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Invertebrate Fauna and Environment of Deposition of the Niobrara Formation (Cretaceous) of Kansas

Halsey W. Miller
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Biographical Sketch of the Author

Halsey W. Miller graduated from Temple University in January, 1954. He received the Master of Science degree from Yale University in June, 1954, and the Doctor of Philosophy from the University of Kansas in 1958. In 1967 he joined the faculty at Fort Hays Kansas State College. Before he came to Hays, he taught at the University of Arizona, Tucson; High Point College, High Point, N. C.; and Wake Forest University, Winston-Salem, N. C.; and was a geologist with the State Geological Survey of Kansas.

Invertebrate Fauna and Environment of Deposition of the Niobrara Formation (Cretaceous) of Kansas

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Invertebrate Fauna and Environment of Deposition of the Niobrara Formation (Cretaceous) of Kansas

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INTRODUCTION

Previous Work

The invertebrate fauna of the Niobrara Formation, for the most part, was originally described before 1900. The usage of older taxonomic concepts led to splitting, especially among the species of *Inoceramus*. The invertebrates have been described as follows; Brown (1940), fossil pearls; Fischer and Fay (1953), an aptychus; Grinnell (1876), *Uintacrinus;* Jeletzky (1955, 1961), belemnites; Johnson and Howell (1948), *Platylithophycus,* a supposed alga; Loetterle (1937), foraminifers and ostracodes; Logan (1898, 1899a, 1899b), macroinvertebrates; Miller (1957a, 1957b), dibranchiates; Morrow (1934, 1935), foraminiferans, ostracodes, and cephalopods.

This paper reevaluates, and where desirable, synonymizes species. Previously unrecorded species are described and illustrated. The environment of the Niobrara Sea in Kansas is described. Abel (1922, p. 299-347) discussed the fauna of the Niobrara Formation of Kansas and concluded that the chalk was deposited in an inland sea having a sediment source to the west. Abel primarily considered the evidence of vertebrate fossils in his discussion. Seemingly he thought of the Niobrara Sea as a normal inland sea, characterized by abundant oyster banks. Reeside (1957) described the regional sedimentational picture of the Niobrara Formation and stated that the known fauna was indicative of shallow depths, unfavorable bottom conditions, and quiet waters in the eastern portion of the basin. More favorable bottom conditions were present in the western portion of the basin.

Present Study

The author collected specimens in Scott, Logan, Gove, Trego, Rooks and Phillips Counties, Kansas. In addition, other specimens, including Logan's types were studied in the University of Kansas

Geological Museum, and the Fort Hays Kansas State College Museum.

The macroinvertebrate fauna of the Niobrara Formation is limited in variety and quantity. The most abundant faunal elements are *Inoceramus* species and *Ostrea congesta*. All other invertebrates are rare by comparison.

Williston (1893, p. 100) stated in part;

"In one day last year, the three members of my party found over 30 saurians, five or six pterodactyls, several turtles, and fishes innumerable, in the upper beds. On the other hand, the invertebrates are here especially numerous, strewing the surface in heaps; large and perfect Haploscaphas, Rudistes, etc., can be obtained literally by the wagon load."

Unfortunately fossils are no longer so abundant on the outcrop of the Niobrara Formation. This has probably been caused by the great amount of collecting done by amateurs and professionals.

ACKNOWLEDGMENTS

This paper was the major portion of a thesis submitted to the University of Kansas in partial fulfillment of the requirements for the degree of Doctor of Philosophy. I wish to thank my advisor, Dr. Charles Pitrat; and Messrs. Robert Mann, Edwin Gutentag, James Richard, who at different times assisted me in the field.

Mr. George F. Sternberg, former curator of the Fort Hays Kansas State College Museum, and Mr. Myrl Walker, the present director, have kindly granted me permission to study and describe many fossils in that museum.

Dr. Tatsuro Matsumoto provided invaluable advice and encouragement during his visit to the United States. Dr. William Cobban, of the United States Geological Survey, and Dr. J. A. Jeletzky, of the Geological Survey of Canada, have corresponded with the author and aided in some cephalopod identifications.

Dr. W. W. Hambleton, of the State Geological Survey of Kansas, has kindly granted me permission to publish this paper.

I alone am responsible for all conclusions and identifications.

STRATIGRAPHY

General Statement

The Niobrara Formation is divided into two members, the Fort Hays Member and the overlying Smoky Hill Member. The Fort Hays Member tends to have a higher $CaCO_3$ content, is more dense, and is white or lighter-colored than the Smoky Hill Member. The two members are easily distinguished by color in subsurface well cuttings. They can be distinguished at outcrops by the absence of any underlying gray chalk in the Fort Hays Member, and by the less massive bedding of the Smoky Hill Member.

The Niobrara Formation consists of up to 750 feet of chalk. The outcrop belt trends southwest from north-central Kansas.

The Fort Hays Member is a light-gray to very light-yellow chalk; it is massively bedded and has thin, light to dark-gray, chalky-clay partings. The Fort Hays Member forms up to the basal 90 feet of the Niobrara Formation.

The Smoky Hill Member is a gray chalk that weathers locally to white, yellow, and orange chalk beds. The member contains thin beds of bentonite, and bentonite and limonite. Locally pyrite concretions are abundant. The chalk of the Smoky Hill Member consists primarily of calcium carbonate with minor amounts of illite, kaolinite, and quartz. Calcium carbonate is present in foraminiferal tests (mainly *Gümbelina*) and as small calcite fragments (plates and needles 2 to 3 microns long). Some of the needles are probably of inorganic origin; however most appear to be coccoliths or rhabdoliths. The insoluble residues of the chalk consist of clay sized and very fine silt sized particles. The silt sized particles consist of quartz, mica flakes, and heavy minerals. There are no gray shale beds in the Niobrara Formation of Kansas.

Stratigraphic Subdivisions

Bass (1926, p. 19-26) discussed the use of key beds for correlation within the Niobrara Formation, and in the Fort Hays Member he defined two groups of beds that he was able to trace through Ellis County and part of Trego County. Bass's measured sections and correlations were restricted to the Fort Hays Member and the lower Smoky Hill Member. Moss (1932, p. 16) in discussing his zonation of the lower Niobrara Formation stated in part:

"The section of the Smoky Hill chalk member is divided into zones, designated by letters starting at the bottom and lettered consecutively upward. These zones are not the same as those used by Bass (1926) and Russell (1929). Their groups do not form a continuous series but designate beds that are separated by undetailed intervals."

Moss grouped the basal 188 feet of the Smoky Hill Member into six zones. Moss's (1932, p. 16) criteria for delimiting zones were; "A zone as used here, consists of 20 to 35 feet of chalky shale capped by a resistant chalk bed. In one case a thick shale (Zone C) is set apart because there is no convenient break in the chalk above."

Moss's use of shale and resistant beds as stratigraphic markers is unsound as these beds are developed by weathering and not sedimentation. Moss (1932, p. 16-17) further stated; "all of the zones contain thin beds of bentonite, which are very important because the intervals between them can be definitely recognized in correlation between exposures. Since there is rarely more than 40 feet of strata represented in any one area and most of the exposures are capped by a resistant bed, these zones form a convenient lithologic unit."

Russell (1929) extended the use of measuring thicknesses and intervals of bentonite beds for correlation within the Smoky Hill Member. Russell's composite measured section showing the supposed thicknesses and intervals lacks an exact, well defined scale, and is too small to be useful to a field geologist. No actual measured sections, or field locations, or field location of measured sections were cited or included in Russell's paper.

The author has measured the thicknesses and intervals of bentonite beds in the upper Smoky Hill Member and finds that there is a lateral variation of the thicknesses and intervals of some of the bentonite beds amounting to 25 percent over a distance of 100 yards. Bentonite beds are very abundant in the Smoky Hill Member. The intervals between the bentonites are usually one to six feet, and the majority of the bentonites are one inch thick. Stratigraphic sections less than one mile apart are difficult or impossible to correlate by this method. It seems likely, therefore, that this method of correlation may be of little use in the upper Smoky Hill Member, even though Bass (1926) was able to employ it successfully in the Fort Hays Member, and both Bass and Moss (1923) seem to have applied this method to the lower Smoky Hill Member.

Williston (1897, p. 239) stated in part;

"The material of which the *Ornithostoma* beds is composed is true chalk throughout their entire thickness. There is no marl, no sandstone, or other material. The color varies, often within short distances from a light blue to a lavender, a white, a buff, a yellow or even a red. This color is, however, not confined to any horizon, save that the lower horizons have the color usually lighter blue or purer white. The yellow color with its varying shades of red where much exposed is confined to the upper beds, and the line of separation is very easily traced from the Smoky Hill east of Monument Rocks to the Saline north of WaKeeney, and thence to the South Fork of the Solomon near Lenora. Not only is the color line easily traced, but the fossils contained in them are characteristic. For convenience I will call them the *Hesperornis* beds and the lower strata the *Rudistes* beds. The impurities of the chalk vary from less than two to about ten percent."

Williston's criteria are based on fossils, *Hesperornis,* a bird and *Ornithostoma (Pteranodon),* a pterosaur, both of which are extremely rare. *Rudistes (Durania)* is more abundant, but not enough so to be of use to a field geologist. The criterion of color of the chalk is of dubious value, because it is at least partly a weathering and not a stratigraphic characteristic.

Elias (1931, p. 41-43) gave a summary of the data available on Niobrara stratigraphy at that time, and presented a few comments and additions to the previous schemes. Elias stated that he had not done any detailed stratigraphic work in the Niobrara Formation. Elias commented on, and expanded the schemes of Williston (1897) and Russell (1929).

Loetterle (1937, p. 16-17) was able to distinguish the Fort Hays Member, the lower Smoky Hill Member, and the upper Smoky Hill Member, on the basis of microfossil content. Loetterle recorded 37 species confined to the Fort Hays Member, 11 species confined to the upper Smoky Hill Member. This is only a gross division and can be determined easily only by a specialist in the laboratory.

It seems unlikely that an easily applicable scheme for zonation of the Niobrara Formation will be found. Schemes based on fossil content are unreliable in that many parts of the Niobrara Formation do not contain abundant index fossils. A zonation based on "soft" and "resistant" beds, or on "shale" and chalk, or on gray and brightly colored chalk is largely dependent on weathering phenomena and is not necessarily dependent on sedimentational features. The zonation by thickness and interval of bentonite beds holds the most promise, but it may be unreliable, at least locally, in the upper Smoky Hill Member, because of differential sediment accumulation rates. A study of well cores is needed to solve this problem.

Age and Correlation

The Niobrara Formation was named in 1861 by Meek and Hayden from exposures along the upper Missouri River Valley in Nebraska. They correlated the Niobrara Formation with the Cenomanian (?) of Europe, and included it within their "Lower Series," the upper portion of which later became known as the Colorado Group (White, 1878, p. 21-22, 30). The Niobrara Formation has been correlated (Cobban and Reeside, 1952) with the Austin Chalk of Texas and the Coniacian and early Santonian Stages (early Senonian) of Europe.

