., vol. XVI, pp. 369, 372 (not described).
1895. *C.* sp. Stanton. In Hill, Am. Jour. Sci., vol. 50, p. 217.
1900. *C. texana* var. *kiowana* Stanton. In Gould, Am. Geol., vol. XXV, p. 37 (not described).

The shell is nearly uniformly convex, and the outline, except for a small portion in the umbonal region, is almost a circle. In front of the beak the surface is slightly depressed over a small area. Surface ornamented by concentric growth lines which on the umbonal portions are very faint and inconspicuous; but are well developed about the margins, some being so prominent as to give a terraced appearance to those portions of the shell. Escutcheon and lunule poorly developed.

Anterior muscle scar narrowly elliptical, acute above, slightly elevated above the interior surface. Posterior scar not well defined. Pallial sinus very faintly marked. Three cardinal teeth in left valve, two in right; posterior cardinal of each valve bifid.

C. kiowana differs from *C. texana* in being thicker and about one and a half times as large. From *C. crassa* as described by Meek it differs in having a more convex surface and being of greater length and height.

For comparison the dimensions of the three species are given:

	C. texana.[1]	*C. crassa.*[2]	*C. kiowana.*
Height	53 mm.	1.93 in.	77 mm.
Length	55 mm.	2.00 in.	79 mm.
Thickness	14 mm.	1.00 in.[3]	30 mm.

Horizon and locality. *C. kiowana* occurs in great abundance in zones 8, 10 and 12 of the Champion Draw section. It is also present in the Champion shell bed and zone 18. It is equally as abundant in the equivalent zones to the west of Sun City and the Bluff Creek sections. It also has been found in the Mentor beds at the Natural Corral and the Windom member at that locality and near Windom.

Cyrena? dakotensis Meek and Hayden.

(Plate XVIII, figures 2-7.)

1857. *Cyprina arenaria* Meek and Hayden. Proc. Philadelphia Acad. Nat. Sci., p. 143.
1864. *Cyrena arenaria* Meek. Smithsonian Check-list Cret. Mollusks, p. 13.
1865. *Cyrena dakotensis* Meek and Hayden. MS., Prime, Monogr. Am. Corbiculidæ, p. 31.
1876. *Cyrena dakotensis* Meek. U. S. Geol. Surv. Territories, vol. IX, pp. 159, 160, pl. 1, figs. 1*a*-*f*.
1893. *Cyrena dakotensis* Boyle. U. S. Geol. Surv. Bull. 102, p. 111 (not described).

Meek's description (1876). Shell subcircular, or very broad-subovate, moderately convex; anterior and posterior margins rather abruptly rounded; base forming a semioval curve; dorsal outline sloping from the beaks, the anterior slope being abrupt, little concave, and the posterior convex. Beaks rather elevated and subcentral; anterior muscular impression narrow-ovate, well defined; posterior broader and more shallow. Pallial line distant, nearly simple, or very faintly sinuous just beneath the posterior muscular scar. Surface marked by more or less distinct concentric striæ. Length, 1.20 in.; height, 1 in.; convexity, about 0.58 in.

Horizon and locality. Meek obtained the specimens figured by him from the "Dakota" sandstones near the mouth of the Big Sioux river in southeastern South Dakota. The species has been identified by Logan from the upper "Dakota" of Kansas.

Exogyra texana Roemer.

(Plate XX, figure 9; Plate XXI, figure 3.)

1849. *Exogyra texana* Roemer. Texas, Bonn, pp. 369, 397.
1852. *Exogyra texana* Roemer. Kreidebildung von Texas, Bonn., pp. 69, 70, taf. 10, figs. 1*a*-*c*.
1889. *Exogyra texana* Cragin. Bull. Washburn Coll. Lab. Nat. Hist., vol. 2, No. 9, p. 36 (not described).
1889. *Exogyra flabellata* Cragin. *Ibid.*, No. 11 (not described).
1891. *Exogyra flabellata* Cragin. Am. Geol., vol. VII, p. 26 (not described).
1893. *Exogyra texana* Boyle. U. S. Geol. Surv., Bull. 102, p. 125 (not described).
1895. *Exogyra texana* Stanton. In Hill, Am. Jour. Sci., vol. L, p. 216 (not described).

The valves of this shell are quite thick and subequal. The outline is elongate and elliptical, the largest individual being 75 mm. long and about 55 mm. wide. The margin is indented near the beak. Beak much twisted,

1. Cragin, Fourth Ann. Rept. Texas Geol. Surv., 1892, p. 176.
2. Meek, Exploring Expedition from Santa Fe to the Junction of Grand and Green Rivers, 1859, p. 128.
3. Meek does not give the thickness; it was derived by measuring his figure.

making almost a complete circle. A ridge extends spirally backwards from the posterior margin on the beak, making nearly a complete revolution. Near the beak its apex is abrupt and the surface of the shell is deflected nearly at right angles. Backward from the beak this ridge becomes lower and less acute and ultimately it merges into the surface.

The surface is ornamented with coarse branching ribs of irregular length. Most of these begin anterior to the ridge described above. Some branches cross the ridge and reach the posterior margin at an angle of about 60 degrees. Other branches trend ventralward and reach the anterior margin.

Compared with specimens from Texas, those from Kansas are somewhat more elongated. In other respects they appear to be the same.

Horizon and locality. Eleven valves have been collected. Six of these came from the Champion shell bed, four from Champion Draw, and two from west of Sun City. One specimen was collected in zone 8 of the Champion Draw section and four from the lower *Gryphæa* zone of Bluff creek. The shell occurs more or less abundantly throughout the Fredericksburg of the Texas and Mexican regions, and it is also present in the Washita formation. Stanton has identified it from the Washita of Tucumcari, N. Mex., and localities in Oklahoma.

Gervillia mudgeana White.

(Plate XVII, figures 1, 2.)

1880. *Gervillia mudgeana* White. Proc. U. S. Nat. Mus., Smithson Misc. Coll., vol. 19, pp. 295, 296, pl. V, figs. 3, 4.

1883. *Gervillia mudgeana* White. Twelfth Ann. Rept. U. S. Geol. and Geol. Surv. Territories, pt. I, pp. 16, 17, pl. 14, figs. 3*a*-*b*.

1893. *Gervillia mudgeana* Boyle. U. S. Geol. Surv., Bull. 102, p. 136 (not described).

White's description. (Additional characters are given in italics.) This shell is known only by natural casts in brown hematite (*limonite*) of the interior *and molds of the exterior.* It is moderately large, laterally distorted; hinge line comparatively long, very oblique, with the axis of the shell producing a somewhat posterior alation, which is distinctly defined from the body of the shell; cartilage pits, *at least seven in a full-grown individual; 5 mm. from center to center and 3 mm. wide and long;* beaks placed very close to the anterior end, beyond which there appears to have been no very distinct anterior ear; beak of the right valve *in mold* more pronounced than that of the other, *extending 8 mm. above the beak of the left valve. Right valve not so convex across the axis as the left;* right valve having a somewhat regular and strong longitudinal convexity, but its transverse convexity is very little in the anterior half, while the posterior half is *slightly concave. Left valve along the axis nearly straight from beak to margin, very convex across the axis, particularly on opposite sides of the axis, the summit being quite gently rounded. Posterior to the axial portion of the shell the surface is flat or slightly concave to the hinge line, the boundary between this nearly flat portion and the steep portion marginal to the axis being quite sharp.*

Except for the small but well-defined growth lines, the surface is ornamented by fine radial lines from ½ to 1 mm. apart. The best mold of the exterior (left valve) has a length at the hinge line of 55 mm. and 75 mm. along the axis. The axial portion of the mold is 25 mm. wide at the margin; the flat posterior portion is 13 mm. at the margin. A nearly perfect mold of the interior has an axial length of 70 mm. Shell probably thin. The adductor scars are faintly shown in all the specimens collected by the writer. White's figure shows a large impression of elliptical outline situated just below the posterior portion of the hinge line.

The shell does not closely resemble any species known to the writer. In being tortuous it bears some resemblance to *G. subtortuosa* Meek and Hayden from the upper Cretaceous, but the resemblance goes no further.

Horizon and locality. Mentor beds, 5 miles west of Smolan; common. A single young specimen in both interior and exterior mold, from Natural Corral. A single specimen was also collected in the zone 10 of the Belvidere section.

Gryphæa corrugata Say.

(Plate XXIII, figures 1, 2; see, also, figures 3-5, and Plate XXII, figures 1, 2.)

1823. *Gryphæa corrugata* Say. Acct. of Exped. Pittsburg to Rocky Mountains, vol. II, Philadelphia, pp. 410, 411.

1889. *Gryphæa pitcheri* Cragin (in part). Bull. Washburn Coll. Lab. Nat. Hist., vol. 2, No. 9, p. 35 (not described).

1890. *Gryphæa pitcheri* Cragin. *Ibid.,* No. 11, pp. 75, 76, 77 (not described).

1891. *Gryphæa pitcheri* Cragin. Am. Geol., vol. VII, pp. 25, 26, 27 (not described).

1895. *Gryphæa forniculata* Stanton and Hill. Am. Jour. Sci., 3d ser., vol. L., p. 216 (not described).

1895. *Gryphæ pitcheri* var. *tucumcarii* Cragin. Am. Geol., vol. XVI, pp. 371, 373.

1897. *Gryphæa forniculata* Vaughan. Am. Jour. Sci., 4th ser., vol. IV, p. 46 (not described).

1898. *Gryphæa corrugata* Hill and Vaughan. U. S. Geol. Surv. Bull. 151, pp. 53-57, pl. V, fig. 8; pl. VI; pl. VII; figs. 1-10, 15-17; pl. XI; pl. XII; pl. XV; pl. XVI; pl. XVIII, figs. 1-3; pl. XIX, figs. 1, 2.

This species resembles *G. navia,* but lacks the keel and the posterior prolongations of the valves which are present in that species. The surface also lacks the escarpments arising from the growth lines. The shells are more oval and less deep than are those of *G. navia.* An average example from the Champion shell bed is about 35 mm. wide, 55 to 60 mm. long and 20 to 25 mm. thick. The resilifer is cone-shaped, axis of the cone curved to become concave anteriorly and upward, 18 mm. long, 6 mm. wide, ridged by small elevations which are parallel to the hinge line. In higher horizons the shells are a little larger, but it is not certain that these are not young forms of the variety *G. corrugata belviderensis.*

Horizon and locality. Occurs in each of the Champion Draw *Gryphæa* beds, being common in the Champion shell bed and in the highest calcareous bed, but abundant in the middle horizons, where, as stated, it may be the young forms of *G. corrugata belviderensis.* It has a similar abundance in other sections of the southern part of the state. It has not been seen in the central part of Kansas.

In Texas, Hill and Vaughan state that it ranges from the upper portion of the Kiamitia shales into the Duck Creek beds. It is generally present in exposures of the Washita between Kansas and Texas.

Gryphæa corrugata belviderensis Hill and Vaughan.

(Plate XXIII, figure 5.)

1893. *Gryphæa corrugata* var. *belviderensis* Hill and Vaughan. U. S. Geol. Surv. Bull. 151, p. 56, pl. IX, figs. 1-3; pl. X, figs. 1, 2.

This shell is like the typical *G. corrugata,* except that it is very large and of somewhat more triangular shape. An average example is from 60 to 70 mm. wide, 75 to 85 mm. long, and 30 to 35 mm. deep. There is no keel which makes possible an easy separation from the large forms of *G. navia* with which it is associated.

Horizon and locality. This shell is found in all the limestone layers of the Kiowa shales except the Champion shell bed. It is particularly abundant in zones 14 and 16 of the Champion Draw section.

Gryphæa corrugata hilli Cragin.

(Plate XXIII, figures 3-4.)

1891. *Gryphæa pitcheri,* var *hilli* Cragin. Am. Geol., vol. VII, p. 181 (not described).
1894. *Gryphæa pitcheri* var. "*hilli* phase" Cragin. Am. Geol., vol. XIV, p. 6 (not described).
1894. *Gryphæa pitcheri* var. *hilli* Cragin. *Idem.*, p. 10 (not described).
1895. *Gryphæa hilli* Cragin. Am. Geol., vol. XVI, pp. 368, 369, 371 (not described).
1898. *Gryphæa corrugata* var. *hilli* Hill and Vaughan. U. S. Geol. Surv. Bull. 151, pp. 20, 56.

This is a small variety of the *C. corrugata* type. The lower valve is boat-shaped and widens from the beak. In most specimens the beak is truncated by the flat surface of attachment and is generally slightly twisted. The shell is thick, surface in many specimens marked by low, rounded, radial ridges. A shallow radial furrow posterior to the axis of the shell. The convexity of the shell decreases toward the ventral margin. Length along the axial portion of the shell from the beak to the anterior margin—the chord of the arc—30 mm.; width across the axis (greatest) 20 to 30 mm.; depth averages 15 mm. The margins in many individuals wavy and crenulated; resilifer triangular cone-shaped with the axis of the cone curved, 3 to 3½ mm. wide, 4 to 4½ mm. long.

The upper valve is of irregular oval outline, narrowest at the hinge line. An average shell is 20 to 25 mm. long, 18 to 20 mm. wide, not over 2 to 3 mm. thick. Quite commonly a little concave outward over the ventral half. Lines of growth coarse. Muscular markings well defined in each valve.

Hill and Vaughan (Idem., p. 76) consider that this is an ancestral form of *G. corrugata* and state that it "shows comprehensive characters of the three forms of *G. Marcoui, G. corrugata,* and *G. navia.*" Without dissenting from this view as to the possibility that it is an ancestral form, the writer wishes to suggest that it is a dwarfed form of *G. corrugata* developed by adverse conditions of environment, under which conditions there arose a reversion to ancestral characters.

Horizon and locality. Occurs in immense numbers in the Champion shell bed at Champion Draw and all other localities where that horizon is developed. Not in higher beds. Cragin states (1895, p. 370) that it is abundant in the Comanche Peak limestone and Walnut beds of Tarrant, Peak and Williamson counties, Texas. This statement is possibly based on mistaken identifications.

Gryphæa navia Hall.

(Plate XXII, figures 1, 2; Plate X, figure 2.)

1856. *Gryphæa pitcheri* var. *navia* Hall. Rept. Expl. and Surv. R. R. from Miss. River to Pacific, vol. III, pt. IV, p. 100, pl. I, figs. 7-10.
1889. *Gryphæa pitcheri* Cragin (in part). Bull. Washburn Coll. Lab. Nat. Hist., vol. 2, No. 9, p. 35 (not described).
1890. *Gryphæa pitcheri* Cragin (in part). Bull. Washburn Coll. Lab. Nat. Hist. vol. 2, No. 11, pp. 75, 76, and 77 (not described).

1891. *Gryphæa pitcheri* Cragin (in part). Am. Geol., vol. VII, pp. 25, 26, 27 (not described).

1896. *Gryphæa pitcheri* var. *roemeri* (in part) Cragin. Am. Geol., vol. XVI, pp. 372, 374 (not described).

1898. *Gryphæa navia* Hill and Vaughan. U. S. Geol. Surv. Bull. 151, pp. 57-59, pls. XVII and XVIII, figs. 4-12.

The lower valve of this species is lopsided, boat-shaped, widens from the strongly incurved twisted beak, greatest width distally from the beak, ventral margin prolonged posteriorly 55 to 60 mm.; length 75 to 80 mm.; thickness, about 30 mm.; depth of cavity, 15 to 18 mm. Muscular scar sharply defined, slightly depressed. Lines of growth rough and sharply defined. A strong, well-marked keel is present, across which the lines of growth have sharp, steep, knoblike escarpments. Anterior to the keel is a radial furrow, in front of which in some specimens there is a second less distinct keel. Resilifer narrowly cone-shaped with axis bent to become concave anteriorly and ventrally, crossed by small ridges parallel to the hinge line, 12 to 15 mm. long, 7 to 8 mm. wide. Cardinal or hinge area ridged. Margins of valve distinctly crenulated.

The upper valve is irregularly oval and a ventral posterior prolongation widens from the beak; greatest width, 60 to 65 mm.; length, about 60 mm.; thickness, 3 to 4 mm. Lines of growth give surface a rough appearance. Surface slightly concave outward; margins distinctly crenulated; hinge area ridged.

Horizon and locality. Very abundant in zone 14 of the Champion Draw section of which zone it is characteristic, occurring in the ratio of about 2 to 1 of *G. corrugata* (keels here not knobby). It is also present in lower beds, but *G. corrugata* dominates. It has not been seen in the Champion shell bed. Forms with knobby keels are in the limestone zones above zone 14. It has not been observed in the highest Gryphæa beds of the Belvidere region nor was it observed in the equivalent beds of the Bluff Creek region although it occurs in the Lower Gryphæa beds of that locality.

In Texas this species is stated by Hill and Vaughan to be present in the Kiamitia clays (p. 95) and it has also been noted in exposures between Texas and Kansas.

Leda acuminata, n. sp.

(Plate XXI, figure 4.)

Shell small, 10 to 12 mm. long, about half so high, about 4 mm. thick for both valves. Surface ornamented with fine concentric lines. Beak in front of mid-length, point turned posteriorly. Shell straight from beak to anterior margin, sharply and uniformly rounded to ventral margin, thence slightly convex to posterior margin, where so sharply rounded that the posterior end is acuminate, thence concave to beak. Structure of hinge and pallial markings not preserved. The shape of the shell is so essentially *Leda*-form that it is felt that no mistake is made in referring it to that genus. Preserved only as molds of the exterior and interior.

Horizon and locality. Mentor beds, 5 miles west of Smolan, and also at Mentor and Natural Corral. Common.

Leptosolen conradi Meek.

(Plate XIV, figures 2-4.)

1872. *Leptosolen conradi* Meek. Hayden's Second Preliminary Rept. U. S. Geol. Surv. Territories, p. 311.
1876. *Leptosolen conradi* Meek. U. S. Geol. Surv. Territories, Hayden, vol. IX, pp. 253, 254, pl. II, figs. 12*a*-*b*.
1893. *Leptosolen conradi* Boyle. Bull. 102, U. S. Geol. Surv., p. 166 (not described).
1895. *Leptosolen conradi* Cragin. Am. Geol., vol. XVI, p. 164 (not described).

Meek's description. Shell enlongate-oblong, nearly three times as long as high, moderately convex; dorsal margin straight, pallial margin more or less nearly straight, and parallel to the dorsal, being a little convex in outline in front of the middle, thence ascending obliquely forward to the narrowly rounded anterior end; posterior margin subtruncated vertically, but rounding abruptly into the dorsal and ventral borders above and below; beaks not raised above the dorsal margin, and very inconspicuous, their position being indicated only externally by the curves of the marks of growth, located about one-third of the length of the valves from the anterior end; surface only showing fine lines of growth. Length, 1.04 in.; height, 0.36 in.; convexity, 0.28 in. Internal casts of this species show the impression of the strong internal ridge, extending directly downwards from the beaks, and gradually dying out below the middle of the valves. These casts also show the impression of a *single* small tooth in the right valve, just in front of the upper termination of the deep furrow left by the strong internal ridge.

The largest shell collected by the writer slightly exceeds 45 mm. in length.

Horizon and locality. Mentor beds, Natural Corral, McPherson county, and 5 miles west of Smolan in Saline county.

Leptosolen otterensis Cragin.

(Plate XIX, figure 9.)

1894. *Leptosolen otterensis* Cragin. Am. Geol., vol. XIV, pp. 8, 9, pl. I, fig. 2.

Cragin's description. Shell compressed, elongated, subrectangular, the height contained nearly two and a half times in the length; dorsal and ventral margins nearly parallel back of the beaks, and somewhat convergent anteriorly from them; anterior margin rounded, posterior truncate; beaks at about the anterior third of the length; valves thin, each presenting a broad, low and gently elevated, distally widening fold, which extends from the beak obliquely downward and forward to the anteroventral margin; cast marked with a strong, distally narrowing and shallowing sulcus which radiates from the beak downward and slightly forward, becoming obsolete before it reaches the ventral margin, and indicating a corresponding rib on the inner face of the valve; surface of cast marked with crowded, fine, concentric, and coarser, rather remote and evenly distributed growth lines. Height, 13 mm.; length, 32 mm.

This is probably the shell which Cragin first designated as *Leptosolen belviderei* (Bull. Washburn Coll. Lab. Nat. Hist., vol. 2, No. 11, p. 76, 1892). Judging from the figure given by Cragin, it bears a very close resemblance to *Leptosolen conradi,* and may be that species. As, however, the writer has not been able to see the original specimen and has found none in his own collections, it is deemed best to consider the shells as two distinct species.