Cobban (personal communication, December, 1957) wrote that an early Campanian age for the uppermost part of the Niobrara Formation is highly probable. Cobban stated;

"In 1953 (Billings Geol. Soc. Guidebook, 4th Ann. Field Conf., p. 100) I pointed out the presence of *Desmoscaphites* some 50 feet below the top of an 180-foot yellowish-orange calcareous shale unit in the Colorado shale of east-central Montana. Common Eagle (early Campanian) ammonites—*Scaphites hippocrepis* and *Haresiceras*—were found in silty shale only 45 feet above the top of these Smoky Hill-like beds. At this locality one gets the impression that the Smoky Hill may be as young as Telegraph Creek (youngest Santonian). That the Smoky Hill may be still younger is suggested by the impressions of large *Baculites* in the upper part of the Smoky Hill chalk near Denver. ~~These *Baculites* in the upper part of the Smoky Hill chalk near Denver~~. These *Baculites* cannot be identified as to species but their large size is comparable to the size of adult Eagle *Baculites*. Of course these observations and those of Jeletzky (1955) are not conclusive. What we need to find is something definite in the Smoky Hill such as *Scaphites hippocrepis, Haresiceras* spp., late *Texanites, or 'Hamites'*. Reeside and I summarized the lines of reasoning for an early Campanian age for the highest Smoky Hill. This was included in our manuscript 'Cretaceous Rocks in the Western Interior of the United States' which Reeside presented at the Mexican Congress a year and a half ago. The manuscript is still unpublished."

The *Baculites* mentioned by Cobban have an odd aperture and are not typical *Baculites*. They may belong to a different genus (Cobban, June, 1958, personal communication). Similar *Baculites*, with attached barnacles *(Stramentum haworthi)*, occur in the Niobrara Formation of Kansas.

Scott and Cobban (1964, p. 5) refer the uppermost portion of the Niobrara Formation at Pueblo, Colorado to the early Campanian. This zone is characterized by smooth *Baculites* with attached specimens of *Stramentum haworthi*, and *Inoceramus simpsoni*. The age determination was largely based upon the presence of *Haresiceras* and *Scaphites hippocrepis* in an underlying bed.

The presence of the *Stramentum* attached to *Baculites* in Kansas suggests the presence of Campanian beds there also. *Bevahites* similar to the Kansas specimens have also been reported from Campanian rocks in Texas (Young, 1959 p. 763); the genus occurs in Santonian as well as Campanian rocks elsewhere.

Inoceramus simpsoni occurs lower in the Kansas section, closely associated with *Clioscaphites chouteauensis*. These specimens are probably from the upper portion of middle Santonian age.

Jeletzky (personal communication, December 1957) wrote that he considers *Uintacrinus* to be indicative of late Santonian age on a global scale. He cited a recently discovered occurrence of *Uintacrinus* in Europe.

Miller, Sternberg, and Walker (1957), stated the distribution of

Uintacrinus in the Smoky Hill Member was from sec. 10, T. 14 S., R. 33 W., near Russell Springs in Logan County to sec. 1, T. 14 S., R. 25 W., Castle Rock area, Gove County. This indicates that *Uintacrinus* occurs at or very near the top of the Smoky Hill Member and possibly within 100 feet of the base of the member. The specimens from eastern Gove County, south of Quinter and the Castle Rock area, are from near the base of the Smoky Hill Member, and this occurrence lowers the base of the range of *Uintacrinus* as previously defined in Kansas. Williston (1893, p. 110) erroneously stated: "I may add that the rare crinoid, *Uintacrinus,* which was originally described from Kansas specimens, seems to be confined to one horizon, near the middle of the beds." Williston (1897, p. 242) stated: "All the specimens of which I have any knowledge have come from the vicinity of Elkader, in the valley of the Smoky Hill, in the horizon just below the yellow chalk."

The base of the *Uintacrinus* zone is more than 50 feet above the base of the Smoky Hill Member, and if Jeletzky's opinion of the stratigraphic zone of *Uintacrinus* is correct, it would place the greater part of the Niobrara Formation within the latter part of Santonian Stage. However, the base of the *Uintacrinus* zone may occur in older rocks, at least in Kansas. Especially in that *Uintacrinus* occurs below the *Clioscaphites chouteauensis* zone in Logan County and below the *Scaphites?* zone in Gove County.

Two slabs of *Uintacrinus* have been found (SW¼ sec. 10, T. 14 S., R. 33 W.) at least 20 feet below the *Clioscaphites chouteauensis* zone. The *Uintacrinus* from near Castle Rock is well below the *Scaphites?* zone, and may be early Santonian.

Clioscaphites vermiformis occurs in beds of early middle Santonian age, and *Baculites* sp. cf. *B. codyensis* occurs in early through middle Santonian rocks.

Inoceramus deformis of Coniacian age is confined to the Fort Hays Member.

Ostrea congesta, and *Inoceramus grandis* occur in both the Fort Hays and Smoky Hill Members. *I. grandis* is most abundant in the lower 100 feet of the Smoky Hill Member. *Durania maxima* has been found only in the Smoky Hill Member, as has *Inoceramus platinus.* Their range may be nearly through the entire member.

Recent studies of the correlation of the Niobrara Formation have tended toward a younger age designation for the upper portion of the Smoky Hill Member. The correlation of the Niobrara Formation of Kansas has been complicated by a scarcity of easily identified marker beds, and ammonites and other fossils considered to be index species.

Although I can not precisely zone the Niobrara Formation, the following is a rough division by groups of associated species of fossils. The divisions are not of equal thickness, and each species does not range all the way through the division in which it occurs.

The thicknesses of the divisions are largely unknown and probably show lateral variations. Not enough sections containing fossils have been measured to accurately locate, add to, or subdivide the divisions. I consider the divisions to be a paleontologic device of use mainly in making correlations, and to be of little use to the field geologist who is mainly interested in lithologic criteria that can be applied in the field.

H. *Stramentum haworthi, Baculites?* (large, smooth). *Ostrea congesta.*

G. *Niobrarateuthis bonneri, Durania maxima, Inoceramus platinus, Ostrea congesta, Uintacrinus socialis, Pecten bonneri.*

F. *Inoceramus simpsoni, I. platinus, I. grandis? Durania maxima, Clioscaphites chouteauensis, Uintacrinus socialis, Ostrea congesta, Baculites* sp. (smooth), *Bevahites?* sp., *Ostrea falcata, Pteria* sp. cf. *P. petrosa, Lucina* sp., *Baculites* sp. cf. *B. codyensis?*

E. *Lucina* sp., *Baculites* sp. (small, smooth).

D. *Uintacrinus socialis, Scaphites?* spp., *Baculites* sp. (smooth), *B.* sp. cf. *B. codyensis, Inoceramus platinus, Ostrea congesta, Durania maxima, Inoceramus grandis.*

C. *Inoceramus grandis, I. involutus, Ostrea congesta.*

B. *Inoceramus grandis, I. deformis, Ostrea congesta.*

A. *Inoceramus deformis, Ostrea* sp.

Divisions A and B are of Coniacian age. Division A includes the lower portion of the Fort Hays Member. Excellent exposures of this division are found north of Hays. Division B includes the upper portion of the Fort Hays Member, and fossiliferous exposures outcrop near Kirwin Dam.

Division C is of late Coniacian and early Santonian age and probably consists of the lower 100 feet of the Smoky Hill Member. I have based this upon the occurrence of *Inoceramus involutus*, that ranges from late Coniacian into early Santonian rocks in England. The *Inoceramus* species are abundant and well preserved in this division.

Division D probably is of the lower portion of the middle Santonian age and includes the zones of *Scaphites?* (*S. depressus?*) and *Clioscaphites vermiformis. Uintacrinus socialis* occurs below the zone of *Scaphites?* (*S. depressus?*) as well as below the zone of *Clioscaphites vermiformis. Inoceramus grandis* and *I. platinus* occur in overlapping zones.

Division E is thin, probably 20 feet, and contains few fossils.

Division F is thick and is of the upper part of middle Santonian age. The zone of *Clioscaphites chouteauensis* occurs within this division. The zone has a thickness of about 10 feet in northwestern Rooks County, and is confined to a small portion of the division. Most of the fossils ascribed to this division occur within the zone of *C. chouteauensis* (*Bevahites?*, *Baculites* spp., *Pteria, Lucina, Ostrea congesta, Inoceramus simpsoni, I. platinus,* and *I. grandis?*) Outside the zone of *C. chouteauensis,* the division contains *I. platinus, O. congesta, Durania maxima,* and *Ostrea falcata.*

Division G is of late Santonian age and is characterized by *I. platinus, Niobrarateuthis bonneri,* and *Pecten bonneri.*

Division H is the uppermost part of the Smoky Hill Member and consists of chalk that weathers with a reddish-hue and is characterized by large, smooth *Baculites?* with attached barnacles, *Stramentum haworthi.* I have not been able to locate the *Baculites?* zone during my field work.

All the fossils reported from the Niobrara Formation of Kansas can not be accurately placed within the divisions given here, in that locality information for many specimens is lacking and associated fossils were not recorded.

ENVIRONMENT OF DEPOSITION

Discussion of Faunal Evidence

Foraminifera.—The foraminiferal fauna of the Niobrara Formation consists largely of planktonic genera such as *Gümbelina* and *Globigerina.* The Fort Hays Limestone Member has more genera of benthonic Foraminifera than the Smoky Hill Member; however, in both members the benthonic species form a minority of the fauna. The normal suite of benthonic Cretaceous foraminifers is missing in the Niobrara Formation, especially from the Smoky Hill Member. The normal suite of Cretaceous foraminiferal genera of the Niobrara Formation, had it been present, should be similar to that of the Austin Chalk, its Gulf Coast correlative.

The following genera are represented by 143 species in the Austin Chalk of Texas (Frizzel, 1954, p. 34). Starred genera occur in the Niobrara Formation of Kansas, mostly in the Fort Hays Member.

Bathysiphon
Pelosina
Ammodiscus
Glomospira
Haplophragmoides
Lituola
Spiroplectammina
Textularia
Verneuilina
**Gaudryina*
Pseudoclavulina
Heterostomella
Arenobulimina
Marssonella
Dorothia
Manorella
**Robulus*
**Lenticulina*
Saracenaria
Marginulina
**Dentalina*
**Nodosaria*
Chrysalogonium
Pseudoglandulina
Citharina
Palmula
Neoflabellina
**Frondicularia*
Pseudofrondicularia
**Kyphopyxa*
Lagena
Globulina
**Ramulina*
Vitriwebbina
Nonionella
Bolivinopsis
**Gümbelina*
Rectogümbelina
**Ventilabrella*
Bolivinoides
Bolivinitella
**Eouvigerina*

Pseudovigerina
*Buliminella
*Bulimina
*Neobulimina
Virgulina
*Loxostomum
*Pleurostomella
Nodosarella
Ellipsonodosaria
*Valvulineria
*Gyroidina
Allomorphina
Hastigerinella
Schackoina
*Globotruncana
Globorotalia
*Globorotalites
Anomalina
*Planulina

The following genera have been found in the Niobrara Formation and not in the Austin Chalk.

Vaginulina
Bullopora
Hantkenina
Bolivina
Globigerina

Arenaceous Foraminifera (except _Gaudryina_) are absent from the Niobrara Formation of Kansas. Arenaceous foraminifers are found in abundance in environments normally unfavorable to calcareous families, such as the deep-sea environment characterized by a cold, lightless area; and in the brackish-water environment characteristic of littoral or lagoonal sediments. The deep-sea arenaceous foraminifers are usually thin-shelled forms; however, the only arenaceous foraminifer found in the Niobrara Formation is _Gaudryina_, a large robust genus. The greater part of the foraminiferal fauna of the Niobrara Formation is composed of pelagic or planktonic genera, and benthonic genera are much less abundant. It is probable that the scarcity of arenaceous foraminifers may be attributed to the absence of suitable living conditions on the benthos.

Lalicker (1948) lists factors responsible for stunting of living protozoans, (1) wrong kind or insufficient amounts of food, (2) too low or too high temperature of the water, (3) unfavorable chemical composition and physical conditions of the water, (4) excessive p^H or acidity, and (5) lack of light. The foraminiferal fauna of the Niobrara Formation in Kansas seemingly is stunted when compared with "normal" species of the same geologic age from the Gulf Coast Cretaceous. Some examples are given in Table 1.

TABLE 1. Measurements of some Cretaceous Foraminifers in millimeters.

Species	Length (or Diameter)	
	Niobrara Formation of Kansas	Gulf Coast, measurements, after Cushman, 1946 except for *Globigerina*
Robulus navarroensis	0.5 to 0.7	1.0 (or more)
Gümbelina globifera	0.27 to 0.33	0.3 to 0.5
Gümbelina plummerae	0.4 to 0.45	0.5 to 0.65
Globigerina "cretacea"	0.2 to 0.26	0.36 to 0.44

(Measurements after Frizzell, 1954)

Grunseth (1955, p. 126) in discussing the Foraminifera of the Niobrara Formation in North Dakota stated in part:

"The microfauna of this section is dwarfed. The dwarfism may be the result of Transgression of Arctic seas during Niobrara time."

Arnal (1955, p. 189) in discussing the environment of abnormal foraminifera states in part:

"Of all the environments investigated so far, Playa del Rey Lagoon displayed the greatest percentage of abnormal Foraminifera. This is probably due to the confined and stagnant state of the water in the lagoon which leads to important changes in oxygen and food available and also brings about salinity variations especially important in summertime. In brief, it is when the environment starts to be fairly different from the oceanic environment that abnormal Foraminifera begin to be abundant."

Abnormalities in foraminifers include size variations and irregular chambers. Presumably an open ocean environment varying from normal could produce abnormalities, such as stunting, in Foraminifera.

An examination of the causes of foraminifer stunting listed by Lalicker (1948), would indicate that stunting of the Niobrara foraminifers may be caused by unfavorable chemical composition and physical conditions of the water, such as low-oxygen content and possibly excessive acidity. Said (1951, 1953) records the presence of stunted foraminiferal faunas in waters with a low-oxygen content.

Annual extremes of temperatures probably were of minor consequence in the Cretaceous Kansas seas. A shallow, inland sea would not have had a cold enough bottom temperature (as proposed by Grunseth, 1955, p. 126), or high enough bottom pressure to have caused stunted individuals or a diminished number of species. Cold currents originating in the Arctic and Antarctic areas are normally restricted to deep-sea basins and do not enter less shallow epeiric seas, such as the Black or Mediterranean Seas.

If we may use the abundance of fossil remains of pelagic and planktonic animals in the Niobrara sediments as an index to the abundance of life, there certainly was no shortage of food in those regions. After death these animals became food for the benthos, eliminating any shortage of food in that region.

Examination of the ecologic relationship of the foraminiferal fauna presents the possibility of unfavorable chemical composition of the water, unfavorable hydrogen-ion concentration, or a lack of oxygen to explain the reduced and stunted benthonic fauna.

Porifera.—Spicules of siliceous sponges were reported by Logan (1898, p. 481). No further work has been done with these remains.

Mollusca.—*Inoceramus* and *Ostrea* are the most abundant molluscs in the Niobrara Formation. These two genera, along with *Durania, Pecten, Lucina,* and *Pteria,* which are rare, are the only benthonic pelecypods discovered to date. The speciments of *Inoceramus* are mostly large, thin-shelled species suggesting calm water.

Pelecypods are unable to grow to large sizes in areas of rapid sedimentation. Slow sedimentation rates are necessary to allow time for the growth of large pelecypods such as *Inoceramus grandis* and *I. platinus. Inoceramus platinus* reaches a maximum length of more than one meter, although its shell is very thin. Pelecypods do not flourish where the bottom sediments are shifted about, although some water motion is necessary to keep in suspension the organic detritus the pelecypods eat.

The presence of a "paper-shell" *Pecten* indicates a calm off shore environment.

Recent oyster banks (Allee and Schmidt, 1951, p. 249) in deep water (34 to 42 meters) may be situated on coherent sands with individuals spaced about a meter apart. These are apparently the conditions under which the Niobrara inocerams grew.

Inoceramus grandis is a variable species, and in this respect it resembles *Crassostrea virginica* Gmelin (Abbott, 1954, p. 375) which has distinct somatic variations effected by different environments in which individuals live.

The limiting environmental conditions for *Durania* are not known. However, *Durania* is a broad, recumbent rudist, a type characteristic of deeper, nonreef water (Berquist & Cobban, 1957, p. 873). Rudists, in general, are characteristic of warm, clear, shallow, normally saline seas. The super-abundance of *Inoceramus* and oysters and the scarcity or lack of other typical benthonic Cretaceous mollusc genera (such as *Exogyra, Tellina, Turritella, Pyropsis,* and *Rostellites*), in the Niobrara Formation, that are present in the underlying and overlying Cretaceous formations, points to the presence of abnormal substrate or benthos conditions during Niobrara time.

The remaining molluscs are swimmers (ammonites, belemnites, and squids) or hitchhiking floaters (*Parapholas*), and are therefore more or less independent of the benthos. Belemnites (Dacque, 1915, p. 425) are characteristic of the boreal zone and are less numerous and stunted in warmer seas.

Naef (1912, p. 192) stated:

"Wir betrachten sie (belemnites) als nektonische Formen der Meeresoberfläche and Kustenzonen, von der sich nur besonders spezialisierte Typen losmachen könnten, um auch die tieferen und offenen Teile des Meeres als freie Schwimmer zu durchziehen."

Belemnites were undoubtedly nektonic or pelagic forms, as are the squids.

The ammonites ecologic niche is disputed by specialists. Schmidt (1930) stated that *Baculites* and *Scaphites* were probably good swimmers. Schoeller (1942) considered *Baculites* to be pelagic and *Scaphites* to be nektonic. Berry (1928) thought *Scaphites* was planktonic. It is probable that ammonites present in the Niobrara Formation of Kansas were all swimming or floating forms. Trueman's (1940) studies of the center of gravity and center of buoyancy of some ammonites suggests that *Scaphites* floated near the surface with the aperature upward. Trueman further considered *Baculites* to have floated with the aperture directed downward.

Other authors, Bubnoff (1922), Diener (1912), and Frech (1915), erroneously considered either *Baculites* or *Scaphites* to be benthonic. *Eutrephoceras* was probably nektonic, as is the living *Nautilus pompilius.*

Annelida.—Only one genus of worm is known from the Niobrara

Formation. Tubes of *Serpula* have been found attached to *Inoceramus shells*. Annelid worms occur in many types of environments and the presence of this particular worm cannot be considered indicative of any specific environment, until more information is available.

Echinodermata.—"The free-swimming crinoid *Uintacrinus* Grinnell (1876) has been found in the Upper Cretaceous rocks of England, Germany, and the Western Interior region of North America. Grinnell's (1876, p. 81) description was based on specimens from the Uinta Mountains of Utah and the Cretaceous of Kansas. The European example, *Uintracinus westphalicus* Schluter (1878), (Zittel, 1913, p. 236) occurs with *Marsupites* and *Bourgetcrinus*.

Neither *Marsupites* nor *Bourgeticrinus* has been found with *Uintacrinus* in Kansas. In Kansas, *Uintacrinus socialis* Grinnell normally occurs in great abundance in small areas. Some slabs of approximately 35 square feet have as many as 250 complete individuals represented.

Logan (1898, p. 483) described two *Uintacrinus* slabs, one of which exhibits specimens of adult size; the other has specimens of one-fourth that size and a few near-adult size specimens. The juvenile specimens on the slab mentioned by Logan measured 14 to 35 mm in diameter. In the fall of 1956 the author discovered a small crinoid slab on which the smallest individuals measured 35 mm. and the largest measured 65 mm in diameter. The diameters of the other calices formed a gradation between the two extremes, but most of them measured 55 mm or larger.

The limestone beds containing the crinoid calices are a coquina of crinoid fragments, and usually the slab is one-quarter to one inch thick. The complete calices are on the underside of the slabs when they are in place in the Niobrara Formation, and fragments form the remainder of the slabs.

The crinoidal coquinas are composed wholly of crinoid fragments; no other fossils are in the slabs, although one slab had several *Ostrea congesta* attached to its upper surface.

Bather (1895, p. 978) stated that a thin layer of carbonaceous material lines the calyx of fossil *Uintacrinus* specimens. Only 0.35% of the material composing slabs collected (from NE¼ SW¼ sec. 10, T. 14 S., R. 33 W., Harding Ranch, Logan County) are insoluble in hydrochloric acid; slabs from other localities have not been tested. The insoluble residue seems to be mostly organic matter; no mineral matter was detected." (Miller, Sternberg and Walker, 1957.)

If the crinoid accumulations represent groups gathered for breeding, it is difficult to explain the slabs of juvenile or immature specimens. On the other hand, it is unlikely that the slabs represent current-formed accumulations as they are limited in size (possibly a maximum size of 250 square feet), and are widely distributed through the Smoky Hill Chalk Member at various stratigraphic levels.

Antedon eschrichtii, the Recent feather star, occurs in large single species groups on the sea floor (Allee and Schmidt, 1951, p. 331). This phenomenon results from suppression of the free-swimming larva because of reduced fecundity under adverse living conditions. *Antedon* lives in areas of low temperature which cause reduced fecundity, an increased egg size and a longer period of incubation which results in suppression of the mobile larval form (Allee and Schmidt, 1951, p. 330). This allows parents and offspring to accumulate in large groups, and form large local accumulations of juvenile and adult crinoids on the sea floor. If *Uintacrinus* lived in similar intertwined planktonic groups we should expect to find (1) fossil remains of *Uintacrinus* in local accumulations, (2) juvenile to adult calyces in these accumulations and a lack of *Ostrea* or *Inoceramus* shells in the crinoid accumulations, as the larvae of the ostreids would have probably been warded off or eaten by the crinoids, and if the crinoids were prey of bottom-feeding pavement toothed fishes the accumulations should be characterized by abundant broken crinoid fragments. These conditions of preservation and association are present in the crinoid slabs described by Miller, Sternberg and Walker (1957, p. 163).