Horizon and locality. Cragin's specimen was collected from his zone No. 5 of the Blue Cut section, a horizon corresponding to one of the limestone zones, 12, 14, 16, of the Champion Draw section. It does not appear to have been seen elsewhere.

Limopsis subimbricatus Cragin.

(Plate XIV, figures 12, 13.)

1894. *Limopsis subimbricatus* Cragin. Am. Geol., vol. XIV, p. 4, pl. I, figs. 6-8.)

Cragin's description. Shell small, obliquely subrotund, or obliquely rotund quadrilateral, of moderate convexity; beaks placed a little in advance of the middle, small but distinct, giving the dorsal outline of the shell an apiculate aspect; hinge plate ample, but gradually narrowed to strait in the mid-part, where its lower border is gently subangulated at a point a little back of that immediately below the beaks; denticles about twenty-three in number, arranged in divaricate series, median and terminal denticles short and minute, the intermediate larger and elongate denticles for the most part curved or angulated; outer surface of shell smooth, except for a few remote, unevenly distributed, coarse, concentric growth lines, or incipient imbrications; margin entire. Measurements: Height, 19 mm.; length, 19 mm.; breadth, 10 mm.

Horizon and locality. Cragin obtained his specimens from the Champion shell bed of the Champion Draw section.

Linearia kansasensis, n. sp.

(Plate XII, figures 9, 10.)

1895. *Linearia,* n. sp., Stanton. In Hill, Am. Jour. Sci., vol. L, pp. 214, 216 (not described).

The shell attains a length of at least 30 mm. and a height of about 18 mm. Beak small, a little anterior to the middle; in a shell 27 mm. long it is 15 mm. from the farthest extension of the anterior margin. This shell is 9 mm. thick.

Both anterior and posterior portions of the shell are radially striate, in the former for about one-fifth the area of the shell and for the latter about one-tenth. The striæ are stronger near the margin than on the central portion of the shell. In addition, the surface is concentrically striated by fine ridges and depressions. There are about ten concentric striæ to a millimeter and not over five radial striæ in the same distance.

Horizon and locality. Mentor beds, 5 miles west of Smolan, Kan. Very abundant.

Lithophagus interrogatum, n. sp.

(Plate VII, figure 5.)

1895. *Lithophagus,* sp. nov., Stanton. In Hill, Am. Jour. Sci., vol. L, p. 216 (not described).

Only the tubes of this organism have been seen. These are abundant in shells of *Gryphæa corrugata,* some shells being simply riddled. The tubes are rarely cylindrical. Neither are they commonly straight or perpendicular to the surface. The basal extremities are abruptly rounded and in some cases a little ridge lies across the base. Diameters vary from 1 to 5 mm.

The shells, judging from the size of the tubes, appear to have grown to a larger size than *L. oviformis* Gabb from the Cretaceous of California, but are not so large as *L. ripleyanus* Gabb and *L. affinis* Gabb, both from the Cretaceous of New Jersey.

Horizon and locality. Occurs at all localities where the *Gryphæa* horizons of the Kiowa shales have been seen.

Mactra antiqua Cragin.

1894. *Mactra antiqua* Cragin. Am. Geol., vol. XIV, p. 9.

Cragin's description. Shell small, triangular, longer than high, of very moderate convexity; upper anterior margin of either valve, in advance of the feebly excavated beak front, forming nearly a straight line a little shorter than the feebly convex line described by the superoposterior margin; anteumbonal and postumbonal slopes depressed so as to form a broad and shallow radial sulcus, the anterior sulcus separated from the discal surface by a slight angulation; beaks slightly in advance of the middle, their apices turned inward and but little forward; hinge narrow; the anterior V-shaped cardinal tooth of the left valve short and stout, its sinus shallow; posterior cardinal narrowed above, broad below, the broad lower extremity bearing on its anterior side a short denticle which imperfectly subdivides the cartilage pit. Measurements: Height, 23.5 mm.; length, 27 mm.; breadth, 16 mm.

Horizon and locality. Cragin's specimens came from the basal portion of his zone 3 of the Champion Draw section, corresponding to zones 8 to 10 or 12 of the writer's section. The shell has not been found in the collections of the writer.

Mactra siouxensis Meek and Hayden.

(Plate XVII, figures 5-7.)

1860. *Mactra siouxensis* Meek and Hayden. Proc. Acad. Nat. Sci. Philadelphia, vol. VIII, p. 179.

1876. *Mactra (Cymbophora?) siouxensis* Meek. U. S. Geol. Surv. Territories, vol. IX, p. 206, pl. i, figs. 7*a*, *b* and *c*.

1893. *Mactra (Cymbophora?) siouxensis* Meek. U. S. Geol. Surv. Bull. 102, p. 177 (not described).

Meek's description. Internal cast oval-trigonal, moderately gibbous; anterior border narrowly rounded, posterior subangular at the extremity; base forming a nearly semiovate curve, the most convex part being toward the front; dorsum declining with a slightly convex outline behind the beaks, and distinctly concave just in front of them; beaks prominent, rather gibbous, very nearly central; pallial impression provided with an oval sinus, which appears to be a little narower behind than in the middle, rounded at the anterior extremity, and extending nearly in a horizontal direction forward, about one-fourth of the length of the valves. Length, 1.55 in.; height, 1.22 in.; convexity, 0.76 in. The only specimens of this species that I have seen are internal casts and molds of the exterior, the shell itself being dissolved out. Some of these molds show that the surface was marked by moderately distinct lines of growth, and that the escutcheon was lanceolate in form, and bounded on each side by a very obscure ridge, which extended from the back part of the beaks to near the posterior basal extremity.

Horizon and locality. In the "Dakota" sandstone two miles above the mouth of the Big Sioux river. The writer has not seen the shell.

Mactra siouxensis smolanensis n. var.

(Plate VIII, figure 10.)

1893. *Mactra siouxensis* Cragin. Am. Geol., vol. XVI, p. 164 (not described).

The speciments collected consist of molds, both of exterior and interior; no portion of the shell has been seen. There is abundant material for most of the details. The shell appears to have had a triangular ovate shape, uniformly and gently rounded from the hinge line to the rounded angular posterior extremity, and thence gently convex to the anterior portion of the hinge line. Anterior to the beaks the margin of the interior mold is slightly concave. The beaks and umbones appear to have been quite prominent. Except for concentric growth lines, the surface is unornamented. The growth lines are closely placed and inconspicuous except for an occasional prominent one. All are low and parallel to the border of the shell and are sharper and more conspicuous immediately anterior and posterior to the umbones. Escutcheon narrow and bordered on each side by a rounded angular ridge. Lunule scarcely perceptible. The shell was probably thin.

The anterior muscular scar is small, depressed a little, deeper on the inner side, elongated oval vertically. Posterior scar circular, about level with the surface. The pallial sinus deep, tapering finger-shaped; 12 mm. deep on the anterior side in a specimen of which the interior mold is 40 mm. long, 32 mm. high and 14 mm. thick, 8 mm. wide at the beginning, about 5 mm. at the top. An average-sized specimen has the dimensions given; a few specimens are about one-eighth larger. Dentition teleodont and well developed.

This shell appears to be very close to *M. siouxensis* Meek and Hayden. It is about the same size and shape, the muscle scars are similar, but the shape of the pallial sinus appears to be a little different, being less elongate oval. The anterior portion of *M. siouxensis* appears to be somewhat more prominent than in this form. The differences do not appear to be more than varietal and may be consequential to ecologic conditions.

Horizon and locality. Occurs in great abundance in the Mentor sandstone about 5 miles west of Smolan, McPherson county, Kansas. Has not been found in the calcareous strata.

Margaritina nebraskensis Meek.

(Plate XII, figures 1-3.)

1871. *Unio (Baphia?) nebraskensis* Meek. Hayden's Second Ann. Rept. U. S. Geol. Surv. Territories, p. 303.

1876. *Margaritina nebraskensis* Meek. U. S. Geol. Surv. Territories, vol. IX, pp. 114, 115, pl. 1, figs. 5a-c.

1893. *Margaritina nebraskensis* Boyle. U. S. Geol. Surv. Bull. 102, p. 178 (not described).

Meek's description. Shell attaining a medium or larger size, thin, cuneate-subovate; being in the adult very gibbous anteriorly and cuneate behind; anterior side very short and rounded; posterior sloping above obliquely from the end of the hinge to the posterior basal extremity, which is narrowly rounded; basal border sinuous behind the middle, and convex in front of it; cardinal margin rather short and nearly straight, or slightly arched; umbones very gibbous, but depressed, oblique, incurved, and placed near the anterior extremity; posterior umbonal slopes subangular from the beaks obliquely backward and downward to near the middle, beyond which they are continued as broadly round ridges to the posterior basal extremity; below and parallel to these ridges there are also, on the flanks, one or two large, oblique, irregular, rounded plications or undulations that continue on to the sinuous posterior basal margin, to which they sometimes impart a distorted or waved appearance. Surface otherwise smooth, excepting moderately distinct lines of growth, which are strongly undulating in places as they cross the oblique ridges or plications of the flanks. Length, 4.10 in.; height, 2.36 in.; convexity, 2.07 in.

Meek states that an external ligament is certainly present and he was not able to observe any posterior teeth. One cast showed the impression of a single compressed anterior tooth with orientation parallel to the anterior slope. The anterior muscular scars are deep, but there are no traces of pedal scars above the anterior adductors. There are no traces of the posterior adductors and the pallial line has not been observed. The writer has not seen the species in any of his collections.

Horizon and locality. "Dakota" sandstone, opposite Sioux City on the Missouri river in Nebraska. Associated with *Cyrena dakotensis.*

Nucula catharina Cragin.

1894. *Nucula catharina* Cragin. Am. Geol., vol. XIV, p. 4.

Cragin's description. Shell small, compressed, triangular, or cuneate-ovate; the entire exterior ornamented with numerous concentric rows of small, closely set, hyphen-like tubercles, with one or two distal, broad, deeply impressed, concentric growth lines, and with delicate radial striæ; each tubercle set so that its trend agrees with the direction of the subjacent concentric growth line, and all the tubercles being arranged not only in concentric series, but at the same time in quincunx order, so as to form two set of intersecting, oblique and gently curving rows. Measurements: Height, 10.5 mm.; length, 15 mm.; breadth, 5 mm., in a small specimen. An imperfect larger specimen indicates dimensions at least one and a half times greater.

In none of the specimens was Cragin able to determine the nature of the hinge structure, so that the reference to the genus *Nucula* must be considered provisional.

Horizon and locality. Cragin obtained his specimens in what are probably zones 8 to 12 of the writer's section.

Ostrea kiowana, n. sp.

(Plate XXI, figures 6, 7; see, also, figures 1, 2.)

1876. *Ostrea* (sp. undt.) Meek. U. S. Geol. Surv. Territories, pp. 12-15, pl. 2, figs. 8*a*-*b*.
1890. *Ostrea franklini* Cragin. Bull. Washburn Coll. Lab. Nat. Hist., vol. II, No. 11, pp. 75, etc. (not described).
1891. *Ostrea franklini* Cragin. Am. Geol., vol. VII, pp. 26, etc. (not described).

Shell narrowly oblong to oval, upper valve flat or nearly so, and apparently a little more narrow than the lower one. Lower valve shallow, umbo truncated by mark of attachment. In young forms the entire valve is frequently attached, and these young forms are commonly attached to older individuals, so that a group has the same general appearance as a group of *Ostrea congesta* from the Niobrara formation.

Shell thin and fragile, surface modified by undulatory growth lines, which are not prominent. The shell is known to have attained a maximum length of 5 cm. and width of 2¾ cm.

The shell described by Meek from the Mentor bed is figured by him as small, of rhombic-subovate outline, having a moderately convex lower valve and a flat upper one. The surface of the latter is stated to have small imbricating lines of growth, while internal casts of the latter show obscure concentric undulations crossed by a few oblique, faintly marked radiating ridges. The specimens from the Mentor bed studied by the writer, which are not certainly known to be the same species as the forms studied by Meek, have the upper valve nearly flat and the surface unmodified except by faintly marked growth lines. The lower valve is very shallow and essentially smooth. The shell is thin. The maximum length observed is about 3½ cm. and maximum width 3 cm.

Horizon and locality. The shell is common in the Kiowa shale at the Blue Cut on the Santa Fe railroad, in the Champion Draw section and other sections to the south toward Sun City and in the Bluff Creek Canyon section. It is quite common in the Windom member in McPherson county. The quartzitic Windom on the southwest corner of sec. 16, T. 20 S., R. 6 W., contains many specimens. Specimens which are believed to belong to this species are common in the Mentor bed near Smolan.

Ostrea quadriplicata Shumard.

(Plate XVI, figure 4.)

1860. *Ostrea quadriplicata* Shumard. Trans. Acad. Sci., St. Louis, p. 608.
1879. *Ostrea quadriplicata* White. Eleventh Ann. Rept., U. S. Geol. and Geog. Surv. Terr., pp. 275, 276, pl. 6, fig. 6*a*; pl. 8, figs. 3*a*-*b*.
1900. *Ostrea quadriplicata* Gould. Am. Geol., vol. XXV, pp. 34, 36 (not described).

The shells are not large and are of somewhat triangular outline. The largest are about 30 to 35 mm. long and 20 to 25 mm. high. The main body of the left valve is ornamented by many small plications which are crossed by lamellar growth lines. Near the margin of each valve there are four large radiating plications which are produced beyond the edge of the valve. On the right valve the small plications are wanting. The specimens occur only as molds of the interior and exterior.

Horizon and locality. Specimens of molds of this shell are extremely common in the Mentor bed to the west of Smolan, in Saline county, and at the Natural Corral in McPherson county. Elsewhere it is rare. It has not been seen in the Kiowa shales or associated strata. It occurs commonly in the Washita formation of Texas, Oklahoma and New Mexico.

Pecten fredericksburgensis Cragin.

(Plate XXII, figure 5.)

1894. *Vola fredericksburgensis* Cragin. Colorado Coll. Studies, Fifth Ann. Publication, p. 52.

This species resembles *P. texanus* in general appearance and apparently is frequently mistaken for that species. It differs in having a more triangular form, and in its ornamentation. The ribs are narrower and more angular on their summits. The ribs are of three kinds—a large set which are separated from each other by either two or three smaller ones; if three, one of the three is very small and is situated near the side of a rib of the largest kind. Other ornamentation consists of small concentric striæ. Beak strongly incurved over the hinge area. No part of the flat valve has been seen. The best-preserved specimen is 25 mm. long, 23 mm. wide.

Horizon and locality. Champion shell bed, Champion Draw, Belvidere, Kan.

Pecten texanus Roemer.

1849. *Pecten æquicostatus* Lamarck. Texas, F. Roemer, Bonn, pp. 398, 399.
1852. *P. texanus* F. Roemer. Kreidebildung von Texas, Bonn, p. 65, pl. VIII, figs. 3*a*-*b*.

The material referred to this species consists of fragments which have the ornamentation characteristic of *P. texanus*, the ribs being flat or gently rounded on top, the summits wide and every third rib being somewhat higher than the two intermediate.

Horizon and locality. Fragments occur rarely in the Champion shell bed at the Champion Draw locality, Belvidere, Kan.

Pharella? dakotensis Meek and Hayden.

(Plate XVII, figure 9.)

1857. *Solen? dakotensis* Meek and Hayden. Proceedings Philadelphia Acad. Nat. Sci., vol. IX, p. 242.

1860. *Pharella? dakotensis* Meek and Hayden. Proceedings Philadelphia Acad. Nat. Sci., vol. XII, p. 425.

1861. *Pharella? dakotensis* Gabb. Synopsis Mollusks Cretaceous, p. 164.

1864. *Pharella? dakotensis* Meek. Smithsonian Check-list Cretaceous Fossils, p. 15.

1876. *Pharella? dakotensis* Meek. U. S. Geol. Surv. Territories, vol. IX, pp. 251, 252, pl. I, fig. 3.

1893. *Pharella? dakotensis* Boyle. U. S. Geol. Surv. Bull. 102, p. 229 (not described).

Meek's description. Shell elongated and narrow, rather compressed; dorsal and ventral margins nearly straight and parallel; posterior extremity very narrowly rounded, and apparently only moderately gaping; beaks scarcely distinct from the dorsal margin, and located nearly or quite centrally. Surface of cast retaining faint traces of concentric marks of growth; cardinal margin of cast showing a very obscure sulcus along its entire length, both before and behind the beaks. Length, about 1.55 in.; height, 0.35 in.; convexity, 0.20 in.

Meek's only specimen was a mold of the interior or exterior; he was not positive which. The specimen consisted of two valves partly open. No markings of muscular or pallial impressions were shown, nor was anything preserved to show the character of the hinge area.

Horizon and locality. "Dakota" sandstones at the mouth of the Vermilion river, Nebraska.

Pholadomya? belviderensis, n. sp.

(Plate XX, figure 7.)

1890. *Pholadomya sancta-sabæ* Cragin. Bull. Washburn Coll. Lab. Nat. Hist., vol. II, No. 11, p. 76.

Shell thin, anterior portion about one-third as long as posterior, surface ornamented by radial striæ and concentric lines, the former becoming obsolete on the posterior portion of the shell and stopping abruptly about 10 mm. from the anterior margin. The posterior margin is nearly smooth; the anterior has a wrinkled surface. The middle portion of the shell is nodular, due to the crossing of the two sets of ornamentation; the ribs or the striæ have sharp or abruptly rounded summits, while the separating depressions are quite uniformly concave from the apex of one rib to that adjacent. Beak closely incurved and turned forward. A small lunule and escutcheon appear to be present. Dentition not determined. Dimensions of the largest specimen: Length, 37 mm.; height, 30 mm.; thickness of the right valve, 15 mm.; left valve not seen.

This shell is doubtfully referred to the genus *Pholadomya,* as the dentition has not been seen. It appears to differ from other described species in the absence of radial striæ over the anterior portion of the shell. It resembles *P. sancta-sabœ,* but differs in the smoothness of the anterior slopes.

Horizon and locality. Champion shell bed, Champion Draw. Extremely abundant in the Mentor beds at the Natural Corral and 5 miles west of Smolan. Also occurs in zone 17 at Champion Draw.

Pinna comancheana Cragin.

1894. *Pinna comancheana* Cragin. Am. Geol., vol. XIV, p. 3.

Cragin's description. Shell large, thin; anteriorly inflated and subcircular in cross section, becoming more compressed and with exteriorly concave upper slopes posteriorly; not, or only very obtusely, angulated along the median line; increase in height with distance from beak more rapid than in *P. lakesi* White; decussately ornamented with rather remote radial costellæ, and somewhat less conspicuously raised remote concentric lines, there being about nine of the radial costellæ on the concave slope. The shell attains a length of at least eight or nine inches.

The writer has seen no specimen of this species and so knows no more of its characters than are given in the description of Cragin.

Horizon and locality. According to Cragin, this shell is common in the Fredericksburg of Kansas, Texas and New Mexico. Cragin's Kansas specimens were derived from the Champion shell bed at Belvidere. Whether the Kansas forms are the same as those from Texas has not been confirmed.

Plicatula senescens Cragin.

(Plate XIV, figures 14, 15.)

1894. *Plicatula senescens* Cragin. Am. Geol., vol. XIV, p. 2, pl. I, figs. 17, 18.

Cragin's description. Shell quite small, compressed, inequivalved, obliquely subpyriform or inequilaterally rounded-triangular beaks depressed and indistinct, that of the right valve subtruncate by the scar of adnation; valves ornamented with numerous punctations and short, radially disposed, punctiform wrinkles, so arranged that the intervening elevations do not constitute distinct, continuous, radial, riblike plicules such as are seen in most species of this genus, but rather faintly suggest them; margins of valve thickened, that of the left valve forming a broad, distinctly elevated, concentrically laminated border in marked contrast with the discal structure; right valve moderately convex, and left flattish or slightly concave. Measurements: Height, 11 mm.; length, 19 mm.; breadth, 4.5 mm.

The writer has not seen this shell.

Horizon and locality. Cragin's three specimens were collected from his zone 3, which corresponds to zone 12 to 14 of the writer's Champion Draw section.

Protocardia texana Conrad.

(Plate XX, figures 1-6.)

1852. *Cardium hillanum* Roemer (Sowerby). Kreidebildung von Texas, Bonn, p. 49, taf. VI, fig. 12.