If the fecundity of *Uintracinus* was reduced (possibly by unfavorable physical factors) then it too would have had a suppressed larval form and would have tended to live in large planktonic groups.

It is probable that the *Uintacrinus* slabs composed of specimens smaller than the average may represent individuals stunted by an unfavorable environment, rather than an accumulation of juvenile individuals.

Arthropods.—Two genera of barnacles (*Squama, Stramentum*) and several genera of ostracodes have been found in the Niobrara Formation. The ostracodes (Richard Benson, personal communication) belong to genera that live today in shallow marine, water. All specimens of ostracodes reported from the Niobrara Formation to date, have been found in the Fort Hays Member. The barnacles are of the "gooseneck" group, are rather rare, and most specimens seem to be attached to shells of a large species of *Baculites.*

Fishes.—Many genera of fish have been found in the Niobrara Formation. Some were bottom feeders (*Ptychodus*), others such as *Xiphactinus,* were fast-swimming predators. The presence of bottom-feeding (or bottom-living) fish does not necessarily mean ideal substrate conditions for a varied fauna. Allee and Schmidt (1951, p. 23) state that fish enter water having a low-oxygen content more readily than water having a high carbon-dioxide content. The carbon-dioxide content of water is associated with acidity and affects animal distribution. The ability of fish to use oxygen (when present in small amounts) decreases with a greater acidity.

Reptiles.—The reptiles are all pelagic marine forms except *Claosaurus, Hierosaurus* and the pterosaurs. The two dinosaurs were probably washed out to sea after death. *Pteranodon* may have filled the ecologic niche held by the albatross today, and therefore formed a normal part of the off-shore fauna. The albatross makes use of the upward thrust of a wave and air currents deflected from the surface of the water when it takes off, so it is not necessary to flap its wings. *Pteranodon* may have used a similar method of becoming airborne, and once airborne it may, again like the albatross, have been a glider riding on thermal currents.

Clidastes was a surface-swimming type of mosasaur, *Platecarpus* was a deep-sea-dwelling form and *Tylosaurus* was probably the deepest diving form (Lane, 1947, p. 312). This denoted a stratification of feeding areas and ecologic niches, although all the genera were dependent on the surface for air.

The turtles (*Archelon* and *Protostega*) are similar to the Recent sea-turtles (such as *Chelone*) and undoubtedly filled the same ecologic niches that the loggerhead and green turtles do today.

Birds.—*Hesperornis* is a well-known nonflying form and apparently was a fast-swimming fish-eater like the modern loons and grebes. *Ichthyornis* was analogous to the Recent shore birds, and may represent shore birds of several different groups lumped together.

Summary of Faunal Evidence

The Niobrara Formation contains an abundance of fossil remains of pelagic and planktonic animals. The normal Cretaceous benthonic fauna is lacking. It seems probable that abnormal conditions (unfavorable for abundant life) were present in the benthonic zone.

Discussion of Physical Evidence

The faunal evidence indicates a shallow tropical or subtropical sea. Dunbar (1949, p. 379) postulates a mild climate during Late

Cretaceous time. Urey, and others (1951) state that the temperature of the Upper Cretaceous sea of the southeastern United States, as well as that of England and Denmark, was approximately 15° to 16° C. (60° F.). This determination was based on the relative abundance of the O^{18} isotope in $CaCO_3$. Intermediate depths in warm, shallow seas are usually low in oxygen because of poor vertical circulation. Such conditions in the Niobrara sea would have made only a limited amount of oxygen available to the benthos. Presumably there would have been no appreciable inflow of oxygenated deep currents from the polar regions into a shallow inland sea.

Most of the available oxygen would have been used in the process of putrefaction of organic matter falling down to the bottom from the zone of abundant pelagic and planktonic life. The lack of oxygen in benthonic areas resulted in a scanty bottom fauna, and local accumulations of pyrite crystals formed in areas where there was much decaying organic matter. Pyrite crystals are more abundant in the upper portion of the Smoky Hill Member. The abundance of organic matter colored the chalk gray. The general lack of bottom-living animals, including scavengers, permitted an excellent state of preservation for the vertebrate fossils, as the bones were not usually disrupted and scattered by scavengers.

The greater number of benthonic foraminifers and ostracodes in the Fort Hays Member indicated that although favorable conditions for benthonic life were probably present at the beginning of Niobrara (Fort Hays Member) sedimentation, conditions for benthonic life became less favorable with the beginning of Smoky Hill Member deposition.

Summary of Physical Evidence

The Niobrara sea during Smoky Hill Member deposition presumably was shallow, probably 40 meters deep, density stratified, marine, clear, relatively calm, and had slow sediment accumulation rates. The slow rate of sediment deposition was that characteristic of an area far off-shore, analogous to the open ocean. This would account for the fine-grain size of the clastics (clay minerals and fine-silt-sized quartz grains) and the open-sea character of the fauna.

The Fort Hays Member was probably deposited in a shallower sea, as the bottom sediments and *Inoceramus* were disrupted by currents or waves. Cross-bedding and uneven bedding are abundant in the Fort Hays Member.

At no time did the fouling or lack of oxygen result in an azoic bottom or the formation of black carbonaceous sediments. The lack of oxygen resulted only in a reduction of the bottom fauna.

COMPOSITION AND WEATHERING OF THE NIOBRARA FORMATION

Fort Hays Member Composition

Runnels and Dubins (1949, p. 17) made many analyses of chalk of the Fort Hays Member and discovered the calcium carbonate content ranges from 88 to 98.2 percent. There was no grain size variation in the chalk samples. The insoluble residue consisted of the heavy minerals, ilmenite, leucoxene, magnetite, tourmaline, zircon, muscovite, biotite, pyrite, limonite, and the light minerals, quartz, feldspar, chalcedony (chert), calcite and collophane (Runnels & Dubins, 1949, p. 10). Runnels and Dubins examined an electron micrograph of Fort Hays Member chalk grain and suggested that the grains may be minute rhombohedrons 0.2 to 0.55 microns in diameter.

The Fort Hays chalk is light colored and contains little organic matter. Organic matter, when present in chalk, colors it gray and is visible as a dark substance in the matrix in thin sections (Plate 7). The detrital mineral content of the Fort Hays Member is lower than that of the Smoky Hill Member.

Chemical analyses of the Fort Hays Member (Appendix A) show the member has less SiO_2 and more MnO_2 content than the Smoky Hill Member. The organic matter content (D. L. O. I., Differential loss on ignition, 105°/550° C.) is very low, when compared with the Smoky Hill Member, and the lighter color of the Fort Hays Member chalk is probably caused by a lack of organic matter.

Fort Hays Member Weathering

The Fort Hays Member is made of massive chalk beds with thin partings of shale. The massive chalk is resistant to erosion and forms prominent outcrops, especially where it caps hills or valley walls underlain by Carlile Shale. The Fort Hays Member tends to have a lower content of iron and sulfur (Table 3) than the Smoky Hill Member, therefore it presumably has a lower pyrite and marcasite content and is less likely to develop the yellow and orange hues than the weathered Smoky Hill chalk. Inasmuch as the Fort Hays Member has a low content of organic matter, and lacks iron sulfides, it does not undergo color changes caused by oxidation and loss of carbonaceous material during weathering.

Smoky Hill Member Composition

The Smoky Hill Member consists of calcite (major constituent), quartz (present in all samples), and varying amounts of montmorillonite, illite, kaolinite, and gypsum. Traces of chlorite? and dolomite? were also detected (x-ray analyses by Ada Swineford). No appreciable variations in composition were detected in the samples submitted for x-ray analyses (Ada Swineford, personal communication, January, 1958).

Chemical analyses furnished the author by Walter Hill show the $CaCO_3$ content varies from approximately 50 to 98 percent. The silica content varies from less than 1 (in the *Uintacrinus* limestone) to approximately 30 percent. Detailed chemical analyses are presented in Table 3 of Appendix A. The Smoky Hill Member tends to have no MnO_2 or a low MnO_2 content which contrasts with the Fort Hays Member. The gray chalk samples tend to have a higher content of organic matter than the brightly colored chalk. The gray chalk has from 1.78 to 5.59 percent of organic matter, with most samples (10 out of 12) having more than two percent. The brightly colored chalk samples have an organic matter content of 0.31 to 1.44 percent and the majority (4 out of 5) have less than one percent. Thin sections of the analyzed rocks show organic matter as a dark coloring material disseminated throughout the matrix of the slide (Plate 7). The thin sections of the brightly colored chalk have less visible disseminated organic matter. The thin sections of Fort Hays chalk have no visible organic matter.

Chalk samples were collected from six foot intervals up a 36 foot high bluff in north center, S½ sec. 25, T. 15 S., R. 33 W. The gray chalk at the base of the bluff becomes yellowish gray at about the 30 foot level and at the 36 foot level the chalk is yellow. The only consistent chemical change accompanying the color change is a reduction in the amount of organic matter from 2.83 to 3.56 percent at the base to 2.47 to 2.60 percent at the 30 foot level to 0.60 to 0.98 percent at the 36 foot level.

The calcite particles that form the groundmass of the thin sections appear to be rods or plates of ½ to 5 microns in length. Rezak and Burkholder (1958) state that coccoliths form a major portion (at least 80% in some samples) of the Niobrara Formation sediments. The coccoliths are small (about 10 microns) and require special techniques for study. It is likely the calcite rods and plates in the Kansas chalk are coccoliths. There is no correlation between calcite rod size and color of the chalk. However, some of the yellow chalk has a minor amount of recrystallized blobs of calcite of up to 15 microns diameter.

Coccoliths were first reported from the Niobrara Formation of Kansas by Dr. W. S. Brunn, who published a short statement in the Lawrence *Home Journal* in January, 1882. Williston (1890a, p. 249) again reported the presence of coccoliths in the chalk. G. M. Dawson (1890, p. 276) stated the "slender rods" reported by Williston may be rhabodoliths, and that coccoliths were abundant in the Niobrara Formation of Manitoba and Nebraska. Williston (1890b, p. 100) wrote that the chalk seemed to be composed wholly of coccoliths, rhabdoliths, foraminifers, and perhaps radiolarians and sponge spicules. Williston stated that the coccoliths were oval or circular bodies 1/3500 to 1/4500 inch diameter, and the rods (rhabdoliths) were 1/1000 to 1/2000 inch long. McClung (1898, p. 424) published illustrations of the coccoliths and rhabdoliths.

Calvin (1895, pp. 213-236) described the composition of the Niobraro Formation of Iowa. He stated that the chalk is composed of a matrix of coccoliths in which foraminiferal tests are embedded. Calvin stated the detrital content varied from one to ten percent.

Smoky Hill Member Weathering

The outcrop of the Smoky Hill Member consists of grayish chalk capped by brightly colored chalk (Figures 1 and 2). Subsurface sections of the Smoky Hill Member are entirely gray chalk. Samples from United Carbon No. 1 Wheeler sec. 21, T. 17 S., R. 41 W., Greeley County were examined and Smoky Hill Member chalk was recorded from 11 to 150 feet as yellow chalk and from 150 to 720 feet as gray chalk; Fort Hays Member (white) chalk was recorded from 720 to 770 feet. Samples from Shell No. 1 Hardin, sec. 24, T. 6 S., R. 40 W., Sherman County, were examined. Gray Smoky Hill Member chalk was recorded from 1310 to 1810 feet. White Fort Hays Member chalk was recorded from 1810 to 1850 feet. The Smoky Hill Member in Shell No. 1 Hardin is overlain by the Pierre Shale and the upper part is presumably unweathered as no cap of yellow chalk is present. The Smoky Hill Member in United Carbon No. 1 Wheeler is overlain by Ogallala Formation sands and the upper 40 feet are presumably weathered, yellow chalk.

Inasmuch as brightly colored Smoky Hill Member chalk extends across the entire outcrop area and always overlies gray chalk and the yellow chalk does not extend downdip, it seems that the brightly colored chalk is not a sedimentational feature, and must develop from the gray chalk after it is exposed. Williston (1897, p. 239) stated:

"It is strange that the division into chalk and shale beds should have been persistently adhered to by writers on the Kansas Cretaceous since the time of Mudge. As I have already said more than once there is no such geological distinction. As a usual thing the blue chalk and its weathered blue shales are found lower down in the valleys of the rivers or their tributaries, that is, where it is more or less saturated with water. Almost always borings for wells encounter the blue chalk, not white, or yellow. Furthermore, frequently one will observe the blue chalk changing to white and yellow as it passes outwards from the water courses, and this change may take place within a few yards distance. Pure white or yellow homogenous chalk may be traced through every foot of the entire thickness from the Fort Hays to the Fort Pierre. I trust the myth of chalk and shale beds will not be again repeated."

Nevertheless, subsequent authors have used the distinction of yellow chalk and gray shale beds when describing measured sections of the Smoky Hill Member.

It seems likely that the yellow chalk develops by weathering of gray chalk once it becomes exposed. Possibly, as Williston suggested, the gray chalk was preserved as such beneath the water table and turned to yellow chalk after the water table was lowered and exposed the gray chalk to weathering agents. The present contact of the gray and yellow chalk may represent an older water table which was lowered during Recent time as the Smoky Hill River system cut down into the valley it now occupies. The yellow chalk buried under the sediments of the Ogallala Formation may represent an older, weathered, outcrop. Weathering agents produce the bright colors by removal of organic matter and oxidation of pyrite to hydrous iron oxides that stain the surface of the outcropping chalk blocks.

PALEONTOLOGY

The synonymies are restricted to papers giving original descriptions or describing specimens from Kansas or to those papers affecting the taxonomy of Kansas specimens.

Phylum Mollusca

Class Pelecypoda

Order Filibranchia

Family Pernidae

Genus *Inoceramus* Sowerby, 1814

Type species: *Inoceramus cuvieri* Sowerby, 1822

Diagnosis

Inoceramus is characterized by a ligament area with many depressions containing resilifers arranged perpendicular to the hinge line (pernid hinge). There are no hinge teeth. The shell ranges from very thin (1mm or less) to thick (several centimeters) and is characterized by a prismatic structure. The surface of the shell may show concentric markings.

Discussion

The *Inoceramus* species of the Niobrara Formation of Kansas are of two general types (a), thick-shelled, convex forms, and (b), thin-shelled, flat forms. Group (a) includes *Inoceramus deformis* Meek and *Inoceramus grandis* Conrad. Group (b) includes *Inoceramus platinus* Logan.

Brown (1940) reported fossil pearls associated with the flat shelled inocerams of the Niobrara Formation of Kansas.

Inoceramus deformis Meek, 1871

Plate 4, Figs. 1, 2, 3

Inoceramus deformis Meek 1871. Ann. Rept. U. S. Geol. Surv. Terr. for 1870, p. 296. White 1876. U. S. Geol. & Geog. Survey West 100 Meridian, v. 4, p. 179, pl. 15, fig. 1 a, b. Meek 1877. U. S. Geol. Surv. Expl. 40th Parallel, v. 4, pt. 1, p. 146, pl. 14, fig. 4, 4a. Logan 1898. Univ. Kans. State Geol. Survey, v. 4, pt. 8, p. 486, pl. 92, fig. 2, pl. 96, figs. 1, 2.

Haploscapha capax Conrad 1874. Ann. Rept. U. S. Geol. Survey Terr. for 1873, p. 456.

Description

Meek (1877, p. 146) described *I. deformis* as, being of

"Large size, obliquely ovate, and rather compressed in young examples, but more rounded, gibbous and irregular and less oblique in adult specimens. More or less inequivalve, but never decidedly so, posterior and basal margins rounded; later curving up more gradually and obliquely to the short anterior margin; hinge short and usually not very oblique; beaks moderately prominent; and placed between middle and anterior margins, neither greatly more elevated than the other. Surface ornamentation with large strong concentric undulations, sometimes moderately regular, but often very irregular, becoming abruptly smaller on the umbones, where curves indicate greater obliquity of the young shell."

The valves are large (up to 7 inches in diameter), very convex, and marked by strong, concentric undulations that are generally parallel to the valve margin. The shell is thin (2 mm) on the main part of test, but becomes thicker (12 mm or more) along the hinge area. The shell is oval in outline, the beaks prominent, and the hinge line relatively short. The valves are probably nearly equal in size. Concentric markings cover the entire valve, and the valves are deformed, in that the valves have a step-like flexure.

Discussion

Meek's first use of *I. deformis* (1871, p. 296) was in a list of fossils from the Niobrara Formation of Colorado. Meek did not describe the specimen, but referred the reader to Hall's figure in Fremont's Report of Exploration of the Rocky Mountains (1845, p. 310, pl. 4, fig. 2). Hall's figured specimen resembles *Inoceramus deformis* closely in that the specimen is completely covered with concentric ridges and shows a well-developed "deformity." The specimen was incomplete and a small portion of the area near the beak was broken away. Hall (1845, p. 310) described his specimen as being inequivalved, and stated that his figured specimen was a (right) flat valve, and that it was associated with a fragment of a larger convex valve, that probably was the lower, or left valve. This portion of Hall's description does not agree with Meek's diagnosis of *I. deformis* and Meek (1877, p. 146) pointed this out. *I. deformis* was further described by White (1876, p. 179, pl. 15, fig. 1 a, b).

In his 1877 description Meek considered *I. deformis* to include Conrad's genus, *Haploscapha,* although Meek had not seen Conrad's specimens.

Meek (1877, p. 146) stated in part, *Inoceramus deformis* is "common in Kansas, and near Pueblo and Colorado City, as well as at other places along eastern base of Rocky Mountains, and farther west; everywhere in the Benton and Niobrara groups."

Haploscapha capax Conrad was apparently based on specimens of *Inoceramus deformis.* Conrad (1874, p. 456) referred to fig. 2 in Hall (1845, p. 310) as an illustration of his species. This is a specimen of *I. deformis.* Conrad's description is not sufficient to tell whether he is describing *I. deformis* or another species, therefore the species are synonymized.

Inoceramus deformis is confined to the Fort Hays Member of the Niobrara Formation in Kansas.

Several specimens are in the University of Kansas Geological Museum (KU 11392).

The specimens reported by Logan as *I. flaccidus* may be distorted specimens of *I. deformis* Meek.

Inoceramus grandis (Conrad) 1875

Plate 1, Figs. 1-12; Plate 2, Figs. 3-4

Haploscapha grandis Conrad 1875. U. S. Geol. Survey Terr., v. 2, p. 23, pl. 66. Logan 1898. Univ. Kans. State Geol. Survey, v. 4, pt. 8, p. 492, pl. 94.

Haploscapha niobrarensis Logan 1898. Univ. Kans. State Geol. Survey, v. 4, pt. 8, p. 493, pl. 116, fig. 2.

Haploscapha eccentrica Conrad 1875. U. S. Geol. Survy. Terr., v. 2, p. 24, pl. 67. Logan 1898. Univ. Kans. State Geo. Survey, v. 4, pt. 8, p. 494, pl. 93.

Inoceramus deformis Meek 1877. U. S. Geol. Geog. Expl. 40th Parallel, v. 4, pt. 1, p. 146 (in part). Stanton 1893. U. S. Geol. Surv. Bull., 106, pp. 85-86 (in part).

Inoceramus concentricus Logan 1898. Univ. Kans. State Geol. Survey, v. 4, pt. 8, p. 490, pl. 116, fig. 1 (not *I. concentricus* Parkinson).

Inoceramus pennatus Logan 1898. Univ. Kans. State Geol. Survey, v. 4, pt. 8, p. 488, pl. 118, fig. 2 (only).

Description

Inoceramus grandis is characterized by a convex, or flattened right valve and a relatively long hinge line. The beak is confined to the anterior portion of the hinge. The shell is ornamented with strong, concentric undulations occupying a well defined portion of the center of the valve. In some specimens the markings tend to be much weaker. Outside this area, the concentric markings are either very weak or absent. The shell becomes relatively thicker with increasing valve size.

The left valve is much larger, convex, ovate, and marked by prominent concentric ridges on the outer and inner surfaces near the beak. The beaks of both valves are of equal size, and are similarly ornamented.

Discussion

Conrad (1874, p. 456) stated in part: "The genus *Haploscapha* described in a former volume of these reports, is not, as I thought at the time, a member of the family Rudistae, but probably belongs to no recognized family." The author has been unable to discover any earlier, published description of *Haploscapha.*

Conrad's (1874) description of the type specimen of *H. capax* was not accompanied by an illustration. The figure Conrad referred to (Hall, 1845, pl. 4, fig. 2) was also referred to by Meek (1871, p. 296) in his description of *I. deformis.* Conrad seems to have described the same species as Meek. The use by Meek and Conrad of Hall's illustration in describing these two species undoubtedly led Stanton (1893, p. 85) and Meek (1877, p. 146) to combine *I. deformis* and the species of *Heploscapha.* Meek (1877, pl. 14, fig. 4, 4a) and Stanton (1893, pl. 14, fig. 1, pl. 15, fig. 1, 2) figured only specimens of *I. deformis.* They did not illustrate any specimens resembling *Haploscapha grandis. Inoceramus deformis* differs from *I. grandis* in that the concentric undulations cover the entire shell of *I. deformis,* the shell is relatively thinner, and the valves are relatively more convex, also the species (*I. deformis*) is restricted to the Fort Hays Member in Kansas. Hall's specimen came from a "light yellowish-grey limestone, probably of the cretaceous (sic) formation" in the Front Range area. Only *Inoceramus deformis* had been found in that region, at that time. Furthermore, *I. deformis* ranges into the basal Smoky Hill Member in the Front Range area (Scott and Cobban, 1964).

Inoceramus grandis ranges from the upper Fort Hays Member into the basal Smoky Hill Member of the Niobrara Formation. It occurs within the *Uintacrinus* Zone, and into the *Clioscaphites chouteauensis* Zone in Rooks County. The shells are much distorted and flattened during preservation. This, combined with the intraspecific variability of *Inoceramus grandis* has led to the description of many species.