1857. *Cardium (Protocardia) texanum* Conrad. Rept. U. S. and Mexican Boundary Survey, p. 150, pl. VI, figs. 6*a-c*.

1871. *Cardium (Protocardia) salinaenses* Meek. Hayden's Second Rept. Geol. Surv. Territories, p. 174, pl. II, figs. 13*a-c*.

1890. *Cardium hillanum?* Cragin. Bull. Washburn Coll. Lab. Nat. Hist., vol. 2, No. 11, p. 81 (not described).

1895. *Protocaria texana* Cragin. Am. Geol., vol. XVI, p. 164 (not described).

1895. *Cardium (Protocardia) texanum* Stanton. In Hill, Am. Jour. Sci., vol. L. p. 218 (not described).

1900. *Protocardia texana* Stanton. In Gould, Am. Geol., vol. XXV, p. 36 (not described).

Large shells of this species are quite common in the Mentor beds at nearly all localities where they contain fossils. The shells from the Kiowa shale are smaller and not so common. It is quite probable that the forms described by Meek as *Cardium salinaensis* were young shells.

Conrad's description. Cordate, subquadrate, obliquely truncated posteriorly, umbo slightly oblique, submedial; disk concentrically ribbed; ribs large and prominent, rounded, laterally abrupt, fine and close on the umbo; post-umbonal area with about 17 tuberculated radiating lines.

For completeness, Meek's description of *Cardium salinaensis* is also given:

"Shell small, nearly orbicular, very slightly longer than high, rather gibbous; pallial margin forming a semicircular curve; anterior margin rounded, the most prominent part being at or a little above the middle, while below this it usually rounds off somewhat obliquely into the base; posterior margin broader, and sometimes slightly subtruncated, or merely broadly rounded; beaks rather depressed, convex, incurved, slightly in advance of the middle; dorsal outline sloping more abruptly in front than behind; posterior umbonal slopes not prominent. Surface ornamented on the sides and front by comparatively rather large, rounded, very regular concentric costæ, separated by smaller furrows; while sixteen to twenty smaller radiating costæ, roughened by very little vaulted prominences, formed by the marks of growth, occupy the posterior region of each valve. Height, 0.66 in.; length, 0.68 in.; convexity, about 0.49 in."

The young shells are elliptical in cross section. With age they tend to become more globose. There are about seventeen of the radial ribs, but there is a variation of two to three on each side of this average. The ribs are rounded; the separating depressions are V-shaped. Laminated lines of growth cross the ribs, giving the nodular appearance described by Conrad. The concentric ribs increase in number and strength with age. Their summits are gently rounded, but the sides are nearly vertical, so that the separating depressions are narrowly V-shaped with the upper portions of the V nearly parallel. The specimens from the Mentor sandstone reach dimensions as follows: Length, 47 mm.; height, 50 mm.; thickness, 35 mm. The specimens from the Belvidere formation are about half as large.

Horizon and locality. Extremely abundant and large in the Mentor sandstone at the Natural Corral; less so at the other localities. Occasional small specimens—considered young shells—occur in the limestone zones of the Kiowa shales in nearly every exposure. Gould obtained the species in the Spring Creek shales.

Pteria belviderensis Cragin.

(Plate XIX, figure 10.)

1894. *Avicula belviderensis* Cragin. Am. Geol., vol. XIV, p. 2.

Cragin's description. Shell strongly ineqivalve, smooth, obliquely purse-shaped, larger than that of *A. subgibbosa* M. & H., as figured in Meek's "Cretaceous Invertebrata" (Plate 28, fig. 12), to which it bears considerable general resemblance, differing from it apparently in having a longer hinge line, a relatively larger and more prominent anterior and larger posterior ear; anterior ear abruptly compressed, marked off by a distinct but shallow sulcus, and marked with one or two inferomarginal folds; posterior ear continuous with the gently concave posterior slope of the shell; left valve strongly and rather narrowly arched from front to rear, much more convex than the right, its beak also more elevated above the hinge line than that of the latter; (?) hinge line as long as or longer than the shell.

A very good specimen collected by the writer shows that the hinge line is the greatest width of the shell, and in this specimen this dimension is 37 mm. Length along the axis from the beak to margin, 42 mm., depth of right valve, 6 mm. On the right valve, the only one the writer has seen, the axial portion of the shell is quite convex, and the surface with slightly decreased convexity continues to the margin of the anterior ear. The convexity abruptly ends posterior to the axis, giving place to a nearly flat or even slightly concave surface over the large posterior ear. The shell resembles *P. salinaensis,* but appears to have a narrower axial portion, is not so deep, and the anterior ear appears to be better developed.

Horizon and locality. Champion shell beds, Champion Draw. Cragin obtained it from the *Cyprimeria kiowana* horizons.

Pteria salinaensis White.

(Plate XVIII, figure 1; Plate XXII, figure 4.)

1879. *Pteria* (*Oxytoma*) *salinaensis* White. Proc. U. S. Nat. Mus., vol. 2, pt. 2, pp. 296, 297, pl. 5, figs. 1, 2; Smithson. Misc. Coll., vol. 19.

1883. *Pteria* (*Oxytoma*) *salinaensis* White. Twelfth Ann. Rept. U. S. Geol. Surv., pt. 1, pp. 15, 16, pl. 16, figs. 2*a*-*b*.

1893. *Pteria* (*Oxytoma*) *salinaensis* Boyle. U. S. Geol. Survey, Bull. 102, p. 243 (not described).

White's description. Shell rather large for a Cretaceous *Pteria;* the body, exclusive of the wings, obliquely subovate, broad at the base; moderately gibbous, distinctly but not very greatly inequivalve; the left valve, as usual, more convex than the right and its beak more prominent; the convexity of the valves somewhat uniform, but increasing toward the umbonal region in each, where it is greatest; anterior wing moderately large, defined from the body of the shell by being laterally compressed, but not by any distinct auricular furrow; the byssal sinus under the anterior wing of the right valve having the usual size and shape common to *Oxytoma;* posterior wing not proportionately large, and not distinctly defined from the body of the shell except by a somewhat gradual lateral compression; its posterior angle not greatly produced; hinge line less than the axial length of the shell; posterior scars not distinct; anterior adductor scars distinct and deep for a shell of this genus, placed immediately in front of the beaks, that of the left valve being more distinct than the other. The shell is know to have reached an axial length of more than 60 millimeters, a transverse width near its base of at least 50 millimeters, and a thickness of about 25 millimeters when both valves were in natural position.

The surface of this shell, except for growth lines, is smooth. The growth lines are quite marked about the margin of the shell, the larger ones being separated by others of somewhat smaller size.

The shell resembles *Pteria belviderensis,* and the two forms may be identical. It appears to differ from that shell in the characters given in the description of the latter.

Horizon and locality. White's specimens were collected in Saline county; those of the writer came from the Mentor bed 5 miles west of Smolan, in that county, and the Natural Corral in McPherson county. Not common.

Remondia ferresi Cragin.

(Plate XIV, figure 9.)

1889. *Remondia ferresii* Cragin. Bull. Washburn Coll. Lab. Nat. Hist., vol. 2, No. 19.
1894. *Remondia ferrisi* Cragin. Am. Geol., vol. XIV, p. 5, pl. I, fig. 1.

Cragin's description with corrections of 1894. Shell compressed, subquadrate or subquinquelateral, closed at the extremities; beaks antero-central, the length of the shell being related to the distance between the anterior extremity and a point opposite the beaks in the ration of 7:3; dorsal margin slightly concave, both anterior and posterior to the beaks; anterior margin rounded; posterodorsal and posteroventral angles produced — the former reaching furtherest posteriorly—and rounded; to the latter extends a rather low but well-marked umbonal ridge; a slight concavity in the surface above the umbonal ridge produces a rather marked concavity of the posterior margin of the shell; ventral margin nearly straight (slightly concave) anterior to the posteroventral angle. Surface irregularly marked by lines of growth, of which two, in the type specimen, are much more pronounced than the others. Interior unknown. Length, 1.02 in.; breadth (approximately), 0.22 in.; height, 0.65 in.

Horizon and locality. The type and only known specimen of this shell, a right valve, was collected from zone 3 of Cragin's Champion Draw section, corresponding to zones 8 to 12 or 14 of the writer's section.

Roudaria quadrans Cragin.

(Plate XIV, figures 10, 11.)

1894. *Roudaria quadrans* Cragin. Am. Geol., vol. XIV, p. 7, pl. I, figs. 14, 15.

Cragin's description. Shell small, short, strongly elevated, triangular, the discs of moderate convexity; beaks situated considerably in advance of the middle, elevated, somewhat compressed on the anterior part and strongly so on the posterior, curved inward and downward and directed somewhat forward; no distinctly limited lunule; anterior and discal slopes flattish-convex, separated from each other by a broadly rounded, scarcely appreciable angulation, their outer surface marked only by ordinary, unequal, concentric growth lines; posterior slope (about one-fourth of the valve) strongly flattened, separated from the discal slope by an abruptly rounded angulation, and ornamented by numerous linear radial costellæ separated by grooves of about their own width. Measurements: Height, 50 mm.; breadth, 36 mm.; in the largest specimen. Most of the other specimens before me are relatively shorter, and some of them much so.

Horizon and locality. Cragin collected his specimens at Champion Draw from his zone 3, chiefly near its basal portion. This corresponds to about zone 8 of the writer's section. The writer did not find any specimens of this form.

Siliqua mentorensis, n. sp.

(Plate XIV, figure 1.)

Shell thin, largest specimen 62 mm. long, 22 mm. high. Shape very elongate-elliptical, slightly broader posteriorly. Beak small, not prominent, 22 mm. from the anterior end of the shell, whose dimensions are given. The internal rib about 2 mm. wide at the upper end, narrowing a little below; at least 12 mm. long, directed transversely in upper half, becoming parallel to the length of the shell in the lower portion. Pallial line parallel to the ventral margin and about one-fourth to one-fifth the width of the shell distant therefrom through the anterior two-thirds of the shell. On the posterior portion of the shell the pallial sinus divides the mantle scar into two acute salients. The surface is ornamented with fine lines of growth.

Horizon and locality. Quite common as fragments in the Mentor beds about 5 miles west of Smolan, Saline county, but not seen elsewhere.

Tapes belviderensis Cragin.

(Plate XIX, figures 4-8.)

1894. *Tapes belviderensis* Cragin. Am. Geol., vol. XIV, p. 7, 8, pl. I, figs. 12, 13.

Cragin's description. Shell of medium size, ovate, or in elevated specimens triangular-ovate, the superior outline excavated in advance of the beaks; valves of moderate convexity, rather thin, beaks placed at less than one-third of the length from the anterior extremity, only moderately prominent (their summits rising, in adult specimens, about two millimeters above the cardinal teeth); hinge of moderate size; the three divergent cardinal teeth separated by clefts of subequal amplitude, but very deep and abruptly excavated in the case of the anterior cleft, and less so in the posterior; anterior cardinal tooth small; second tooth larger and compressed, but not sharply so; third large, broad, flattish-topped and feebly channeled or bifid; posterior lateral tooth rather large and long; surface marked with ordinary concentric growth lines, of which a few, not regularly spaced, are usually much stronger than the rest.

Cragin gives the dimensions of 45 mm. for the height, 49 mm. for the length, and a thickness of 22 mm. for an elevated example.

The shells exhibit considerable variation in shape, one from the higher beds of the Champion Draw section being more elongate than those below.

Horizon and locality. Cragin obtained his specimens from zones 3 and 4 of his Champion Draw section. The writer's collections were obtained from the Champion shell bed and from zones 8 to 14 of the Champion Draw section and equivalent horizons to the west of Sun City. Poorly preserved specimens referred to this species were collected in zone 2 to the Champion Draw section.

Tellina subscitula Meek.

(Plate XIX, figures 1, 2; Plate XXI, figure 5.)

1871. *Tellina subscitula* Meek. Hayden's Second Ann. Rept. U. S. Geol. Surv., Territories, p. 310.

1876. *Tellina* (*Œne?*) *subscitula* Meek. U. S. Geol. Surv., Territories, pp. 195, 196.

1893. *Tellina* (*Œne?*) *subscitula* Boyle. U. S. Geol. Surv. Bull. 102, p. 175 (not described).

Meek's description. Shell small, elliptic-subovate, much compressed; pallial margin forming a regular semielliptic curve; extremities narrowly rounded, the posterior being a little shorter and faintly subtruncated, with a very obscure flexure, and most narrowly rounded below; dorsal outline sloping gently in both directions from the beaks, the posterior slope being a little convex in outline, and the anterior nearly straight above; beak depressed, compressed, and placed a little behind the middle; muscular impressions moderately distinct, the posterior one being broader than the other; pallial sinus very deep, or extending slightly beyond the middle, nearly horizontal, and rather broadly rounded. Surface with only fine lines of growth. Length, 0.84 in.; height, 0.47 in.; convexity, about 0.15 in.

Meek states that this shell is very like *T. scitula* from the Upper Cretaceous, but is proportionately more depressed, has a different pallial sinus, and appears to have less strongly defined lines of growth.

Horizon and locality. Meek's specimens came from Mentor beds, 12 miles southwest of Salina.

Trigonia emoryi Conrad.

(Plate XIII; figures 1-3.)

1857. *Trigonia emoryi* Conrad. Rept. U. S. and Mex. Bound. Surv., vol. I, pt. 2, p. 148, pl. 3, figs. 2*a-c*.
1889. *Trigonia emoryi* Cragin. Bull. Washburn Coll. Lab. Nat. Hist., vol. 2, No. 9, p. 75 (not described).
1895. *Trigonia emoryi* Cragin. Am. Geol., vol. XVI, p. 164 (not described).
1895. *Trigonia emoryi* Stanton. In Hill, Am. Jour. Sci., vol. L, pp. 214, 216 (not described).
1897. *Trigonia emoryi* Vaughan. Am. Jour. Sci., vol. IV, p. 48 (not described).
1900. *Trigonia emoryi* Gould. Am. Geol., vol. XXV, p. 37, (not described).

The shells are triangular-avate in outline, with the posterior extremity narrowly rounded and somewhat compressed. The ribs which ornament the surface meet the anterior margin nearly at right angles and are there widest, highest and farthest apart. The largest ribs are about 2 mm. wide at the base and about 1½ mm. high. The separating spaces are gently concave and from ½ to 1 mm. wider than the ribs. The summits of the ribs are ornamented by elliptical nodules, which are slightly compressed transversely to the ribs. On any limited portion of the shell the nodules are of approximately equal development. The ribs converge posteriorly and become lower and smaller as they approach the margin of the escutcheon, where they are reduced almost to striæ. The escutcheon is bounded by a sulcus, of which the transverse profile is triangular with the bounding sides convex inward. The sulcus is margined on each side by a low rounded ridge. After crossing the sulcus the ribs change direction, trending from the beaks, thence curving upward almost to the beaks. They also increase in size and reach the posterior (in this case upper) margin at angles which are acute downward.

The beaks appear to be directed posteriorly, but the extreme tips apparently have anterior direction. The muscle scar (posterior) is very prominent, nearly circular in outline, placed in a shallow depression and margined upward by a convex, quarter-moon-shaped ridge. Hinge line sharply striated with about ten teeth.

The largest shells are about 45 mm. high, 50 mm. long, and at least 25 mm. thick.

Horizon and locality. Extremely abundant in the red sandstones of the Mentor beds, particularly about 5 miles west of Smolan, Saline county. Not uncommon in the Mentor beds at the Natural Corral, but has been seen in nearly every place where the Mentor strata show float or exposures. Not uncommon in every limestone bed of the Kiowa shales. To the south it occurs in the Washita formation of New Mexico, Oklahoma and Texas.

Trigonarca salinaensis Meek.

(Plate XV, figure 9.)

1876. *Trigonarca (Breviarca?) salinaensis* Meek. U. S. Geol. Surv., Territories, vol. IX, pp. 92, 93, pl. 2, figs. 1*a-c*.
1893. *Trigonarca (Breviarca?) salinaensis* Boyle. U. S. Geol. Surv. Bull. 102, p. 289 (not described).

Meek's description. Shell small, suborbicular, gibbous; rounded-sub-truncate anteriorly, semiovate below, and apparently slightly truncated behind; hinge line declining rather distinctly from the beaks; hinge denticles comparatively rather strong, about eight of them being seen on what appears to be the anterior side of the beaks of one valve; muscular impressions very faintly marked; beaks prominent, central, very gibbous, and incurved without visible obliquity. Hinge area and surface markings unknown. Length, about 0.26 in.; height, 0.23 in.; convexity, 0.23 in.

The denticulate area on the posterior side of the hinge area is about 5 mm. long and contains about five denticles to two millimeters. On the posterior end of the hinge line the denticulated area is not more than half so long. The shell is much smaller than *T. siouxensis,* and it is quite improbable that it is the young of that species. The specimens are wholly in the form of internal molds.

Horizon and locality. Mentor beds, rather rare. The writer's specimens came from 5 miles west of Smolan, Saline county, and Meek's specimens from twelve miles southwest of Salina.

Trigonarca siouxensis Hall and Meek.

(Plate XV, figure 13.)

1854. *Pectunculus siouxensis* Hall and Meek. Members Am. Acad. Arts and Sci., vol. V, p. 384.
1861. *Pectunculus siouxensis* Gabb. Synopsis Mollusks Cretaceous Formation, p. 103.
1864. *Axinæa siouxensis* Meek. Smithsonian Check-list Cretaceous Invertebrate Fossils, North America, p. 8.
1876. *Trigonarca (Breviarca?) siouxensis* Meek. U. S. Geol. Surv., Territories, vol. IX, p. 92, pl. 1, fig. 6.
1883. *Trigonarca (Breviarca?) siouxensis* Boyle. U. S. Geol. Surv. Bull. 102, p. 289 (not described).

Meek's description. Shell (as inferred from internal casts) subquadrangular, gibbous, a little longer than high; basal margin rather straight; anterior outline vertically subtruncated, but convex along the middle, and rounding rather abruptly into the base, as well as to the hinge above; posterior side obliquely truncated above and narrowly rounded below; hinge margin a little straightened along the middle, but curving downward at each end; hinge denticles small and rather crowded; beaks nearly central, and slightly or not at all oblique. Cardinal area and surface markings unknown. Length, about 0.93 in.; height, 0.84 in.

The writer has not seen this species.

Horizon and locality. Meek's specimens came from the Dakota sandstone from exposures at the mouth of the Big Sioux river in South Dakota.

Yoldia microdonta Meek.

(Plate XV, figures 11, 12.)

1872. *Yoldia microdonta* Meek. Hayden's Sixth Ann. Rept. U. S. Geol. Surv., Territories, p. 304.
1876. *Yoldia microdonta* Meek. U. S. Geol. Surv., Territories, vol. IX, p. 109, pl. 2, fig. 2.
1893. *Yoldia microdonta* Boyle. U. S. Geol. Surv. Bull. 102, p. 315 (not described).

Meek's description. Shell small, longitudinally subovate; anterior margin more or less narrowly rounded, being generally more prominent above the middle; pallial margin forming a semiovate curve, being more prominent before than behind the middle, and curving up gradually and obliquely at both ends; posterior side compressed, and with its margin narrowly rounded, or almost subangular at its connection with the hinge above; cardinal margin sloping gradually from the beaks, the posterior slope being very slightly concave in outline, and the anterior nearly straight; beaks rather depressed and placed a little in advance of the middle; hinge line equaling about three-fourths the entire length, and provided with very fine, regular, pointed denticles, of which 26 may be counted behind, and 20 before the beaks, in each valve. Muscular and pallial impressions very obscure, and not visible on internal casts. Surface not well known. Length, 0.50 in.; height, 0.28 in.; convexity, 0.14 in.

Horizon and locality. This shell is extremely rare. Of the writer's specimens one came from the Mentor beds at the locality 5 miles west of Smolan, Saline county, and the other from the Natural Corral, McPherson county. Meek's specimen came from the same strata at a locality 12 miles southwest of Salina.

CEPHALOPODA.

Engonoceras belviderensis Cragin.

(Plate XI, figures 1-4.)

1890. *Ammonites pedernalis* Cragin. Bull. Washburn Coll. Lab. Nat. Hist., vol. 2, No. 11, p. 75 (not described).
1890. *Ammonites belviderei* Cragin. *Idem.*, p. 76 (not described).
1891. *Ammonites belviderei* Cragin. *Idem.*, p. 27 (not described).
1891. *Ammonites belviderei* Cragin. Idem., p. 27 (not described).
1894. *Ammonites belividerei* Cragin. Am. Geol., vol. XIV, pl. I, figs. 3-5 (no description).
1895. *Sphenodiscus sp.* Stanton. In Hill, Am. Jour. Sci., vol. L, p. 217 (not described).
1899. *Buchiceras (Sphenodiscus) belviderensis* Cragin. Colorado Coll. Studies, vol. VII, pp. 27-29.
1899. *Buchiceras (Sphenodiscus) belviderensis* var. *uddeni*. *Idem.*, p. 30, pl. I, figs. 3, 4.
1899. *Buchiceras (Sphenodiscus) belviderensis* var. *mentorensis*. *Idem.*, p. 31, pl. I, figs. 6. 7.
1899. *Buchiceras (Sphenodiscus) belviderensis* var. *mons-comancheanus*. *Idem.*, p. 29, pl. I, fig. 5.

Cragin's description. "Shell of medium size, flattish-lenticular, the venter (periphery) truncate, narrowly so on the younger whorls, broadly and less sharply and less evenly so on the oldest one, particularly on the body chamber; body chamber occupying three-eighths to one-half of a volution; umbilicus narrow, the greater part of the height of the second whorl being embraced within one-third to one-half of that of the body chamber; suture "ceratitic," much like that of *Sphenodiscus pedernalis* von Buch, the part corresponding to the outer saddle of (strictly so-called) *Buchiceras* being divided into five saddles by means of four leaves, of which the very unequal outer two are much smaller than the subequal inner two; all of the saddles of the suture rounded to flattish, or, in case of some of the inner ones, emarginate at fundus, some symmetrically, some obliquely so, and all much broader than the leaves, excepting the next to the outermost of those formed by the lobing of the outer buchiceran saddle; the leaves little cleft at the summit; ornamentation of the shell consisting usually of at least two revolving series of low tubercles on either side; one consisting of few tubercles, one or two of the newer of which sometimes become more prominent than any other tubercles on the shell; the other, presented ventrally on the ventrolateral margin, and consisting of numerous tubercles so compressed as to trend with that margin, and so arranged that those of the right alternate with those of the left margin, half (consisting of every other one) of these tubercles constituting the termini of broadly and feeble accentuated lateral ribs, which are confined to the outer part of the flank, and at whose inner ends (one at the end of each) the very low and diffuse tubercles of a third revolving series may be developed."

Cragin states that this is the commonest member of its genus in the Comanche Peak limestone of Texas, while it is the only representative of the genus in the strata of the Kansas Comanchean. He distinguishes five varieties;

that from the Champion shell bed he calls *mons-comancheanus.* This form is said to have its—

"Suture relatively complex for this species, having even the smaller leaves more or less cut at the summit, usually with two or three simple, obtuse lobules, and the larger leaves cleft into a larger number (4-6) of processes, which are either simple and short (toothlike) to somewhat larger (subdigitiform), or show a tendency to secondary toothing, or two of the processes being expanded at the extremity and abruptly truncated or notched. Of the saddles centripetally succeeding the five secondary saddles, the first three are simple and subrotund (the first one a little compressed), with simple to truncate extremity, the next two (respectively, just outside of and opposite the circum-umbilical tubercles) are broader than deep and strongly emarginate or bilobate, being parted into two lobes by a small and short clavate leaflet."

The variety *uddeni* is stated to have the—

"Suture relatively complex, the primary lateral and the larger secondary lateral and auxiliary leaves little different from those of var. *mons-comancheanus,* the leaves and saddles interior to the secondary ones being as follows: First and second lateral leaves irregularly and obtusely dentate, inclosing a large, simple, subrotund saddle—these followed in succession by a deeply emarginate saddle; an intermediate-sized, asymmetrical, feebly denticulate leaf; three simple, subrotund, subequal saddles, parted by two small, simple, clavate leaves; a small emarginate leaf; a small deeply emarginate saddle; a narrow emarginate leaf; a broad emarginate saddle (this is the line of the series of circum-umbilical tubercles); and finally, a small leaf and saddle, both emarginate."

The variety *mentorensis* is said to be "distinguished by having the two simple truncate saddles second and third exterior to that which is the course of the circum-umbilical tubercles, remarkable broad and shallow."

It is questionable what emphasis should be placed on the differences pointed out by Cragin and to what extent they really exist as persistent characteristics. Considering the fragmentary and scanty material which has been collected from the Kansas Comanchean of this shell, it follows that there is considerable basis for error.

Horizon and locality. The writer collected no specimens of this species in the Belvidere region. It is said to be present in the Champion shell bed and higher strata. The variety differentiated as *uddeni* was found in the Windom member near Lindsborg, Kan. The specimens collected by the writer were obtained from the Mentor beds at the locality five miles west of Smolan, Kan.

Schloenbachia belknapi Marcou.

(Plate XI, figure 5.)

1858. *Ammonites belknapi* Marcou. Geol. North America, p. 34, pl. 2, figs. 1*a*, 1*b*.

Marcou's description. Shell oval compressed, subdiscoidal, sharp and strongly carinated. The sides are ornamented with large, rounded ribs, widening toward the back, slightly flexuous; they usually occupy the entire breadth of the sides, but some irregularly distributed stop at two-thirds the distance, beginning at the back. Although this specimen has lost its central portion, it is easy to see that the spire increases very rapidly and that the whorls are compressed and two-thirds concealed by each other. The last whorl is almost as large as half the diameter of the entire shell. In regard to the keel, the ribs do not correspond, but alternate. . . . Septa with four trifid lateral lobes widely separate and very distinct upon this specimen.

Fragments of one side of a large cephalopod with large coarse ribs like those of *S. belknapi* are not uncommon in the Kiowa of the Champion Draw section. A fragment of a whorl is 12 cm. wide and there are fragments indicating a larger size. No septal markings are preserved.

Horizon and locality. Five fragments of specimens have been collected in zones 8, 12 and 14 of the Champion Draw section. One specimen was collected at the Blue Cut section on the Santa Fe railroad. The species is quite common in the Washita formation of Texas (Duck Creek beds).

Schloenbachia kiowana, n. sp.

(Plate IX, figure 1.)

Only fragments of this shell are known. It attains a large size, as an impression of a whorl at least 9 cm. across is known. Shell with a large keel, which is gullied at its margin with the main body of the shell. This keel is 13 mm. wide in a shell where the whorl with the keel is 6 cm. wide. Ribs poorly S-shaped, without nodes of any kind, of imbricated aspect, swollen at the outer ends, abrupt toward the aperture and gently sloping in the opposite direction. On the inner side of a whorl they bend sharply forward for about one-fifth their length, thence bend backward so as to cross the axis of the whorl at about right angles and bend forward toward the aperture a little at the outer ends. The tops of the ribs are gently rounded.

This shell may be the one identified by Cragin under the name of *Ammonites belviderei* (Washburn Coll. Lab. Nat. Hist., vol. 2, No. 1, 1890, p. 76). It resembles *S. trinitensis* Gabb from the Fredericksburg of Texas, but differs in the summits of the ribs, being less sharp and less symmetrical. The keel in that species is also not known to be developed to the extent that it is in this specimen.

Horizon and locality. Champion shell bed, Champion Draw, near Belvidere, Kan., and in the higher Kiowa at Blue Cut mound on the Santa Fe railroad to the west of Belvidere.

Schloenbachia peruviana von Buch.

(Plate IX, figure 5.)

1853. *Ammonites acuto-carthatus* Shumard. Exploration Red River, La., Paleontology, p. 197, pl. 1, fig. 3.
1858. *Ammonites peruvianus* Marcou. Geol. North America, 34, 35, pl. 5, figs. 1, 1*a*, 1*b*.
1890. *Ammonites acutocarinatus* Cragin. Bull. Washburn Coll. Lab. Nat. Hist., vol. II, No. 11, pp. 75, 76 (not described).
1891. *Ammonites acutocarinatus* Cragin. Am. Geol., vol. VII, pp. 26, 27 (not described).
1892. *Schloenbachia peruvianus* Cragin. Fourth Ann. Rept., Texas Geol. Surv., pp. 242, 243.
1895. *Schloenbachia peruvianus* Stanton. In Hill, Am. Jour. Sci., vol. L, p. 217 (not described).

Ammonites peruvianus was described by Leopold von Buch from fragments collected by Alexander von Humboldt on the Rio Marañon, one of the tributaries of the upper Amazon. The writer has not seen either the descriptions or illustrations of von Buch's specimen and so cannot affirm that the shell of the southwestern part of the United States identified as *Ammonites peruvianus* is the species of von Buch. In stating this identity the writer follows

Cragin, Marcou and Stanton. Shumard (Marcy's Exploration of the Red River) described the shell as *Ammonites acuto-carinatus.* His description fits fairly well, but his illustration resembles a brachiopod quite as much as it does a cephalopod. The description is as follows, the italicized words being the present writer's:

"Shell much compressed, sharply carinated, ornamented with from 30 to 34 transverse ribs; ribs simple, distinctly elevated, flexuous, commencing narrow at the umbilicus and widening to within a short distance of the dorsal (*ventral*) border, where they are again somewhat contracted; dorsal (*ventral*) carina prominent, sharp, smooth, marked on each side by a shallow depression; aperture elongate-cordate, lateral septa trilobate."

In young to half-grown shells the ribs have flat or gently rounded summits and are considerably wider than the separating depressions. In mature to old shells the last half or two-thirds of the outer whorl has the ribs considerably higher and more abruptly rounded, while the separating depressions are about as wide as the ribs. Most of the ribs begin at the umbilicus, but every third to fifth rib arises from one-half to three-fourths inch from the umbilicus through bifurcation of a rib which begins at the umbilicus. A full-grown specimen may have as many as 90 ribs.

Horizon and locality. Only fragments have been collected by the writer from Kansas horizons. These came from the Kiowa shales of the southwest, where it is not uncommon in the Champion shell bed and in zones 8, 10, 12 and 14. It has not been found in the Mentor beds. The shell is common, and in some localities abundant, in the Washita formation of Texas (Kiamitia and Duck Creek beds) and Oklahoma, and it is also quite common in the Fredericksburg formation.

BIBLIOGRAPHY.

An attempt has been made to include all papers in which specific reference has been made to the marine strata as described in this article. A few of the important papers relating to the "Dakota" have been included, but no attempt has been made to include or even examine all the literature which has been devoted to this division. In addition, some other papers to which reference has been made are incorporated.

1. 1856. Meek, F. B., and Hayden, F. V., Descriptions of New Species of Gastropods from the Cretaceous Formations of Nebraska Territory: Proc. Philadelphia Acad. Sci., vol. VIII, pp. 63-69.

2. 1859. Meek, F. B., and Hayden, F. V., Remarks on the Lower Cretaceous Beds of Kansas and Nebraska: Am. Jour. Sci., 2d ser., vol. 27, pp. 219-227.

3. 1860. Meek, F. B., and Hayden, F. V., Geological Exploration in Kansas Territory: Proc. Philadelphia Acad. Sci., vol. XI, pp. 8-30. Reproduced in Am. Jour. Sci., 2d ser., vol. XXVII, pp. 424-432.

4. 1861. Meek, F. B., and Hayden, F. V., Descriptions of Fossils Collected in Nebraska by the Reynolds Expedition, with Remarks on the Rocks from Which They Were Obtained: Proc. Philadelphia Acad. Sci., vol. XIII, pp. 415-417.

5. 1868. LeConte, J. L., Notes on the Geology of the Survey for the Extension of the Union Pacific Railway, E. D. from the Smoky Hill River, Kansas, to the Rio Grande: Philadelphia.

6. 1872. Mudge, B. F., Red Sandstone of Central Kansas: Trans. Kansas Acad. Sci., vol. I, pp. 37-39. Reprinted 1896.

7. 1872. Cope, E. D., On the Geology and Paleontology of the Cretaceous Strata of Kansas: Geol. Surv. of Montana and Adjacent Territory, p. 327.

8. 1872. Meek, F. B., Lists of Fossils, with Descriptions of Some New Types: Geol. Survey of Wyoming and Contiguous Territory, Hayden's Fifth Ann. Rept., pp. 297-313.

9. 1874. Lesquereux, L., The Cretaceous Flora: Rept. U. S. Geol. Surv., Territories, vol. VI.

10. 1875. Cope, E. D. Vertebrata of the Cretaceous Formations of the West: Rept. U. S. Geol. Surv., Territories, vol. II, pp. 17, 67, 68.

11. 1875. Mudge, B. F., Geology of Kansas: Kansas State Board of Agriculture, Fourth Ann. Rept., pp. 107-126.

12. 1875. Lesquereux, L., New Species of Fossil Plants from the Cretaceous Formations of the Dakota Group: U. S. Geol. and Geog. Survey Territories, vol. I, No. 5, pp. 391-400.

13. 1876. Meek, F. B., A Report on the Invertebrate Cretaceous and Tertiary Fossils of the Upper Missouri Country: Rept. U. S. Geol. Surv., Territories, vol. IX.

14. 1876. Mudge, B. F., Report on the Geology of Kansas: Trans. Kansas Acad. Sci., vol. V, p. 6.

15. 1876. Mudge, B. F., Notes on the Tertiary and Cretaceous Periods of Kansas: U. S. Geol. and Geog. Surv., Territories, vol. II, No. 3, pp. 211-221.

16. 1877. Mudge, B. F., Notes on the Cretaceous and Tertiary Periods of Kansas: Geol. and Geog. Surv. of Colorado and Adjacent Territory, Hayden's Ninth Ann. Rept., pp. 290-294.

17. 1878. Mudge, B. F., Kansas State Board of Agriculture, First Biennial Rept., pp. 47 *et al.*

18. 1879. White, C. A., Descriptions of New Cretaceous Invertebrate Fossils from Kansas and Texas: Proc. U. S. Nat. Mus., vol. II, pp. 292-296.

19. 1883. Lesquereux, L., The Cretaceous and Tertiary Flora: U. S. Geol. Surv., Territories, vol. VIII.

20. 1883. St. John, O. P., Kansas State Board of Agriculture, Third Biennial Rept., pp. 571 *et al.*

21. 1883. White, C. A., Cretaceous Fossils of the Western States and Territories: U. S. Geol. Surv., Twelfth Ann. Rept., pp. 15-17.

22. 1885. Cragin, F. W., Notes on the Geology of Southern Kansas: Bull. Washburn Coll. Lab. Nat. Hist., vol. I, No. 3, pp. 85-91.

23. 1886. Cragin, F. W., Further Notes on the Gypsum of Kansas. Bull. Washburn Coll. Lab. Nat. Hist., vol. I, No. 4, pp. 166-168.

24. 1887. St. John, O. P. Notes on the Geology of Southwest Kansas: Kansas State Board of Agriculture, Fifth Biennial Rept., pp. 132-152 *et al.*

25. 1887. Hay, Robt., Report on Geology: Trans. Kan. Acad. Sci., vol. X, p. 22.

26. 1889. Cragin, F. W., Geological Notes on the Region South of the Great Bend of the Arkansas: Bull. Washburn Coll. Lab. Nat. Hist., vol. II, No. 9, pp. 33-37.

27. 1889. Hill, Robt. T., Neozoic Geology of Southwest Arkansas: Geol. Surv. Arkansas for 1888, vol. II, p. 115.

28. 1889. Cragin, F. W., Contributions to the Paleontology of the Plains: Bull. Washburn Coll. Lab. Nat. Hist., vol. II, No. 10, pp. 65-68.

29. 1890. Cragin, F. W., On the Cheyenne Sandstone and Neocomian Shales of Kansas: Bull. Washburn Coll. Lab. Nat. Hist., vol. II, No. 11, pp. 69-81.

30. 1890. Hay, Robt., A Geological Reconnaissance in Southwestern Kansas: U. S. Geol. Surv., Bull. 57, p. 49.

31. 1890. Cragin, F. W., On the Cheyenne Sandstone and Neocomian Shales of Kansas: Am. Geol., vol. VI, pp. 233-238; continued in vol. VII, 1891, pp. 23-33.

32. 1891. Cragin, F. W., Further Notes on the Cheyenne Sandstone and Neocomian Shales; Am. Geol., vol. VII, pp. 179-181.

33. 1892. Williston, S. W., Geologic Map of Kansas.

34. 1892. Lesquereux, L., The Flora of the Dakota Group: U. S. Geol. Surv., Mon. 17.

35. 1893. Hay, Robt., Kansas State Board of Agriculture: Eighth Biennial Rept., pp. 99 *et al.*

36. 1893. Cragin, F. W., Invertebrate Paleontology of the Texas Cretaceous: Texas Geol. Surv., Fourth Ann. Rept.

37. 1894. White, C. A., Notes on the Invertebrate Fauna of the Dakota Formation: Proc. U. S. Nat. Mus., vol. XVII, pp. 131-138.

38. 1894. Cragin, F. W., New and Little Known Invertebrata from the Neocomian of Kansas: Am. Geol., vol. XIV, pp. 1-12, pl. I.

39. 1894. Ward, L. F., The Cretaceous Rim of the Black Hills: Jour. Geol., vol. II, pp. 250-266.

40. 1894. Case, E. C., Geological Reconnaissance in Southwest Kansas and No Man's Land: Kansas University Quarterly, vol. II, pp. 143-147.

41. 1894. Williston, S. W., On Various Vertebrate Remains from the Lowermost Cretaceous of Kansas: Kansas University Quarterly, vol. III, No. 1, pp. 1-4.

42. 1894. Cragin, F. W., Descriptions of Invertebrate Fossils from the Comanche Series in Texas, Kansas and Indian Territory: Colorado College Studies, Fifth Ann. Publication, pp. 49-69.

43. 1894. Cragin, F. W., Vertebrates from the Neocomian of Kansas: Colorado College Studies, Fifth Ann. Publication, pp. 69-73.

44. 1895. Cragin, F. W., The Mentor Beds, Am. Geol., vol. XVI, pp. 162-165.

45. 1895. Hill, Robt. T., Discovery of a Dicotyledonous Flora in the Cheyenne Sandstone: Letter to the Editor, Am. Jour. Sci., 3d ser., vol. XLIX, p. 273.

46. 1895. Hill, Robt. T., On Outlying Areas of the Comanche Series in Kansas, Oklahoma and New Mexico: Am. Jour. Sci., 3d ser., vol. L, pp. 205-234.

46a. 1895. Cope, E. D., Jour. Acad. Nat. Sci., vol. IX, pt. 4, pp. 445-447.

47. 1895. Cragin, F. W., A Study of the Belvidere Beds: Am. Geol., vol. XVI, pp. 357-386.

48. 1896. Haworth, E., Reconnaissance Geological Map of Kansas: Kansas Geol. Surv., vol. I, pl. XXXI.

49. 1897. Cragin, F. W., Notes on Some Fossils of the Comanche Series: Science, new ser., vol. VI, pp. 134-136.

50. 1897. Prosser, C. S., Comanche Series of Kansas: Kansas Geol. Surv., vol. II, pp. 96-181; The Dakota Sandstone, pp. 182-194.

51. 1897. Logan, W. N., Upper Cretaceous of Kansas: Kansas Geol. Surv., vol. II, pp. 206-213.

52. 1897. Marcou, J., Jura and Neocomian of Arkansas, Kansas, Oklahoma, New Mexico and Texas: Am. Jour. Sci., 4th ser., vol. IV, pp. 197-212.

53. 1897. VAUGHAN, T. WAYLAND., Additional Notes on the Outlying Areas of the Comanche Series in Oklahoma and Kansas: Am. Jour. Sci., 4th ser., vol. IV, pp. 43-50.

54. 1898. JONES, A. W., The Mentor Beds: Trans. Kansas Acad. Sci., vol. XIV, pp. 111, 112.

55. 1898. GOULD, C. N., On a Series of Transition Beds from the Comanche to the Dakota Cretaceous: Am. Jour. Sci., 4th ser., vol. V, pp. 169-175.

56. 1899. JONES, A. W., New Developments in the Mentor Beds: Trans. Kansas Acad. Sci., vol. XVI, pp. 65, 66.

56a. 1898. BEEDE, J. W., The McPherson Equus Beds: Trans. Kansas Acad. Sci., vol. XV, pp. 104-110. Shows geologic map of McPherson and Saline counties.

57. 1899. CRAGIN, F. W., *Buchiceras* (*Sphenodiscus*) *belviderensis* and Its Varieties: Colorado College Studies, vol. VIII, pp. 27-31, pl. II.