This species has the typical pernid hinge line that characterizes *Inoceramus* and need not be considered a separate genus. The shell is large (more than 35 cm wide by 28 cm high), thick (to 1 cm), and subovate in outline. Only right valves have been previously described for this species. The left valves are usually larger, thinner, and less well preserved, and consequently are less collected and figured. The larger, cup-like left valve is on the bottom and the right valve is the lid. The left valves are usually crushed and fragmented during fossilization, and found as pieces inside or around the right valve. Right and left valves have been found associated in several specimens; FHKSC Museum 11959, 11885, 13032, 12028 and 11916. Specimen 11916 clearly has a partial left valve, that is less deep than the right valve. Specimen 11959 FHKSC Museum consists of cemented, fragmentary left and right valves, as does 12028. Seemingly the valves opened at death and both valves lay on the sea floor with the interiors upward. Pressure of overlying sediments usually fractured and flattened the more convex lower valves. Right valves are more abundant only in that complete specimens are more easily found. FHKSC Museum 11885 consists of a pair of large, fragmentary, attached valves, greatest preserved length along hinge line, 390 mm, and greatest height of preserved portion of lower valve 255 mm. The interior of the lower valve is deep and ornamented with shallow furrows extending away from the hinge line, and parallel to the valve margin. The upper valve is less deep, and the interior is ornamented with deeper furrows in the central portion of the valve. The upper valve is a right valve.

KU 10702 is a similar, large right valve.

FHKSC Museum 13032 consists of a well-preserved, typical right valve of *I. grandis,* attached along the hinge line to a left valve. The left valve is well preserved, and has a beak area similar to FHKSC Museum 11916. Away from the beak region, the left valve is similar to that of FHKSC Museum 11885, and is ornamented with shallow furrows.

Conrad (1874, pp. 455-456) discussed his genus *Haploscapha,* and stated that it was closely related to *Inoceramus involutus* Sowerby. *I. involutus* occurs from the base of the *Micraster cortestudinum* zone through the base of the *Micraster coranguinum* zone (Coniacian and Santonian stages) of England. This species is characterized by a larger, convex left valve, which is smooth, and a flat or slightly convex right valve, which has strong concentric markings (Woods 1912, pp. 7-11). The Kansas specimens of *I. grandis* differ from *I. involutus* in that the beak of *I. involutus* is more strongly developed and spirally curved on the left valve, and the left valve is relatively much larger. Furthermore, the left valve of *I. grandis* has strong concentric markings near the beak.

Cope (1875, p. 17) stated:

"Near Fort Hays, the best section may be seen at a point eighteen miles north, on the Saline River. Half way between this point and the fort, my friend N. Daniels, of Hays, guided me to a denuded tract, covered with the remains of huge shells described by Mr. Conrad, at the close of this section, under the names of *Haploscapha grandis* and *H. eccentrica.*"

These specimens presumably came from the area of T. 12 S., R. 18 W., an area in which the Fort Hays Member crops out. Logan (1898) seems to have considered the genus *Haploscapha* (*I. grandis*) as characteristic of, if not confined to, the Smoky Hill Member. Specimens of *I. grandis* are especially abundant in the lowermost Smoky Hill Member, just above the contact. The writer has discovered many specimens of *I. grandis* in the Fort Hays Member, near Kirwin Dam.

Inoceramus simpsoni Meek, 1860

Plate 4, Fig. 5

Inoceramus simpsoni Meek, 1860. Proc. Acad. Nat. Sci. Phil., p. 312.

Description

Several flattened casts. FHKSC Museum 11912 has a greatest preserved height of 100 mm and a greatest preserved width of 92 mm. The hinge is elongate and is well preserved on FHKSC Museum 11922, the greatest preserved length is 80 mm. This specimen is ornamented with regular, concentric undulations, some other specimens (FHKSC Museum 11893) have fine concentric lines in between the coarser ones.

Discussion

Logan reported this species in the Fort Hays Member, although he said that it was rare. No specimens identified as this species from the Fort Hays Member of Kansas are preserved in the University of Kansas collection. The type of *I. simpsoni* according to Meek (1860, p. 312) came from the "North Plat (sic) above the bridge, from the horizon of no. 2 or 3 of the Nebraska cretaceous (sic) series."

Specimen KU 4141 labelled "*I. simpsoni* Whitfield, Niobrara Formation, Cretaceous, Ellsworth County, Kansas," is apparently from the Fort Hays Member of Colorado (W. A. Cobban, personal communication July 31, 1958) as the lithology of the matrix is a compact, crypto-crystalline limestone and not a chalk. The specimen (KU 4141) is probably *Inoceramus inconstans* Woods.

The specimens in the Fort Hays College Museum came from northwestern Rooks County and were associated with *Clioscaphites chouteauensis* and a smooth *Baculites* sp.

Inoceramus flaccidus White, 1876

Not illustrated

Inoceramus flaccidus White 1876. U. S. Geog. and Geol. Surv. West of The 100th Meridian, v. 4, p. 187, pl. 16, fig. 1 a, b. Logan 1898. Univ. Kans. State Geol. Surv., v. 4, pt. 8, pp. 485-486, pl. 90.

Discussion

Inoceramus flaccidus White is confined to rocks of Turonian age (Carlile Shale) and can not reasonably be expected to occur in the Niobrara Formation.

Logan reported this species from the lower Smoky Hill Member in Kansas. There are no specimens identified as this species from the Niobrara Formation in the University of Kansas Geological

Museum, Logan's illustrated specimen appears to be an internal cast, probably it is a picture of White's type specimen.

Inoceramus platinus Logan

Plate 3, Figs. 1-4, Plate 4, Fig. 4

Inoceramus platinus Logan 1898. Univ. Kans. State Geol. Survey v. 4, pt. 8, p. 491.

Inoceramus subtriangulatus Logan 1898. Univ. Kans. State Geol. Survey v. 4, pt. 8, p. 488, pl. 120, fig. 1.

Inoceramus pennatus Logan 1898. Univ. Kans. State Geol. Survey v. 4, pt. 8, p. 488, pl. 129, fig. 2 (only).

Description

Logan described *I. platinus* as follows: "Shell large, thin, flat, oblong oval; hinge margin long, straight, smooth, marked by shallow pits or undulations." The size of an adult specimen was given as from 3 to 4 feet long (length of longer dimension) and from one and one-half to two feet in height. Logan did not define his usage of "length" and "height."

Inoceramus platinus is a large, flat, thin shelled species. The largest known specimens have heights and widths slightly in excess of 50 inches. The shell is very thin in the central portion of the valve (1 mm or less) and it thickens toward the hinge line. The hinge line is relatively long, straight, pernid, and the beak is subdued and confined to the (anterior) end of the hinge line. The interior of the valve is smooth, or marked by subdued concentric undulations. The exterior surface of the valve is marked by slight concentric undulations or ridges that seem to represent growth stages, rather than typical inoceram ornamentation.

Discussion

Inoceramus platinus was described by Logan, however, the specimen he figured for the illustration of the type is *Inoceramus subconvexus* Logan from the "Benton limestone" on Salt Creek, south Mitchell County, or near Ellsworth, Kansas. This (KU 5783) is the type specimen of *I. subconvexus* and was collected by Logan from one of the two previously mentioned localities. The type specimen of *Inoceramus platinus* Logan has never been illustrated. The type specimen is listed as KU 4204 in the catalog of the University of Kansas Geological Museum, and could not be located.

This species occurs throughout the Smoky Hill Member, and is especially abundant in the upper portion, however, the shell is very thin and fractures easily and complete or nearly complete specimens are very rare and are very difficult to collect. George F. Sternberg, formerly of the Fort Hays Kansas State College Museum has discovered and collected two well-preserved specimens of this species. They are the only complete specimens known at the present time. One is in the American Museum of Natural History, AMNH 18956, and is from Elkader, Logan County, Kansas. The specimen is 51.4 inches high and 49 inches wide. The second specimen is number 2086 of the Fort Hays Kansas State College Museum. This specimen came from "about 25 miles southwest of Oakley, Kansas, and 7 or 8 miles northwest of Elkader, Kansas," according to Sternberg. It is the better preserved of the two specimens and measures 35.5 inches high and 34 inches wide. The shell of either valve is 1 mm or less in thickness in the central portion.

Another specimen was discovered in NW¼ sec. 6, T. 15 S., R. 32 W. This specimen measured 54 inches wide by 50 inches high, and the shell material of the valve was less than 1 mm thick. However, it was too fractured to be removed from the chalk.

TABLE 2. Measurements of *Inoceramus platinus*, in inches.

Specimen	Height	Width	Remarks
Logan-Type?	18?	36?	Specimen not figured; measured in field?
Logan-Type?	24?	48?	Specimen not figured; measured in field?
AMNH 18956	51.4	49	Well preserved specimen
FHKSCM 2086	35.5	34	Best preserved specimen
H. W. Miller	50	54	Specimen measured in field, and not collected.
KU 10748	14	12	Specimen incomplete.

The measurements given in Table 2 indicate wide variation in the width to height ratio of *I. platinus*. However, the variation is not so great if Logan's measurements are ignored. Such a course can not be followed because measurements are included in Logan's description of the species. However, one must take into account that Logan did not have a complete specimen when he wrote his description, and that his only observations of complete, or nearly complete specimens were made in the field. His measurements may be in error.

Specimen KU 10748 (Tatsuro Matsumoto, personal communication) resembles the flat variety of *I. inconstans* Woods and is close to *I. amakusensis* Nagao and Matsumoto from Santonian rocks of Japan. *Inoceramus inconstans* Woods was described by Woods (1911, p. 285-293) as a variable species that ranged from the zone of *Holaster planus* to the zone of *Belemnitella mucronata* (Turonian to Maestrichtian). Woods (1912, p. 16) stated *I. inconstans* was probably derived from *I. labiatus* var. *latus*. Both these species (*I. labiatus* and *I. latus*) are present in Turonian ("Benton Group") rocks of Kansas. The flat variety of *I. inconstans* from the English Cretaceous is much smaller (height and width, approximately 65 mm) than *I. platinus*. If this variety of *I. inconstans* and *I. platinus* are synonymous, the name *I. platinus* has priority.

Logan stated that *Inoceramus truncatus* Logan was closely related to *I. platinus* and was confined to the lower Smoky Hill Member. This species may be a thicker shelled variety of *I. platinus*, however, it resembles the larger specimens referred to as *I. involutus* herein, and seems to lack the distinctive ornamentation of *I. platinus*.

The type specimen of *I. subtriangulatus* (KU 11262) is from Gove County. The specimen is a small, incomplete, thin-shelled valve. Logan's illustration (1898, pl. 120, fig. 1) is more complete than the type specimen, inasmuch as it shows the hinge line. The illustration shows a crack or fracture separating the hinge from the body of the valve, and presumably the hinge like portion of the type specimen has been lost.

The interior of the valve is exposed, the exterior of the valve is embedded in chalk matrix. The specimen may be a young valve of *Inoceramus platinus*.

Two specimens of *Inoceramus pennatus* were figured in Logan's original description. The specimen figured first (page preference) on plate 118, fig. 2, (KU 5785) is a specimen of *Inoceramus grandis* Conrad. The second specimen figured by Logan (pl. 120, fig. 2, KU 5784) is not complete or well preserved. It probably belongs to a thin-shelled species of *Inoceramus*, possibly *I. platinus*.