57a. 1899. STANTON, T. W., U. S. Geol. Surv., Twentieth Ann. Rept. pp. 63-65.

58. 1899. WARD, L. F., U. S. Geol. Surv., Twentieth Ann. Rept., p. 65.

59. 1900. GOULD, C. N., The Lower Cretaceous of Kansas: Am. Geol., vol. XXV, pp. 10-40.

59a. 1900. WILLISTON, S. W., Some Fish Teeth from the Kansas Cretaceous: Kan. Univ. Quarterly, vol. IX, pp. 27-42, pl. VI-XIV.

60. 1901. DARTON, N. H., Preliminary Description of the Geology and Water Resources of Southern Half of the Black Hills and Adjoining Regions in South Dakota and Wyoming: U. S. Geol. Surv., Twenty-first Ann. Rept., pt. IV, pp. 526-532.

61. 1901. GOULD, C. N., The Dakota Cretaceous of Kansas and Nebraska: Trans. Kansas Acad. Sci., vol. XVII, pp. 122-176. Gives a bibliography of the Dakota sandstone.

61a. 1902. WILLISTON, S. W., Notes on Some New or Little Known Extinct Reptiles: Kansas Univ. Sci. Bull., vol. I, p. 247.

62. 1903. JONES, A. W., Further Studies in the Mentor Beds: Trans. Kansas Acad. Sci., vol. XVIII, pp. 104, 105.

63. 1905. JONES A. W., The Fauna of the Mentor Beds: Trans. Kansas Acad. Sci., vol. XIX, p. 122.

64. 1905. STANTON, T. W., The Morrison Formation and its Relations with the Comanche and Dakota Formations: Jour. Geol., vol. XII, pp. 657-669.

65. 1906. DE LAPPARENT, A., Traite de Geologie, vol. 3, pp. 1406-1408.

66. 1906. GRABAU, A., Types of Sedimentary Overlap: Bull. Geol. Soc. Am., vol. 17, pp. 567-636.

67. 1907. CHAMBERLIN, T. C., and SALISBURY, R. D., Geology, vol. 3.

68. 1908. KAYSER, E., Lehrbuch der Geologie, pt. 2.

69. 1908. HAWORTH, E., Geologic Map of Kansas: Kansas Geol. Surv., vol. IX, pl. I.

70. 1910. WILLIS, BAILEY, Principles of Paleogeography: Science, vol. XXXI, new ser., No. 790, pp. 241-260.

71. 1910. SCHUCHERT, CHAS., Paleogeography of North America: Bull. Geol. Soc. Am., pp. 584-585.

72. 1912. STOSE, G. W., U. S. Geol. Surv., Geol. Atlas, Apishapa Folio (No. 186).

73. 1911. TODD, J. E., Is the Dakota Lower or Upper Cretaceous? Trans. Kansas Acad. Sci., vols. XXIII and XXIV, pp. 65-69.

74. 1914. PARKS, A., A Textbook of Geology, London.

75. 1916. SCOTT, W. B., Introduction to Geology, 2d ed., 8th reprint, chapter XXXIV.

76. 1916. FINDLEY, G. I., U. S. Geol. Surv., Geol. Atlas, Colorado Springs Folio (No. 203).

77. 1918. TWENHOFEL, W. H., The Comanchean of Central Kansas: Trans. Kans. Acad. Sci., vol. XXVIII, pp. 213-223.

78. 1920. TWENHOFEL, W. H., The Comanchean and Dakota Strata of Kansas: Am. Jour. Sci., 4th ser., vol. XLIX, pp. 281-297.

79. 1920. BERRY, E. W., Concerning Diastrophism: Science, new ser., vol. LII, pp. 315-318.

80. 1920. BERRY, E. W., The Age of the Dakota Flora: Am. Jour. Sci., 4th ser., vol. L, pp. 387-390.

81. 1922. BERRY, E. W., The Flora of the Dakota Sandstone of Kansas: U. S. Geol. Surv., Prof. Paper, 129-I, pp. 199-231.

82. 1922. STANTON, T. W., Some Problems Connected with the Dakota Sandstone: Bull. Geol. Soc. Am., vol. 33, pp. 255-272.

DESCRIPTION OF PLATES.

PLATE VII.

Serpula cragini, n. sp.
(Page 52.)

FIG. 1. View of a portion of a rock wholly composed of the tubes, × 2. Champion shell bed, Champion Draw.

Nerita? semipleura, n. sp.
(Page 56.)

FIG. 2. Cast of the exterior in dental wax, × 2. Mentor bed, 5 miles west of Smolan.

Anisomyon? cragini, n. sp.
(Page 54.)

FIG. 3. Top view of the type specimen, × 3. Mentor beds, 5 miles west of Smolan.

Nereis? incognita Cragin.
(Page 51.)

FIG. 4. The figure given by Cragin; a cross section is shown on the left. Champion shell bed, Champion Draw.

Lithophagus interrogatum, n. sp.
(Page 74.)

FIG. 5. Borings in *Gryphæa corrugata*, × 2. Zone 14 of Kiowa shale, Champion Draw.

Natica? smolanense, n. sp.
(Page 56.)

FIG. 6. Internal mold of a specimen in sandstone, × 2½. Mentor bed, 5 miles west of Smolan.

Salenia kansasense, n. sp.
(Page 52.)

FIG. 7. View showing the aboral side of the type specimen, × 2. Champion shell bed, Champion Draw.

PLATE VII.

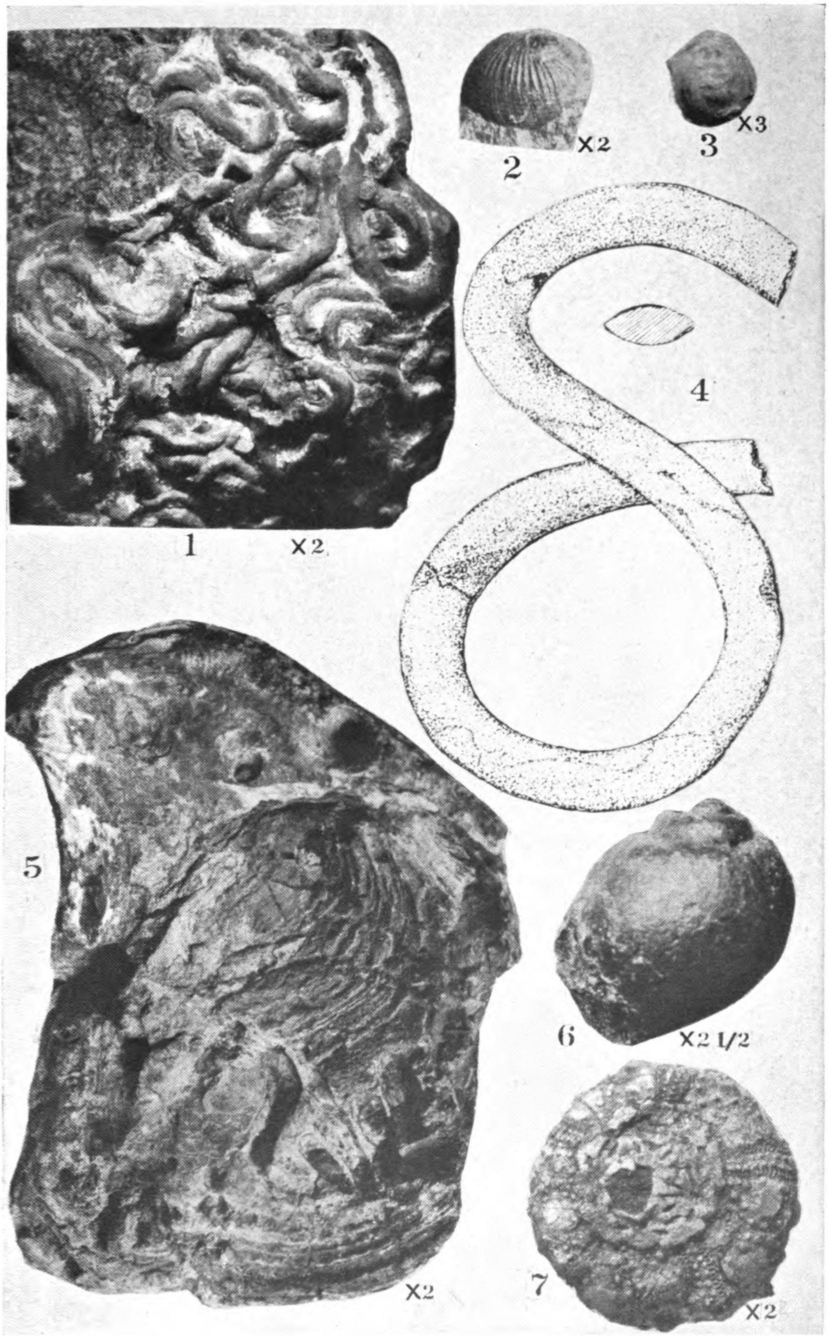


PLATE VIII.

Turritella seriatim-granulata var. *belviderii* Cragin.

(Page 58.)

FIG. 1. The largest example seen, natural size. Zone 18 of Kiowa shale, Champion Draw.

FIG. 2. Showing surface ornamentation, × 2. Zone 18 of Kiowa shale, Champion Draw.

Turritella kansasensis Meek.

(Page 57.)

FIG. 3. Artificial cast, natural size, after Meek. Mentor bed, 12 miles southwest of Salina. The type specimen.

FIG. 4. Cast in sandstone, natural size, after Meek. Mentor bed, 12 miles southwest of Salina.

FIG. 5. Cast in dental wax, × 2. Mentor bed, 5 miles west of Smolan

Margarita ornata, n. sp.

(Page 56.)

FIG. 6. Cast in dental wax from the type specimen, × 2. Mentor bed, 5 miles west of Smolan.

Margarita marcouana Cragin.

(Page 55.)

FIG. 7. View of specimen collected by the writer, which appears to be this species, × 2. Zone 10, Champion Draw.

Margarita mudgeana Meek.

(Page 55.)

FIG. 8. Gutta percha cast from a mold, after Meek. Mentor bed, 12 miles southwest of Salina.

FIG. 9. Cast of the interior of type specimen, after Meek. Mentor bed, 12 miles southwest of Salina.

Mactra siouxensis smolanensis, n. var.

(Page 75.)

FIG. 10. The type specimen, a mold of the interior, × 2. Mentor bed, 5 miles west of Smolan.

PLATE VIII.

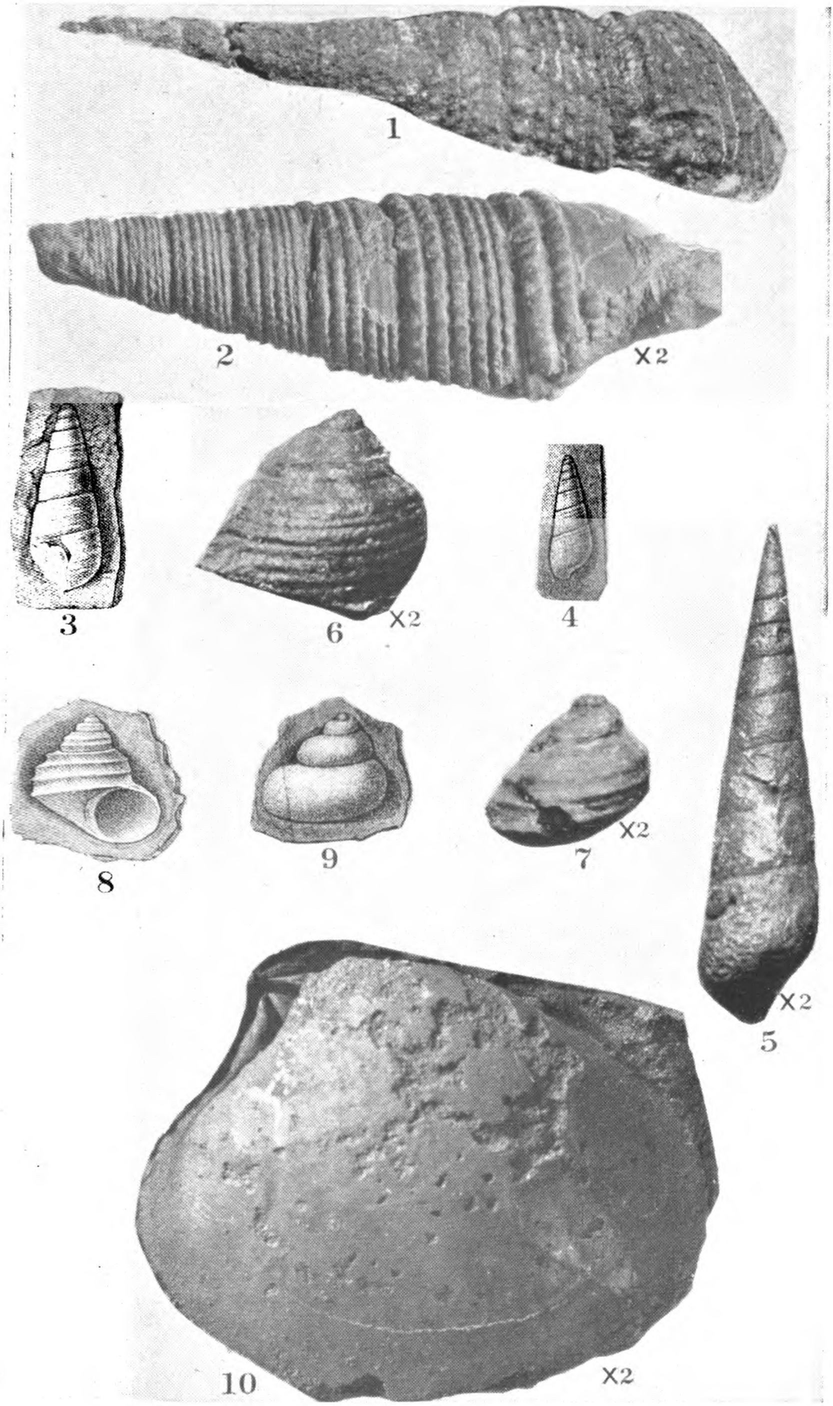


PLATE IX.

Schlœnbachia kiowana, n. sp.

(Page 89.)

FIG. 1. The type specimen, × 1¼. Champion shell bed, Champion Draw.

Anchura kiowana.

(Page 53.)

FIG. 2. Specimen from Champion shell bed, Champion Draw.

FIG. 3. Cast in dental wax, × 2. Mentor bed, 5 miles west of Smolan.

Trochus texanus Roemer.

(Page 57.)

FIG. 4. Specimen from zone 14, × 2. Kiowa shale, Champion Draw.

Schlœnbachia peruviana von Buch.

(Page 89.)

FIG. 5. View of largest fragment collected, × 1¼. Zone 12, Kiowa shale, Champion Draw.

PLATE IX.

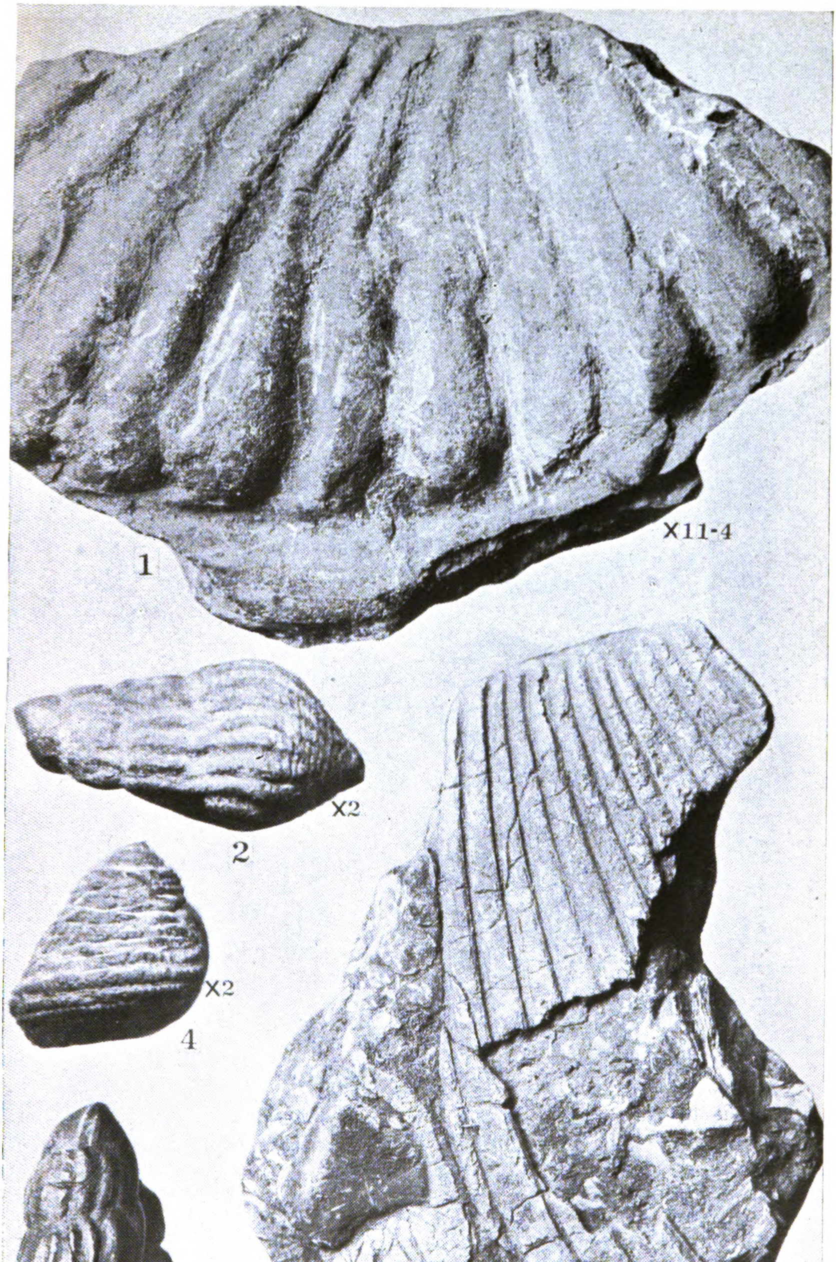


PLATE X.

Cyprimeria kiowana Cragin.
(Page 67.)

Fig. 1. Surface of the valve, natural size. Zone 12, of Kiowa shale, Champion Draw.

Gryphæa navia Hall.
(Page 71.)

Fig. 2. View showing the external surface of upper valve, × 1⅛. Zone 14, Kiowa shale, Champion Draw.

Gryphæa corrugata Say.
(Page 71.)

Fig. 3. View of a specimen from the Champion shell bed referred to this species, Champion Draw, × 1⅛.

Astrocœnia nidiformis Cragin.
(Page 51.)

Fig. 4. View showing a portion of a colony, × 2. Champion shell bed, Champion Draw.

PLATE X.

PLATE XI.

Engonoceras belviderensis Cragin.

(Page 87.)

FIG. 1. Specimen showing the sutures, × 1¼. Mentor bed, 5 miles west of Smolan.

FIG. 2. View of specimen, after Cragin. Locality not given.

FIG. 3. A specimen showing the sutures, after Cragin. Locality not given.

FIG. 4. Analysis of the sutures by Cragin.

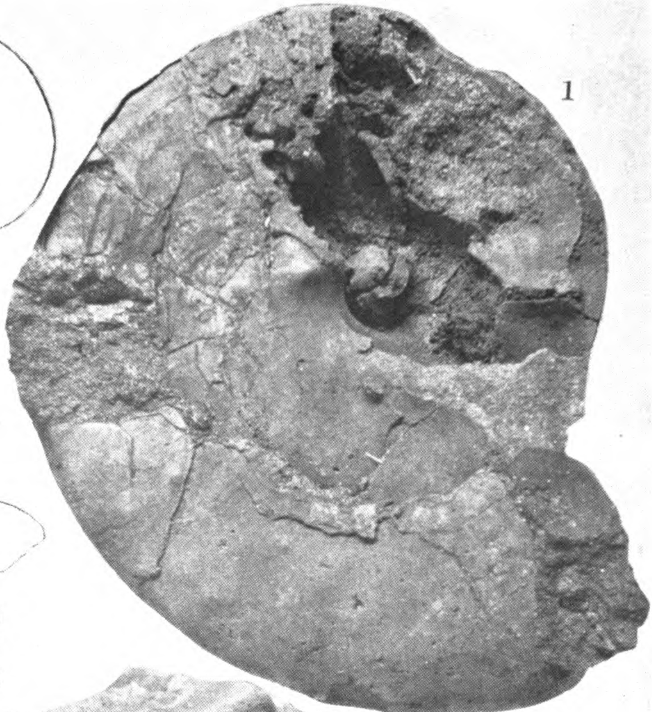
Schloenbachia belknappi Marcou.

(Page 88.)

FIG. 5. View of a fragment of a specimen, × 1⅞. Zone 10, Kiowa shale, Champion Draw.

PLATE XI.

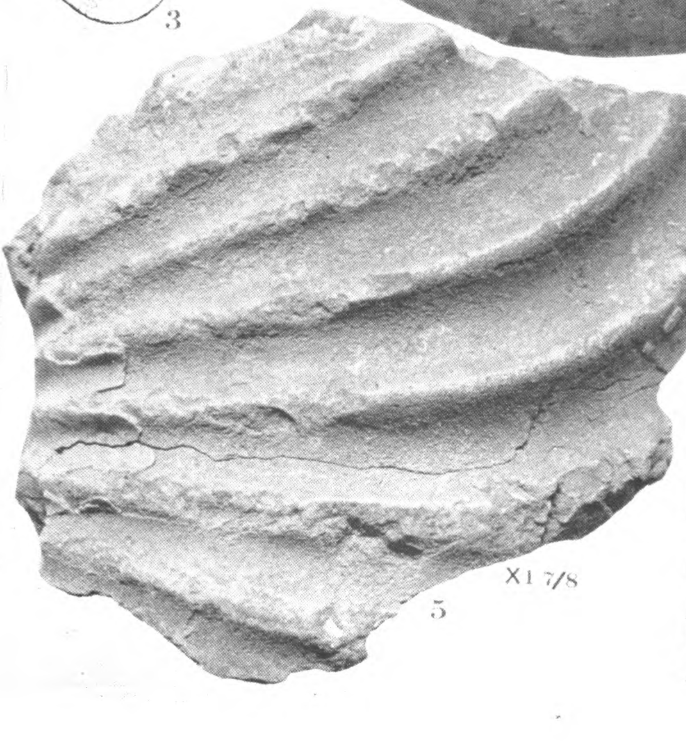
2.



1

X1 1/4

3



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5

PLATE XII.

Margaritina nebraskensis Meek.

(Page 76.)

FIG. 1. Type specimen, natural size, after Meek, from the "Dakota," opposite Sioux City on the Missouri river.

FIG. 2. Dorsal view of the type specimen, natural size, after Meek.

FIG. 3. View of a small specimen, natural size, after Meek. Same locality and horizon as preceding.

Arcopagella mactroides Meek.

(Page 61.)

FIG. 4. Type specimen, natural size, after Meek. Mentor bed, 12 miles southwest of Salina.

FIG. 5. Mold of the interior, × 2. Mentor bed, Natural Corral.

FIG. 6. Outline showing internal structure of left valve, after Meek.

FIG. 7. Outline showing interior of right valve, after Meek.

FIG. 8. Internal mold, × 2. Mentor bed, 5 miles west of Smolan.

Linearia kansasense, n. sp.

(Page 74.)

FIG. 9. Cast of the interior in dental wax, × 2. Mentor bed, 5 miles west of Smolan.

FIG. 10. Mold of the interior. Mentor bed, 5 miles west of Smolan.

PLATE XII.

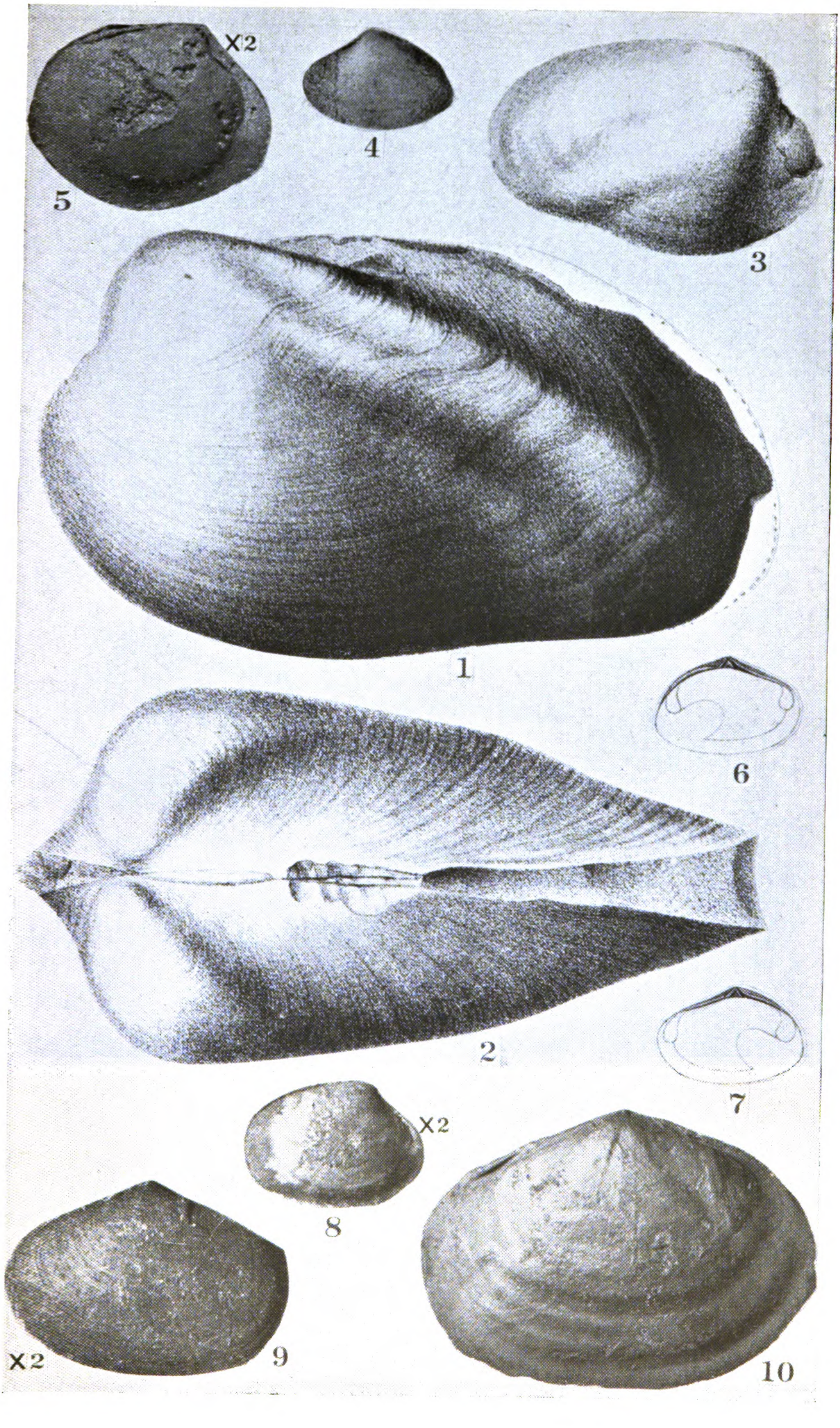


PLATE XIII.

Trigonia emoryi Conrad.
(Page 85.)

FIG. 1. Cast of the exterior in dental wax, × 1¼. Mentor bed, 5 miles west of Smolan.

FIG. 2. Mold of the interior, × 1½. Mentor bed, 5 miles west of Smolan.

FIG. 3. Specimen showing exterior, × 2. Kiowa shale, lowest "oyster" bed, Bluff Creek canyon.

Cardita belviderensis Cragin.
(Page 62.)

FIG. 4. View of a well-preserved specimen, × 2½. Champion shell bed, Champion Draw.

FIG. 5. Exterior of the shell, after Cragin. Kiowa shale, Belvidere.

FIG. 6. View of interior, after Cragin. Kiowa shale, Belvidere.

Crassatellina oblonga Meek.
(Page 66.)

FIG. 7. Interior of right valve, × 2, after Meek.

FIG. 8. Internal mold, × 5. Mentor bed, Natural Corral.

FIG. 9. Interior of left valve, × 2, after Meek.

FIG. 10. Mold of the interior, natural size, after Meek. Mentor bed, 12 miles southeast of Salina.

FIG. 11. The type specimen, natural size, after Meek. Mentor bed, 12 miles southwest of Salina

FIG. 12. Dorsal view of mold of the interior, natural size, after Meek. Mentor bed.

Cyprimeria kiowana Cragin.
(Page 67.)

FIG. 13. View showing hinge line, × 2. Zone 12, Kiowa shale, Champion Draw.

PLATE XIII.

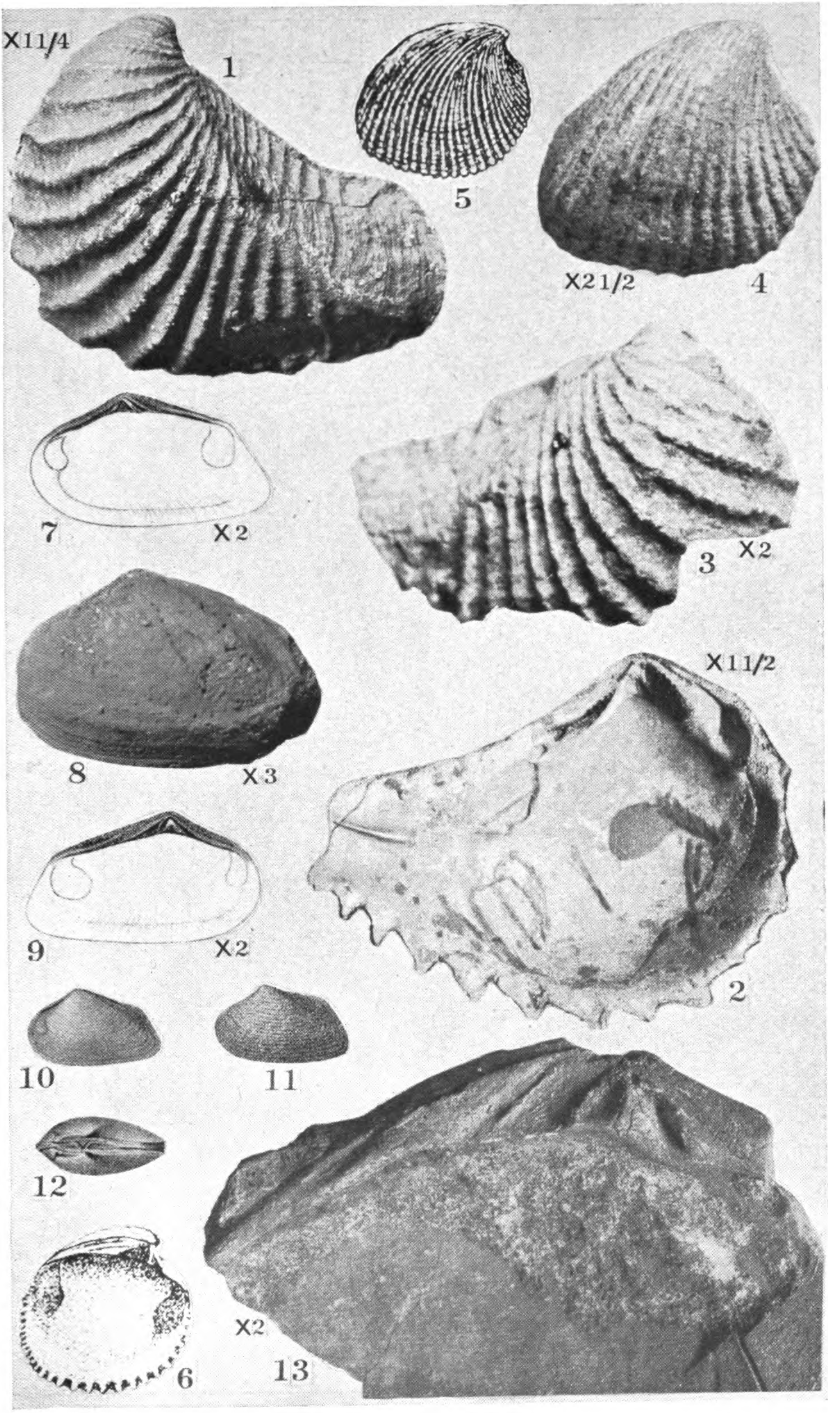


PLATE XIV.

Siliqua mentorensis, n. sp.
(Page 83.)

FIG. 1. Mold of the interior, × 1¼. Mentor beds, 5 miles west of Smolan.

Leptosolen conradi Meek.
(Page 73.)

FIG. 2. The type specimen, × 2, after Meek. Mentor beds, 12 miles southwest of Salina.

FIG. 3. View showing the exterior of the shell, × 2, after Meek. Mentor beds, 12 miles southwest of Salina.

FIG. 4. Mold of the interior, × 1½. Mentor beds, Natural Corral.

Barbatia parallela Meek.
(Page 61.)

FIG. 5. View of the type specimen, natural size, after Meek. Mentor beds, 12 miles southwest of Salina.

Corbicula nucalis Meek.
(Page 65.)

FIG. 6. An average specimen, about × 2½, after Meek.

FIG. 7. The type specimen, natural size, after Meek. Mentor beds, 12 miles southwest of Salina.

Corbicula subtrigonalis Meek.
(Page 64.)

FIG. 8. The type specimen, natural size, after Meek. Mentor beds, 12 miles southwest of Salina.

Remondia ferrisi Cragin.
(Page 83.)

FIG. 9. The exterior of the shell, after Cragin. About zone 14 of the Kiowa shale, Champion Draw.

Roudaria quadrans Cragin.
(Page 83.)

FIG. 10. The shell in profile, after Cragin. About zone 14, Kiowa shale, Belvidere.

FIG. 11. View showing exterior of shell, after Cragin. Locality and horizon as in 10.

Limopsis subimbricatus Cragin.
(Page 74.)

FIG. 12. View of the interior, after Cragin. Champion shell bed, Champion Draw.

FIG. 13. The exterior of the shell of left valve, after Cragin. Champion shell bed, Champion Draw.

Plicatula senescens Cragin.
(Page 80.)

FIG. 14, 15. Reproduced from Cragin, supposedly natural size. About zone 12 or 14 of Kiowa shale, Champion Draw.

Cardium bisolaris Cragin.
(Page 62.)

FIG. 16. Specimen showing exterior, supposedly natural size. Champion shell bed, Champion Draw, Belvidere.

PLATE XIV.

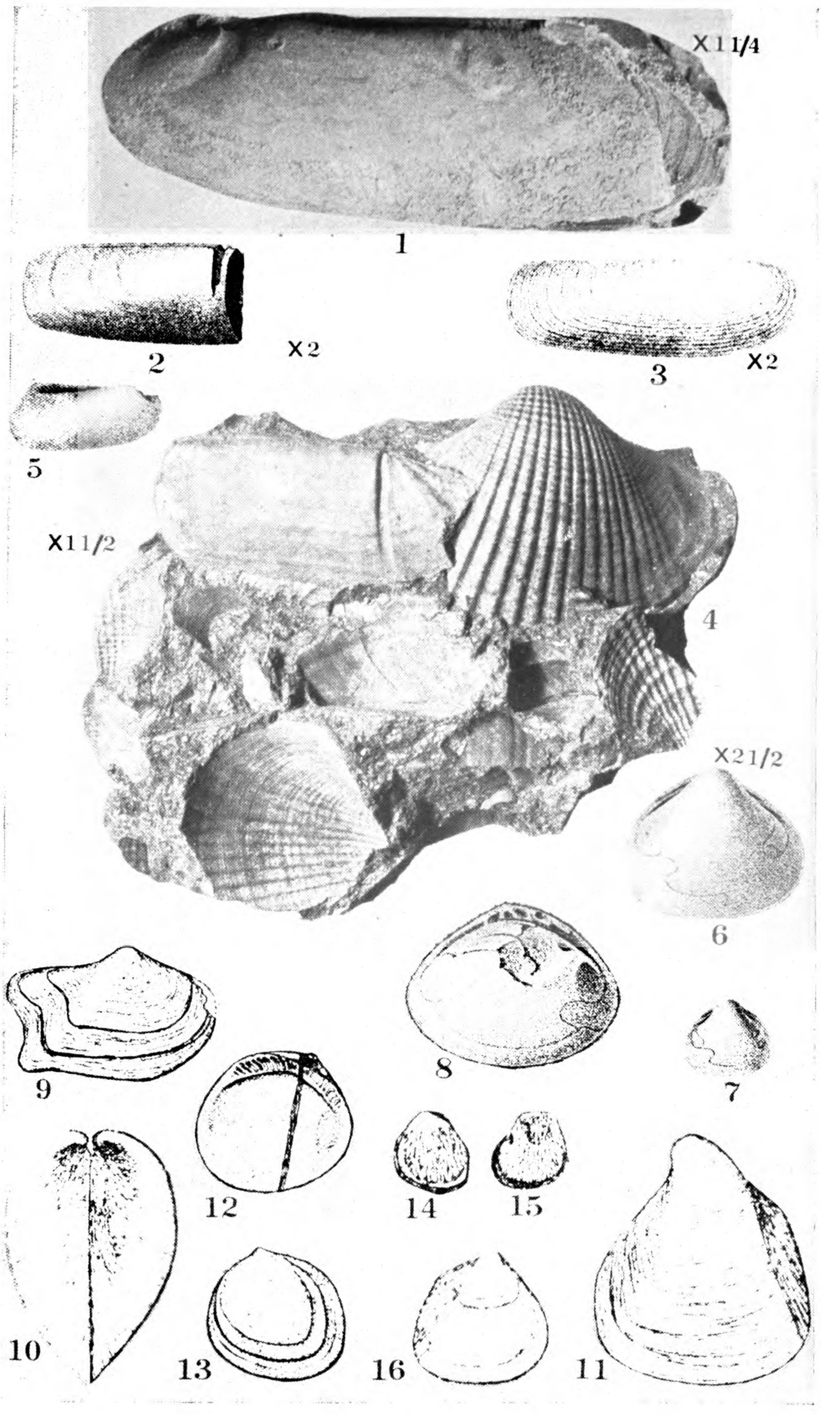


PLATE XV.

Cardium kansasense Meek.
(Page 63.)

FIG. 1. View showing the left valve, × 2. Zones 8 to 14, Kiowa shale, Champion Draw.

FIG. 2. Mold of the interior, × 2; shows molds of sockets on the hinge area. Mentor beds, 5 miles west of Smolan.

FIG. 3. Mold of the interior of same specimen shown in figure 2, × 2.

FIG. 4. Mold of the interior of the right valve, × 1, after Meek. Mentor beds, 12 miles southwest of Salina.

FIG. 5. Reproduction of Meek's figure, showing a mold of the interior surface of the right valve.

FIG. 6. Showing hinge structures and muscle scars, × 1, after Meek.

FIG. 7. Reproduction of Meek's figure, showing the interior.

FIG. 8. Showing profile of the shell, × 2. Zones 8 to 14 of Kiowa shale, Champion Draw.

Trigonarca salinæensis Meek.
(Page 85.)

FIG. 9. Mold of the interior of right valve, × 3. Mentor beds, Natural Corral.

Corbula crassicostata Cragin.
(Page 65.)

FIG.10. View showing shape and exterior ornamentation of the shell, × 3. Champion shell bed, Champion Draw.

Yoldia microdonta Meek.
(Page 86.)

FIG. 11. Reproduction of the Meek's figure of the type specimen. Mentor beds, 12 miles southwest of Salina.

FIG. 12. Mold of a specimen in sandstone; shows hinge line with teeth, × 2. Mentor bed, 5 miles west of Smolan.