Inoceramus browni Cragin, 1889

Not illustrated

Inoceramus browni Cragin 1889. Cont. to the paleontology of the plains, Washburn Coll. Lab. Nat. Hist., Bull. 2, n. 1, pp. 65-68.

Discussion

Cragin's original description was not accompanied by an illustration and the species can not be recognized with certainty at this time. It may be synonymous with *Inoceramus deformis* Meek, however this can not be proved. The species is therefore referred to as a nomen nudum.

Inoceramus involutus Sowerby, 1828

Plate 2, Figs. 1-2, 5-6, Plate 9, Fig. 8.

Inoceramus involutus Sowerby, 1828. Min, conch., v. 6, p. 169, pl. 583, fig. 1-3.
Inoceramus truncatus Logan 1898. Univ. Kans. State Geol. Survey, v. 4, pt. 8, p. 492, pl. 114.

Description

Specimen 12032 in the FHKSC Museum, consists of a crushed and flattened lower valve with the upper valve still in place. The lower valve has a concentrically rugose and pitted outer surface, resembling Woods' figure (1912, p. 332, fig. 93). The upper valve seems to have a nearly smooth exterior, however, a portion of it has peeled backward and reveals a ridged interior resembling that of *I. grandis*. The upper valve is very thin (less than ½ mm). The umbo region of the lower valve is covered by *Ostrea congesta*. The shell of the lower valve is 2 mm thick. The greatest height of the crushed specimen is 120 mm. The lid has a greatest width of 75 mm, and a greatest (estimated) height of 60 mm.

Specimen FHKSC Museum 13031 is a flattened and fragmentary left valve, of a larger size than FHKSC Museum 12032.

Discussion

The species is apparently not abundant, however, right valves of *I. grandis* and those of *I. involutus* are somewhat similar, and some previously illustrated right valves of *I. grandis* or of *I. involutus* may be misidentified specimens. *I. truncatus* Logan may be a fragment of the left valve of a large *I. involutus*.

The type specimen of *I. truncatus* is incomplete, about 14 cm high by approximately 15 cm wide and consists of seven fragments glued together. There is no indication of a hinge line, and the margins of the shell are not present, although the right side of the specimen is close to the edge of the valve. The shell is from 8 to 12 mm thick, smooth on the interior surface and fine concentric growth lines and pits ornament the exterior surface of the valve.

Logan described *Inoceramus truncatus* from a fragment of what is apparently a large, flattened, thick-shelled *Inoceramus* (type specimen, KU 5782, from Saline River, north of Ellis). Logan remarked that this species reached a "height" of one to one and one-half feet and has a "longer axis" of three feet.

The author has discovered more fragmentary specimens of *Inoceramus* that resemble *I. truncatus*, and they are indistinguishable from *I. involutus*. The species occurs in the lower Smoky Hill Member.

Family Ostreidae

Genus *Ostrea* Linnaeus, 1758

Type species: *Ostrea edulis* Linnaeus

Diagnosis

The genus *Ostrea* includes those pelecypods with a single, large, muscle scar in the center of the shell, asymmetrical valves, no hinge teeth and a ligament contained in a resilifer-like depression. The left valve is lowermost and normally is attached to some foreign object during life. The right valve forms a lid, although it tends to be the same size and shape as the left valve.

Discussion

The genus *Pseudoperna* Logan, 1899, is considered to be synonymous with *Ostrea* Linnaeus, 1758.

Ostrea congesta Conrad, 1843

Plate 2, Figs. 7, 8

Ostrea congesta Conrad 1843. Nicollet's Rept. of Explor. in Northwest, p. 167. Logan 1898. Univ. Kans. Geol. Surv., v. 4, pt. 8, p. 444, pl. 99, fig. 10, 11, 13.

Description

Ostrea congesta is attached by the flattened surface of the left valve. The shell is small, up to 30 mm in height by 20 mm in width, and thin (less than 1 mm). The shells grew attached to the larger shells of *Inoceramus,* or even to other shells of *O. congesta*, and they tend to form masses. As a result of crowding of the shells, most of them are deformed and do not have a definite symmetry of outline.

The left (lower valve) is cup-shaped and has a flattened area of attachment on the bottom. The upper or right valve is flattened, lid-like, and is smaller than the lower valve. The lower valve forms a cup in which the upper valve sits. The valves have a symmetrical, oval outline, if they grow where they are not crowded.

Discussion

Several excellent specimens of *Ostrea congesta* Conrad are preserved in the University of Kansas Geological Museum, KU 11395. The species ranges throughout the Niobrara Formation.

Ostrea falcata Morton, 1830

Plate 2, Figs. 10, 11

Ostrea falcata Morton 1830. Jour. Acad. Nat. Sci. Phila., 1st. ser., v. 6, p. 50, pl. 1, fig. 2.

Ostrea (*Alectryonia*) *larva* Lamarck: Logan 1898. Univ. Kans. State Geol. Surv., v. 4, p. 485.

Description

The following description is taken from Logan's paper. The shell is 30 mm long, 10 mm wide and deeply crenulate along the posterior side. The deepest crenulation stands 5 mm above the shell. The shell is subelliptical in outline. The hinge line is short, almost straight and is tangential to the rounded back. The margins of the shells interlock along the crenulations. The Fort Hays College Museum has one specimen, FHKSC 11960, that consists of both valves, has a greatest length of 29 mm and a greatest width of 15 mm. The shell has seven major crenulations.

Discussion

Logan described but did not figure any specimens of this species of oyster from the Niobrara Formation of Kansas. Logan stated that all three of the species into which Morton divided *O. larva* (*O. falcata, O. mesenterica,* and *O. nasuta*) were represented in the University of Kansas collections. According to him, the species occurs throughout the Smoky Hill Member, but it is not abundant. The catalog lists KU 4112 as *O. larva,* from the Niobrara Formation of western Kansas. The specimen can not be located. FHKSC Museum specimen 11960 came from three miles northeast of Elkader.

Ostrea exogyroides Logan, 1899

Plate 5, Figs. 6-11

Ostrea exogyroides Logan 1899. Kans. Univ. Quart., v. 8, n. 2, p. 91, pl. 20, fig. 3.

Ostrea incurva Logan 1899. Kans. Univ. Quart., v. 8, n. 2, p. 92, pl. 22, figs. 1, 3, 5, 6.

Ostrea attenuata Logan 1899. Kans. Univ. Quart., v. 8, n. 2, p. 93, pl. 22, figs. 2, 4.

Ostrea crenula Logan 1899. Kans. Univ. Quart., v. 8, n. 2, p. 93, pl. 21, figs. 7, 8, 9.

Ostrea lata Logan 1899. Kans. Univ. Quart., v. 8, n. 2, p. 94, pl. 22, fig. 7, 8, 9, 10.

Ostrea leeii Logan 1889. Kans. Univ. Quart., v. 8, n. 2, p. 94, pl. 21, figs. 10, 11.

Ostrea jewellensis Logan 1899. Kans. Univ. Quart., v. 8, n. 2, p. 95, pl. 22, fig. 11.

Description

Small, nearly *Gryphaea*-like to plumose oysters. Maximum length of 18 examined specimens 35 mm, and greatest width 25 mm. The lower valve is convex and deep. The inside of the valve is smooth, the exterior may bear weak costae or be smooth. The beak is nearly coiled in some specimens. The upper valve is flat.

Discussion

The type specimens of Logan's oysters could not be located. They may have been in the Chicago Museum of Natural History. Specimens in the Fort Hays College Museum (FHKSC 11983) show the extreme variations described by Logan as distinct species. I consider this to be merely intraspecific variation.

Ostrea rugosa (Logan), 1899

Plate 5, figs. 12, 15

Pseudoperna rugosa Logan 1899. Kans. Univ. Quart., v. 8, n. 2, p. 96, pl. 23, fig. 1, 2, 3, 4, 5.

Pseudoperna torta Logan 1899. Kans. Univ. Quart., v. 8, n. 2, p. 96, pl. 23, figs. 6, 7.

Pseudoperna attenuata Logan 1899. Kans. Univ. Quart., v. 8, n. 2, p. 97, pl. 23, figs. 8, 9.

Pseudoperna orbicularis Logan 1899. Kans. Univ. Quart., v. 8, n. 2, p. 97, pl. 23, figs. 10, 11.

Description

Oval oyster with deep, cup-like lower valve and flattened upper valve. The lower valve may be smooth or costate. The beak is flattened. The borders of the valves are usually crenulate, and may be cancellate. Valve height is as much as 50 mm, and maximum valve width is 35 mm.

Discussion

Logan's type specimens could not be located. The Fort Hays College Museum has three upper valves (FHKSC 11911-3) that belong to this species, and the University of Kansas Geological Museum has a lower valve (KU 7107) that may belong to this species.

Family Pteriidae
Genus *Pteria* Scopoli, 1777
Type species *Mytilus hirundo* Linnaeus

Diagnosis

Valves inequivalved, oblique, and inequilateral. Left valve is more convex. Long, straight hinge line. Winglike ears, byssal sinus under right anterior ear. Single adductor muscle in adults.

Pteria cf. *P. petrosa* (Conrad)

Plate 2, Fig. 9

Pteria petrosa (Conrad) 1853. Jour. Acad. Nat. Sci. Phila., 2d. ser., v. 2, p. 274, pl. 24, fig. 15.

Description

A crushed and partially preserved left valve. Length of hinge 35 mm, greatest width 40 mm, and greatest preserved height 30 mm. The anterior ear is distinctly separated from the body of the valve.

Discussion

The specimen is unlike *P. gastrodes* in that the hinge line is shorter than the greatest width of the shell. Furthermore, it is unlike *P. linguaformis* in that the anterior ear is distinct. In general form and outline it is most like *Pteria petrosa* from the Upper Cretaceous of the Atlantic and Gulf Coastal Plains. The specimen is FHKSC Museum 11919, and came from the *Clioscaphites chouteauensis* zone of northwestern Rooks County.

Family Pectinidae

Genus *Pecten* Osbec, 1765

Type species *Pecten adscenionis*

Diagnosis

Inequivalved shells, straight hinge, well developed ears, byssal notch on right valve tends to separate ear from main portion of shell. Triangular resilium in middle of hinge, single adductor muscle.

Pecten bonneri new species

Plate 2, Figs. 12-14; Plate 5, Fig. 13

Description

Both valves of a nearly smooth form, ornamented with fine, concentric growth lines. The valves are slightly crushed and oval in outline. The byssal notch is well defined. A ctenolium is present and shows that the adult was attached by a byssus. The posterior sinus is poorly developed. The greatest preserved height of the right valve is 46 mm, the hinge is 27.5 mm long. The greatest preserved height of the left valve is 47 mm and the hinge is 27.5 mm long.