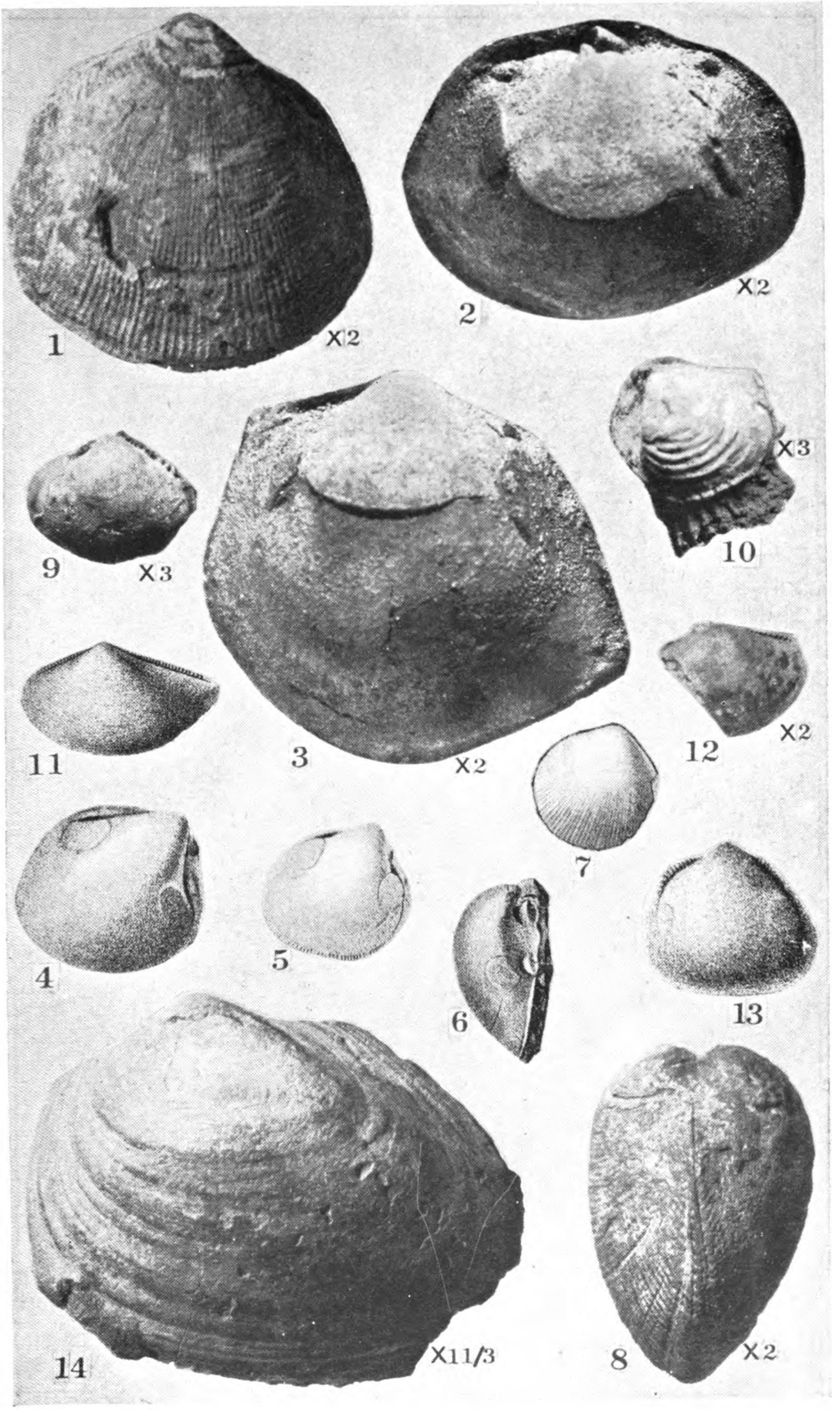
Trigonarca siouxensis Hall and Meek.
(Page 86.)

FIG. 13. Mold of interior of left valve, natural size, after Meek. "Dakota" sandstone at the mouth of Big Sioux river.

Cucullæa recedens Cragin.
(Page 66.)

FIG. 14. View of the left valve, × 1⅓. Champion shell bed, Champion Draw.

PLATE XV.



8—996

PLATE XVI.

Cucullæa recedens Cragin.

(Page 66.)

FIG. 1. View showing the hinge area of the specimen shown on plate XV, figure 14, × 2.

FIG. 2. Mold of the interior of the right valve, × ¾. Mentor bed, Natural Corral.

FIG. 3. View of the left valve of a large specimen, × 1½. Champion shell bed, Champion Draw.

Ostrea quadriplicata Shumard.

(Page 78.)

FIG. 4. View of the under valve, internal mold. Mentor bed, 5 miles west of Smolan.

Tylostoma elevata (Shumard).

(Page 59.)

FIG. 5. The largest specimen collected, × 2. Champion shell bed, Champion Draw.

PLATE XVI.

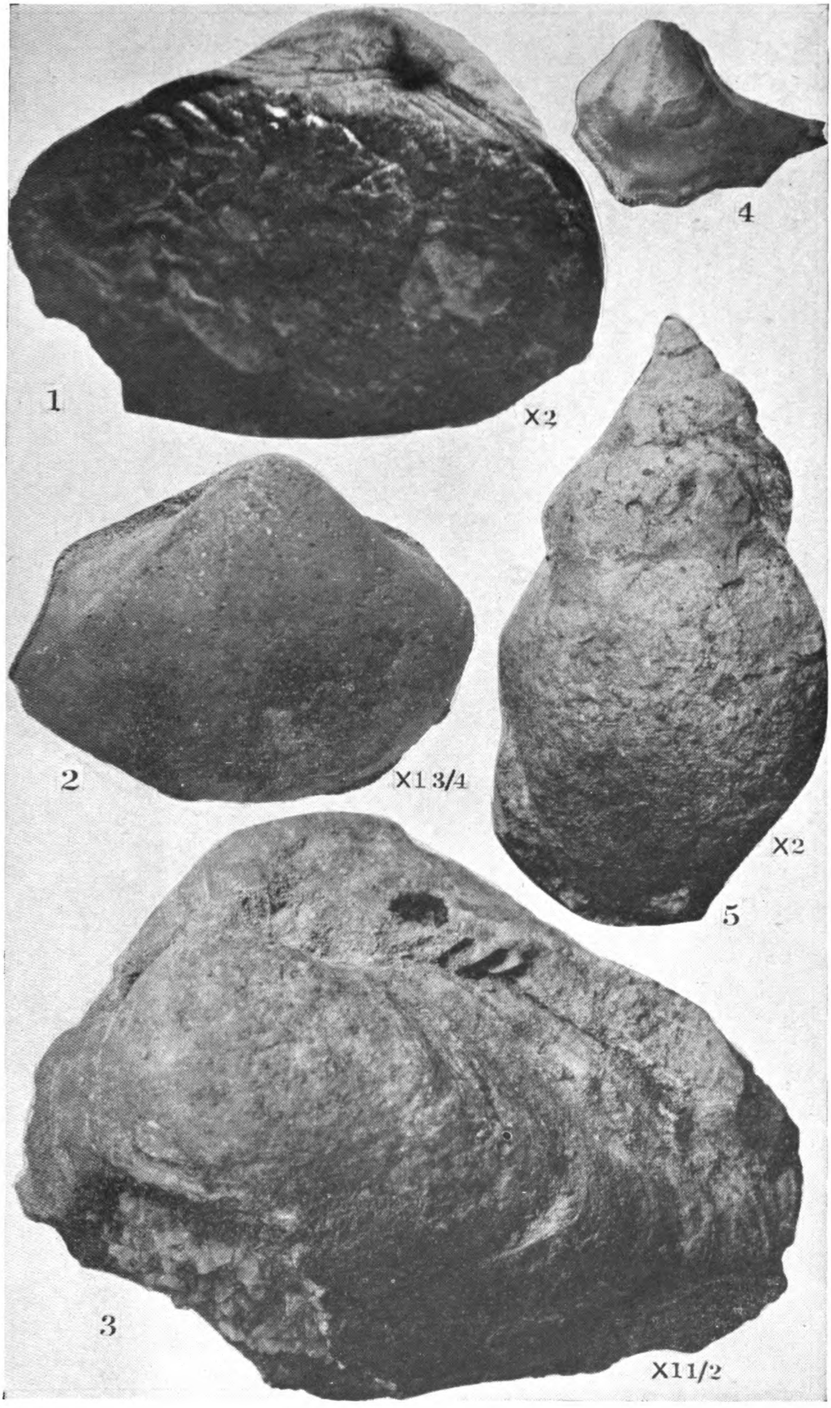


PLATE XVII.

Gervillia mudgeana White.

(Page 69.)

FIG. 1. Mold of the interior of the left valve, × 1¼. Mentor bed, 5 miles west of Smolan.

FIG. 2. View showing molds of the cartilage pits, × 1¼. Mentor bed, 5 miles west of Smolan.

Cucullæa recedens Cragin.

(Page 66.)

FIG. 3. View of specimen showing radiating lines on the internal mold, × 2. This may be an entirely different species. Mentor bed, 5 miles west of Smolan.

FIG. 4. Reproduction of figure by Cragin, showing character of the hinge. Champion shell bed, Champion Draw.

Mactra siouxensis Meek and Hayden.

(Page 75.)

FIG. 5. Posterior view of the type specimen, natural size. "Dakota" sandstone, 2 miles above the mouth of the Big Sioux river.

FIG. 6. Specimen showing the exterior ornamentation, natural size, after Meek. Same locality and horizon as preceding.

FIG. 7. Side view of a mold of the interior, natural size. Same locality and horizon as preceding.

Filling of the Burrow of a Mollusk (Meek).

(Page —.)

FIG. 8. Reproduction of a figure by Meek, natural size. "Dakota" sandstone; locality not given.

Pharella? dakotensis Meek and Hayden.

(Page 79.)

FIG. 9. Reproduction of Meek's figure of the type specimen, natural size. "Dakota" sandstone about the mouth of the Big Sioux river.

PLATE XVII.

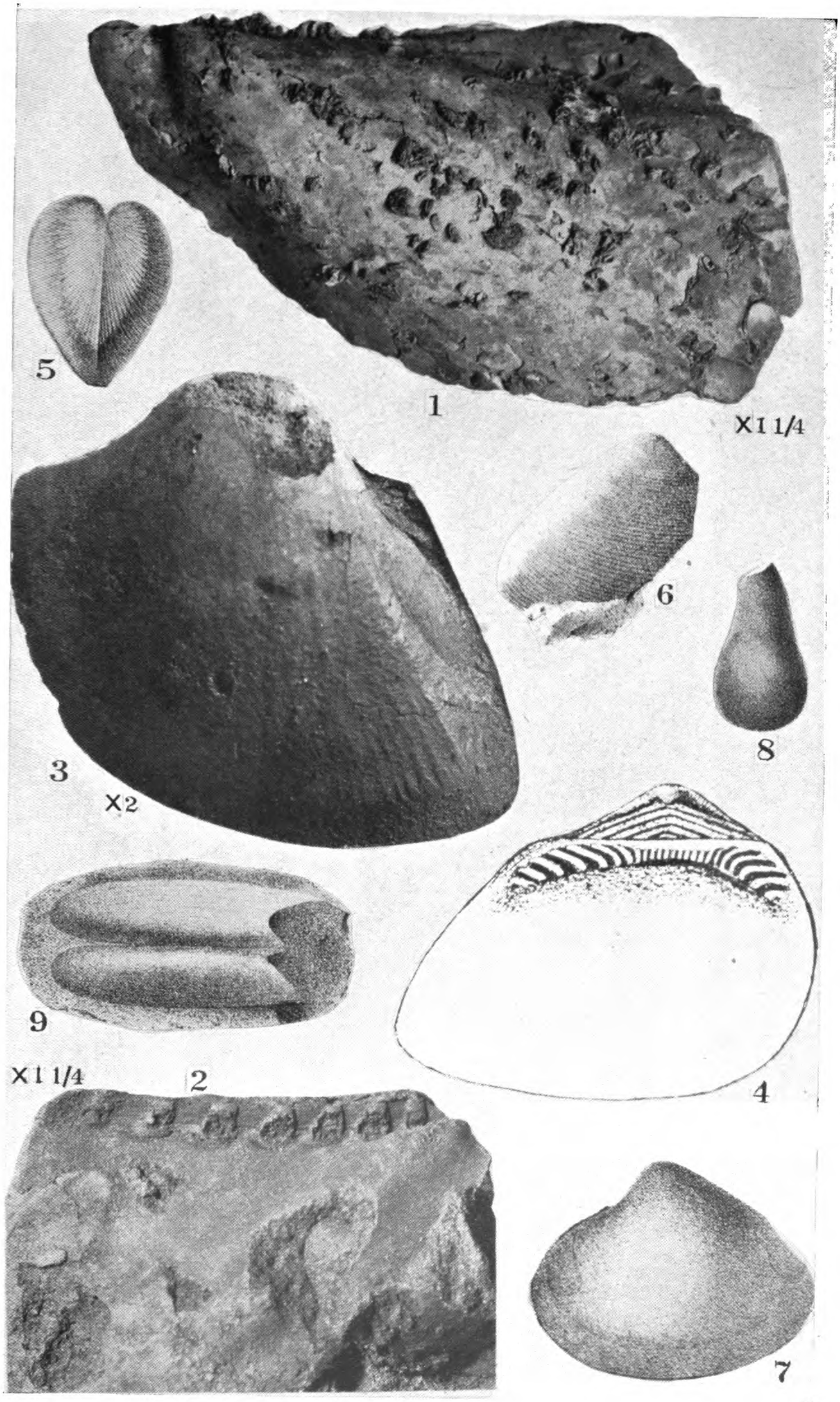


PLATE XVIII.

Pteria salinaensis White.
(Page 82.)

Fig. 1. Left valve of a robust specimen, × 1½. Mentor bed, 5 miles west of Smolan.

Cyrena dakotensis Meek.
(Page 68.)

Fig. 2. Posterior view, natural size, after Meek. "Dakota" sandstone, mouth of Big Sioux river.

Fig. 3. Mold of the interior, showing muscular impressions, natural size, after Meek. Horizon and locality as preceding.

Fig. 4. View of the left valve of a large example, natural size, after Meek. Locality and horizon as preceding.

Fig. 5. Dorsal view of a specimen, showing the two valves in position, after Meek. Locality and horizon as preceding.

Fig. 6. View of left valve of a smaller example, natural size, after Meek. Horizon and locality as preceding.

Fig. 7. View along hinge line of a mold of the interior, after Meek, natural size. Same specimen as figure 2.

Cucullæa gigantea, n. sp.
(Page 66.)

Fig. 8. View showing right valve, × 1. Mentor beds, Natural Corral.

PLATE XVIII.

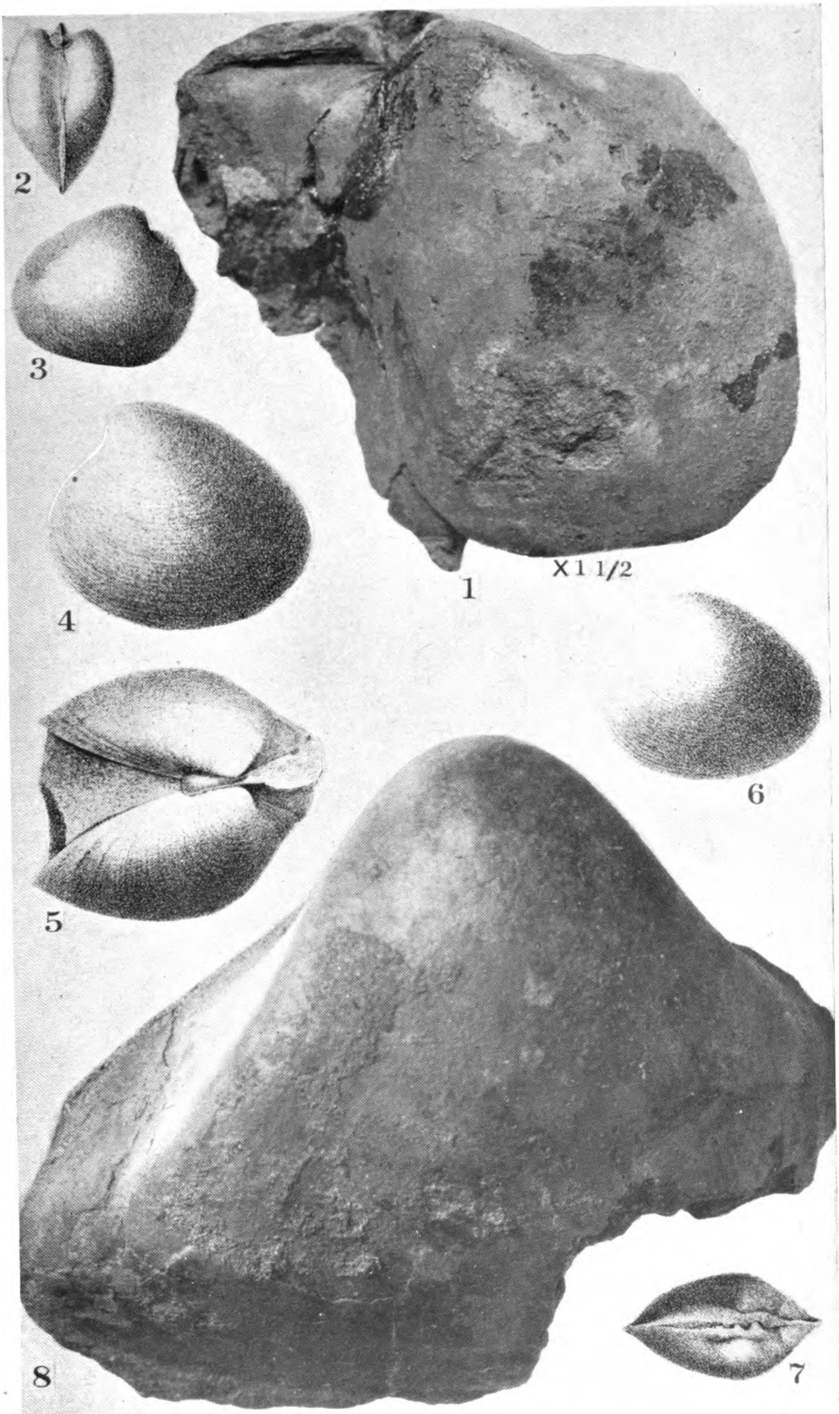


PLATE XIX.

Tellina subscitula Meek.

(Page 84.)

FIG. 1. Internal cast of left valve, type specimen, × 2, after Meek. Mentor bed, 12 miles southwest of Smolan.

FIG. 2. The same specimen as in figure 1, natural size.

Arcopagella? macrodonta Meek.

(Page 60.)

FIG. 3. Mold of the interior, from the type specimen. "Dakota" sandstone, on Big Sioux river, 3 miles above its mouth.

Tapes belviderensis Cragin.

(Page 84.)

FIG. 4. View of the right valve, × 1⅔. Middle portion of the Kiowa shale, between Belvidere and Sun City.

FIG. 5. View showing the hinge area of the specimen of figure 4.

FIG. 6. View of the right valve of a younger and more rotund example, × 2. Upper portion of the Kiowa shale, Champion Draw.

FIG. 7. View of the hinge area, after Cragin.

FIG. 8. Cragin's figure of the right valve of the type specimen.

Leptosolen otterensis Cragin.

(Page 73.)

FIG. 9. Reproduction of Cragin's figure, from the Blue Cut shale. Kiowa shale, Blue Cut, on the Santa Fe railroad.

Pteria belviderensis Cragin.

(Page 81.)

FIG. 10. View of the right valve of the only specimen seen by the writer, × 1¼. Champion shell bed, Champion Draw.

PLATE XIX.

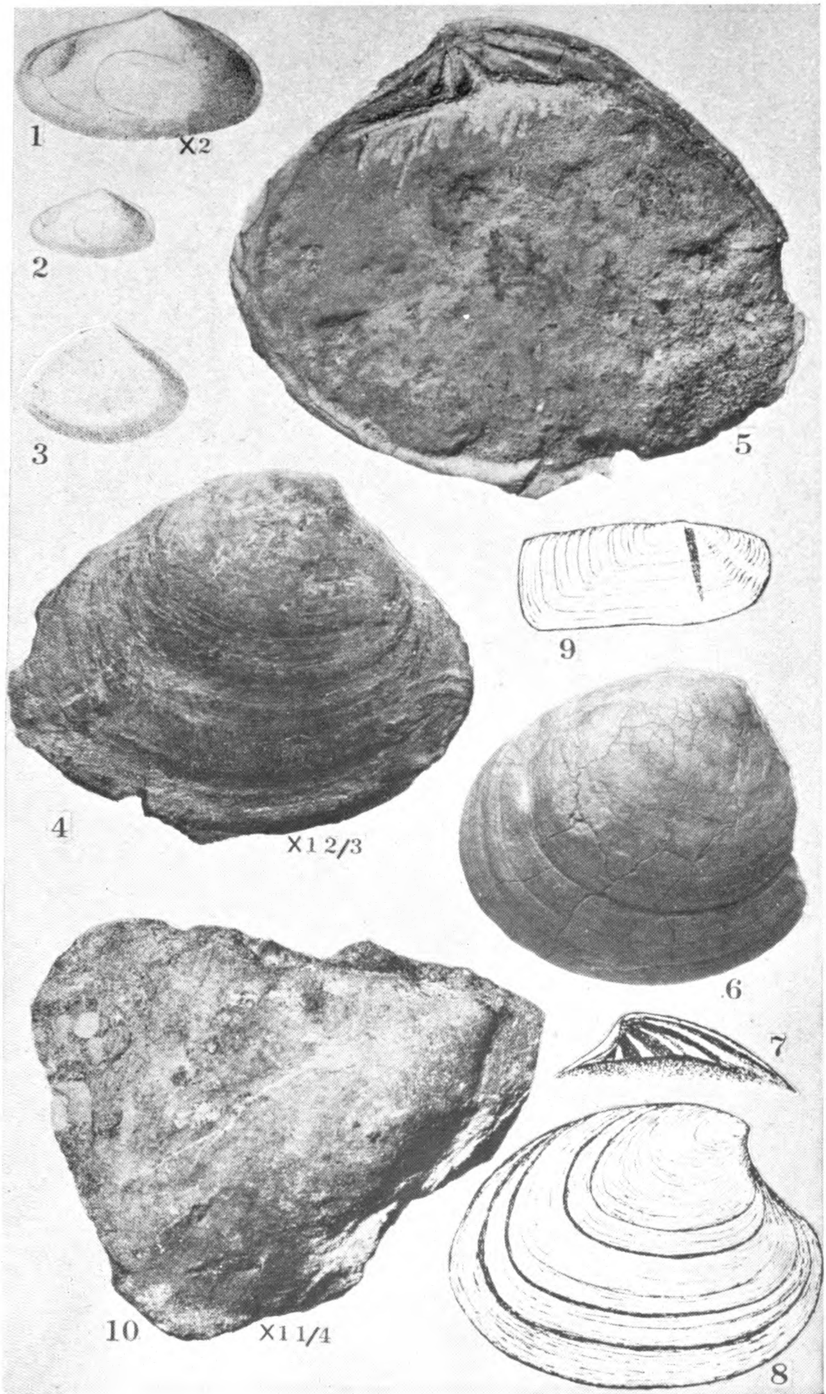


PLATE XX.

Protocardia texana Conrad.

(Page 80.)

FIG. 1. Cast in dental wax from a mold of the exterior, × 2. This specimen shows that the shell attained larger dimensions than shown by Meek. Mentor beds, 5 miles west of Smolan.

FIG. 2. Specimen showing exterior, natural size, after Meek. Mentor beds, 12 miles southwest of Salina.

FIG. 3. Mold of the interior, natural size, after Meek. Mentor beds, 12 miles southwest of Salina.

FIG. 4. Mold of the interior, × 1½. Mentor beds, 5 miles west of Smolan.

FIG. 5. Exterior of shell, × 3, after Meek. Mentor beds, 12 miles southwest of Salina.

FIG. 6. Specimen showing the exterior, × 2. Windom member, northeast of Windom.

Pholadomya? belviderensis, n. sp.

(Page 79.)

FIG. 7. Mold of the interior, × 2. Mentor beds, Natural Corral.

Corbicula? elongata, n. sp.

(Page 64.)

FIG. 8. Mold of the interior, × 3. Mentor beds, 5 miles west of Smolan.

Exogyra texana Roemer.

(Page 68.)

FIG. 9. Showing interior of valve, × 1½. Champion shell bed, Champion Draw.

PLATE XX.

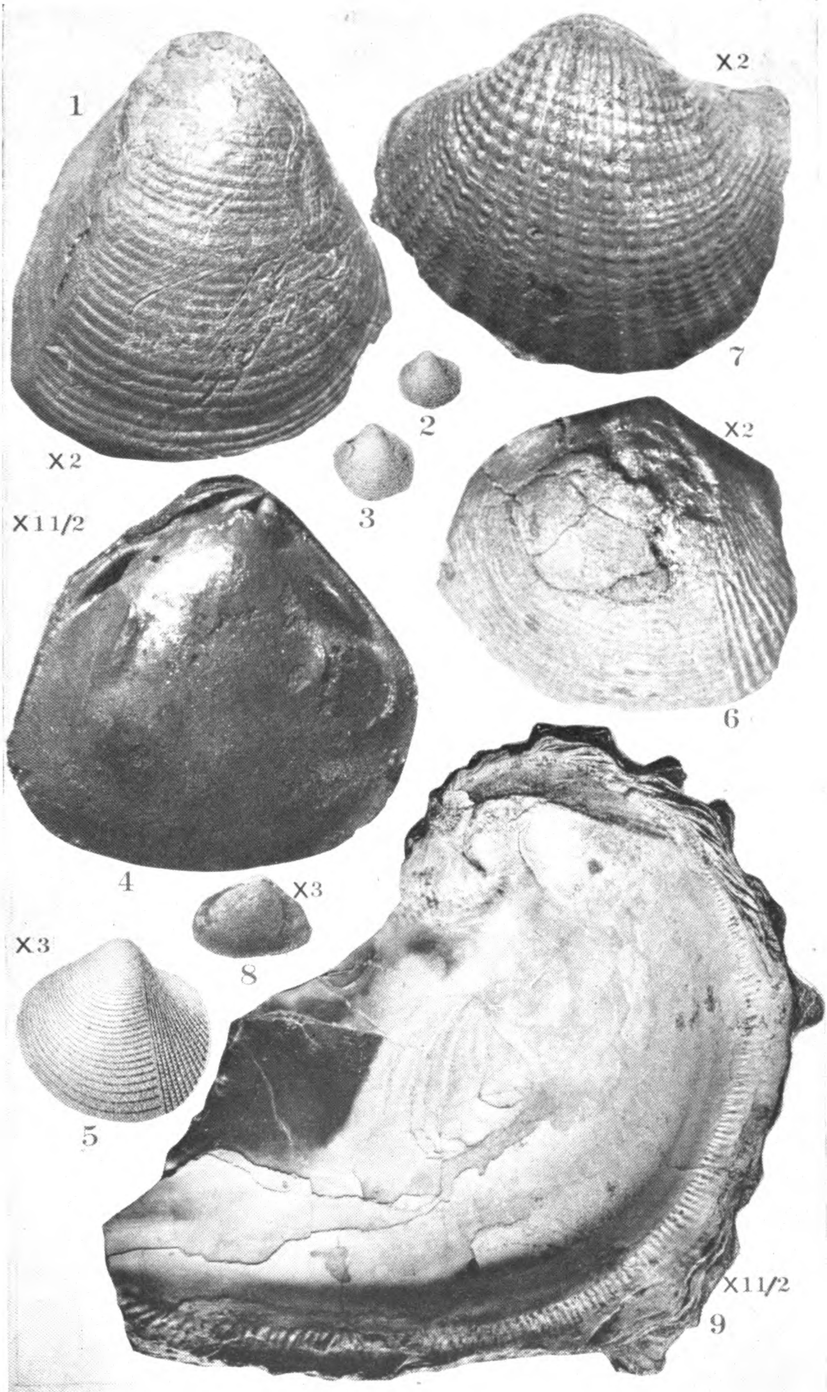


PLATE XXI.

Ostrea sp. Meek.

(Page 77.)

FIG. 1. Mold of interior, lower valve, × 1, after Meek. Mentor bed, 12 miles southwest of Salina.

FIG. 2. Mold of exterior, upper valve, × 1, after Meek. Mentor bed, 12 miles southwest of Salina.

Exogyra texana Roemer.

(Page 68.)

FIG. 3. Exterior of valve, × 2. Kiowa shale near middle, west of Sun City.

Leda acuminata, n. sp.

(Page 72.)

FIG. 4. Mold of the interior; the type specimen, × 3. Mentor bed, 5 miles west of Smolan.

Tellina subscitula Meek.

(Page 84.)

FIG. 5. Mold of the interior, × 2, Mentor bed, 5 miles west of Smolan.

Ostrea kiowana, n. sp.

(Page 77.)

FIG. 6. Lower valve of a specimen from slightly different shale than following, × 1¾. Kiowa shale, Blue Cut, on Santa Fe railroad.

FIG. 7. The lower valve of a specimen, × 2. Zone 12 of Kiowa shale, Champion Draw.

PLATE XXI.

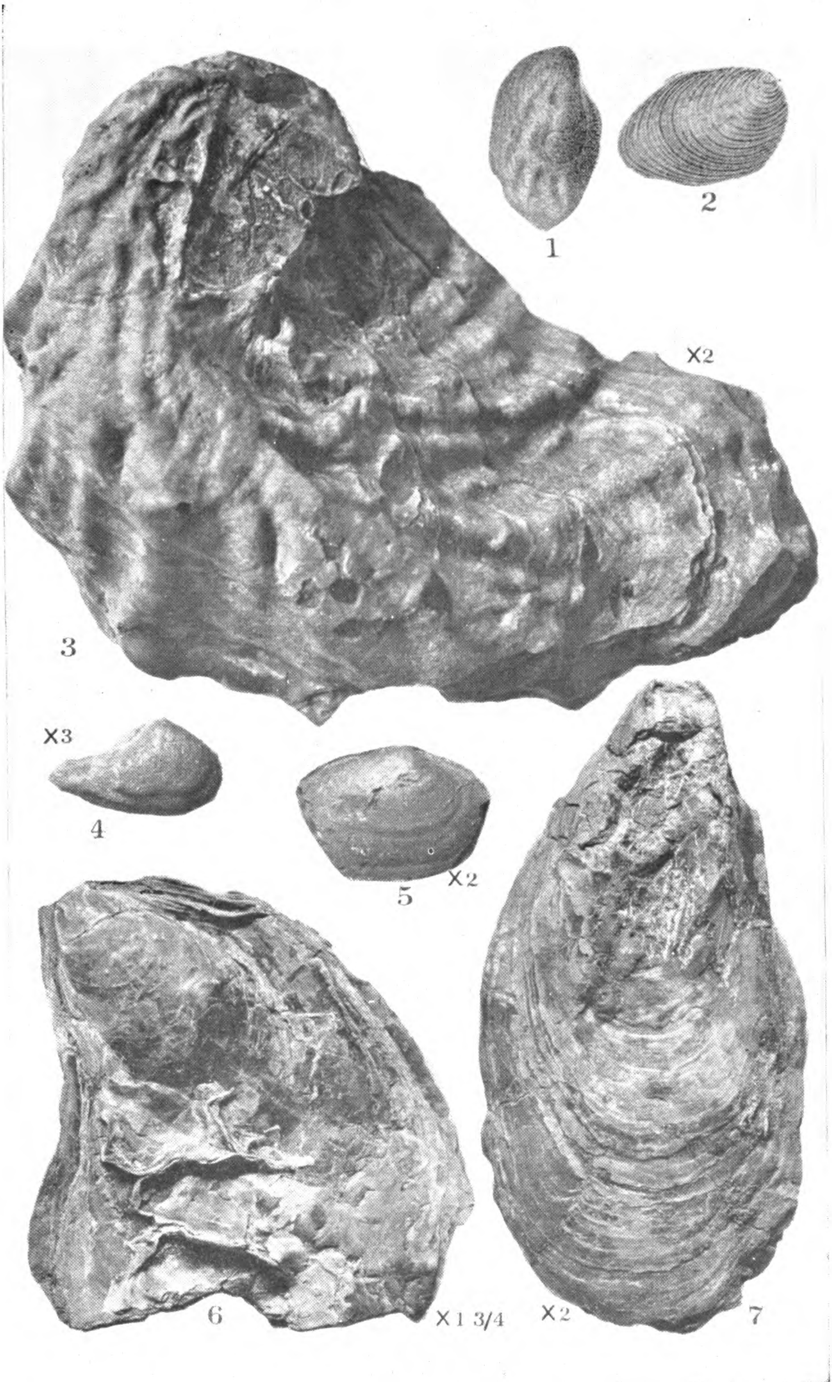


PLATE XXII.

Gryphæa navia Hall.
(Page 71.)

FIG. 1. View showing the lower valve, the angularity on the posterior portion and the strongly incurved beak, natural size. Zone 14, Kiowa shale, Champion Draw.

FIG. 2. The same specimen as in figure 1, showing the interior, natural size.

Tylostoma elevata (Shumard).
(Page 59.)

FIG. 3. Smaller form, quite abundant in strata above the Champion shell bed, × 2. Zone 14, Kiowa shale, Champion Draw.

Pteria salinænsis White.
(Page 82.)

FIG. 4. View of the right valve of a specimen, × 1¼. Mentor bed, Natural Corral.

Pecten fredericksburgensis Cragin.
(Page 78.)

FIG. 5. Showing the nature of the ornamentation, × 2. Champion shell bed, Champion Draw.

PLATE XXII.

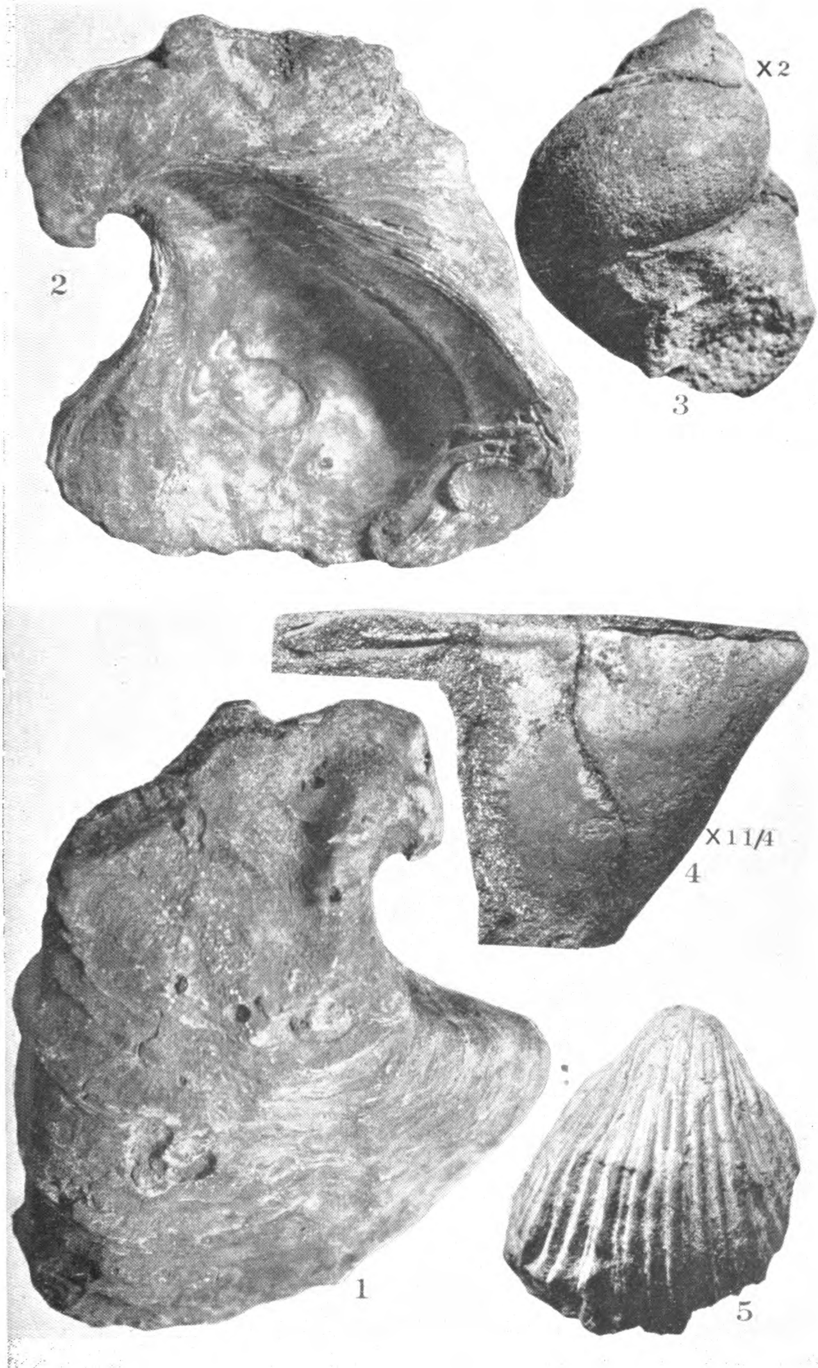


PLATE XXIII.

Gryphæa corrugata Say.

(Page 70.)

FIG. 1. External surface of lower valve, showing shape of shell, × 1⅛. Zone 12, Kiowa shale, Champion Draw.

FIG. 2. View of a specimen from the lowest "oyster" bed of Bluff Creek canyon.

Gryphæa corrugata hilli Cragin.

(Page 71.)

FIG. 3. Showing upper side and external surface of upper valve, × 2, Champion shell bed, Champion Draw.

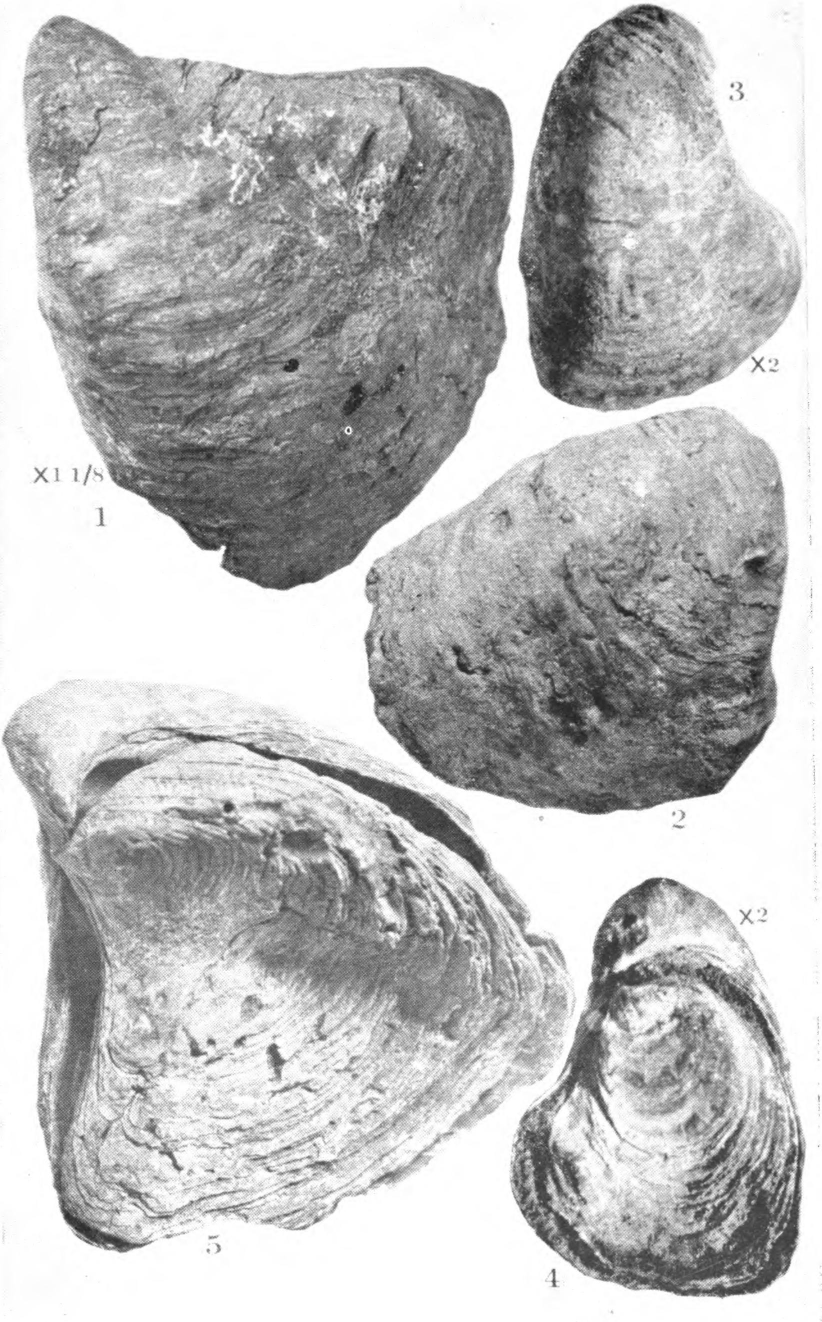
FIG. 4. View showing the under valve, × 2. Champion shell bed, Champion Draw.

Gryphæa corrugata belviderensis Hill and Vaughan.

(Page 70.)

FIG. 5. Showing the top side of the shell, natural size. Zone 14, Kiowa shale, Champion Draw.

PLATE XXIII.



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