Discussion

The specimen is FHKSC Museum number 11908-2, and was discovered by M. C. Bonner three miles south of Russell Springs in SW¼ sec. 36, T. 13 S., R. 35 W. Thin-shelled Pectens are considered to be inhabitants of calm water, although this species was probably planktonic, and lived attached to floating objects. This *Pecten* belongs in the subgenus *Camptonectes*. It differs from *P. simplicius* in that *P. bonneri* has a more distinct right anterior auricle and byssal notch. *P. bonneri* lacks the radial lines of *P. conradi*, and also differs from *P. burlingtonensis* in that it (*P. bonneri*) is more elongate and the greatest width of the valves extends beyond the extent of the hinge line. *P. bonneri* lacks the fine radiating striae of *P. platesea.*

Suborder Heterondonta
Family Lucinidae
Genus *Lucina* Bruguiere 1797
Type species: *Lucina pensylvanica* Linnaeus

Diagnosis

Obicular valves that are laterally compressed with small cardinal teeth, and well developed lateral teeth.

Lucina sp.

Plate 5, Figs. 5, 14

Description

Flattened impressions, greatest height 17 mm, and greatest width 19 mm. The surface is ornamented with fine concentric lines. The hinge does not show. The beak points to the anterior noticeably.

Discussion

The specimen figured is FHKSC Museum 11909 and came from the *Clioscaphites chouteauensis* zone in northwestern Rooks County. Most specimens come from a lower zone characterized by the presence of a smooth, small, *Baculites* sp.

Family Radiolitidae
Genus *Durania* Douville, 1908
Type species: *Biradiolites cornupastoria* Desmoulins, 1826

Diagnosis

The cells composing the shell have polygonal outlines, no true pillars are present, the right valve is smooth inside. Pseudopillars are present, but are not abundant, the oscules of the right valve are opposite the pseudopillars. A ligament is present, although it may be reduced.

Durania maxima (Logan), 1898

Plate 4, Figs. 6, 7, 8

Radiolites maximus Logan 1898. Univ. Kans. State Geol. Surv., v. 4, pt. 8, pp. 494-495, pls. 115, 119, fig. 1.

Description

The right valve is usually flattened and broad and the walls are usually thick. The diameter of the valves is variable. The diameter of the body cavity varies from about 6 centimeters to 10 centimeters. The wall thickness measurements vary from approximately 15 cm to approximately 30 cm. Logan (1898, p. 494) recorded specimens of up to three or four feet in height. The great majority of the specimens examined were much smaller than this. No left valves have been discovered to date.

The exterior of the right valve is marked by rounded, cancellate, longitudinal striations. The apical angle may vary widely, from approximately 80° to approximately 45°.

The wall cells are polygonal (and one mm in diameter) and mostly lack any definite arrangement, however, there is an outward flexion of the cells of the wall, about 15 mm wide, which resembles a pseudopillar.

The funnel plates are nearly horizontal and are crossed by vascular markings, some of which branch.

Discussion

Durania maxima was considered by Logan (1898, p. 495) to be confined to the lower Smoky Hill Member, and possibly to occur in the upper part of the Fort Hays Member. However, specimen KU 4196, is listed as coming from Wallace County (Mudge collection), specimen FHKSC Museum 10336 is from Gove County, and specimen KU 4078 is from Logan County. Specimen FHKSC Museum 4092 was collected by Mr. Sternberg in sec. 24, T. 13 S., R. 28 W., Gove County, which is in the lower half of the Smoky Hill Member. This would extend the range of the species throughout the whole of the Smoky Hill Member.

Specimens of *D. maxima* that grew in close association with other members of the species tended to become more elongate, and have a relatively thinner wall, with respect to the size of the body cavity. Therefore, the variation of the specimens of *Durania* is probably ecologic and not of taxonomic value. Zapfe (1937) demonstrated similar shape variations of *Hippurites,* that were caused by crowding.

The type specimen is KU 4201 from Trego and Ellis counties.

Suborder Adapeodonta
Family Pholadidae
Genus *Parapholas* Conrad, 1848
Type species: *Parapholas californica* Conrad

Diagnosis

Conrad's original description reads:

"Shell pholas-like; accessory valves two, nearly similar in form, elongated; one extending from the umbo to the posterior extremity; the other united to the base; hinge plate thick; adductor muscular impressions greatly elongated."

Parapholas sphenoideus White, 1876

Not illustrated

Turnus sphenoideus White 1876. Geol. Uinta Mtns., p. 117.

Parapholas sphenoideus (White) 1879. Ann. Rept. U. S. Geol. Surv., for 1877, pp. 300-302, pl. 5, fig. 1 a-d. Logan 1898. Univ. Kans. Geol. Surv., v. 4, pt. 8, p. 495, pl. 94, fig. 12.

Discussion

Logan reported this species from either the Fort Hays Member or the lower Smoky Hill Member. Logan's revised description was quoted from White (1879, p. 300-301), and Logan's illustrations are copies of White's (1879, pl. 5, fig. 1 a-d) illustrations of the type specimen. Logan (1898, p. 497) stated in part, "A piece of fossil wood collected from the Niobrara beds near Hays City contains the casts of forms very similar in general character to the above-described species" (*P. sphenoideus*). Logan neither described nor figured the Niobrara specimens. Logan's specimens may be in the University of Kansas Geological Museum, as there is an unnumbered, unlabelled *Pholas?* in the Logan collection, Plate 9, fig. 6. No specimens have been found in recent collections, although fragments of fossil wood, bored by mollusc shells of unknown identity have been discovered in the Fort Hays Member.

Class Cephalopoda
Order Nautiloidea
Family Nautilidae
Genus *Eutrephoceras* Hyatt, 1894

Type species: *Eutrephoceras dekayi* Morton, 1833

Diagnosis

Eutrephoceras include those nautiloids with a nautilicone shell and nearly straight suture lines. The shell is smooth, subglobose, has a small umbilicus and a large hyponomic sinus. The siphon is small, orthochoanitic; its position varies but is never marginal.

Eutrephoceras sp.

Plate 6, Figs. 6, 7

Eutrephoceras sp. Morrow 1935. Jour. Paleontology, v. 9, n. 6, pp. 463-73.

Discussion

The genus *Eutrephoceras* is represented by a single, incomplete specimen from the Smoky Hill Member in NE¼ sec. 2 T. 3 S., R. 20 W. Phillips County, Kansas. The specimen is poorly preserved and can not be specifically identified. Morrow (1935, p. 473) stated in part: "The septa are not preserved and the specimen is of value only in showing the presence of this nautiloid in the Kansas area."

Nautiloids are rare fossils in the Niobrara Formation of Kansas and have been reported previously only by Morrow (1935, p. 473).

Order Ammononidea
Suborder Lytoceratina
Superfamily Turrilitacea
Family Baculitidae
Genus *Baculites* Lamarck, 1799
Type species: *Baculites vertebralis* DeFrance, 1830

Diagnosis

The initial stage of *Baculites* is small and consists of one or two closely coiled whorls; with further growth the shell becomes uncoiled and has the form of a lituiticone. The cross section of shell may be oval, circular, constricted, or compressed. The surface may be smooth or it may have rounded or arcuate ribs; the ribs may form nodes or tubercles on the sides. The suture is bifid, except for internal lobes.

Baculites sp. cf. *B. codyensis* Reeside

Plate 6, Figs. 8, 9; Plate 9, Fig. 1

Baculites codyensis Reeside 1927. USGS. Prof. Paper 150A, p. 4, pl. 2, figs. 6-19.

Baculites sp. Morrow 1935. Jour. Paleontology, v. 9, n. 6, pp. 463-73.

Description

One specimen (KU 11403) from sec. 34, T. 14 S., R. 31 W. has a width of 22 mm across the chambered portion of the shell, however, the shell is flattened. The chambered portion bears indistinct, rounded nodes. An indistinct suture line is present at the forward end of the specimen.

Two specimens from the *Clioscaphites chouteauensis* zone of northwestern Rooks County. The smaller specimen (FHKSC Museum 12032) has a greatest width of 16 mm and a greatest preserved length of 90 mm. Arcuate nodes are spaced 10 mm. apart, measured crest to crest. The larger specimen (FHKSC Museum 12031) has a greatest width of 19 mm and a greatest preserved length of 90 mm. It has similar nodes with an identical spacing.

W. A. Cobban (personal communication, April 21, 1958) wrote in part:

"The baculite, KU 11403 from the chalk monuments in secs. 33 and 34, T. 14 S., R. 31W., Gove County, Kansas, resembles a late form of *B. codyensis* Reeside of early Santonian age. *Baculites* of this type are common in the *Clioscaphites vermiformis* zone of the Cody shale of Wyoming, the Colorado shale of Montana.—The Kansas specimen also could pass for an immature *B. haresi* Reeside of late Santonian or early Campanian age."

The specimens are too poorly preserved to warrant accurate specific identification. Morrow (1935, p. 473) discussed this specimen and noted its resemblance to *B. ovatus*. This species is found in the Pierre Shale and Telegraph Creek Formation and is much larger than the Niobrara specimen.

Ammonites are very rare fossils in the Niobrara Formation of Kansas. Williston (1897, p. 242) stated:

"Of the cephalopods, ammonites occur, though rarely and almost always only impressions are found, with but little of the shell substance. Once or twice I have seen such impressions a foot in diameter."

Mr. George F. Sternberg, formerly of Fort Hays Kansas State College Museum (personal communication) told the author he had discovered a few impressions of ammonites in the chalk, but he had never attempted to collect any of the impressions. Neither Williston (1897) nor Logan (1898) described or figured any of the ammonites Williston discovered in the Niobrara Formation. Morrow's (1935, pl. 53, figs. 1, 7) paper has the only previously described and illustrated ammonites from the Niobrara Formation of Kansas.

Baculites sp.

Plate 6, Fig. 10; Plate 9, Fig. 3

Description

Several specimens of a smooth *Baculites* sp. are associated with *Clioscaphites chouteauensis*. FHKSC Museum 1188-2 has a greatest preserved length of 265 mm and a flattened width of 21 to 27 mm. The widest specimen FHKSC Museum 11915 has a flattened width of 31 mm.

Another specimen was discovered in SW¼ sec. 34, T. 14 S., R. 31 W. This specimen is much flattened, shows no suture lines, and no nodes. The specimen is 21 mm across at its smaller end and 29 mm across at its larger end. The greatest preserved length of the specimen is 122 mm. The specimen is preserved in the University of Kansas Geological Museum, no collection number.

Discussion

The *Baculites* seem to be similar to those described by Scott and Cobban (1964) from the *Clioscaphites chouteauensis* zone and associated with *Inoceramus simpsoni* in the overlying bed.

Some of the *Baculites* have small oysters attached. No barnacles are present on the specimens from this zone. The specimens came from northwestern Rooks County.

Baculites sp.

Not illustrated

Description

Three specimens of what may be a smaller species of smooth *Baculites*. The smallest specimen (FHKSC Museum 12033) has a greatest width of 9 mm and a greatest preserved length of 35 mm. Another specimen (FHKSC Museum 12034) as a greatest width of 13 mm and a greatest preserved length of 50 mm. The largest specimen (FHKSC Museum 12035) has a greatest width of 20 mm. All the specimens are flattened.

Discussion

The specimens came from a zone characterized by abundant *Lucina*, and from below the *Clioscaphites chouteauensis* zone in northwestern Rooks County. The specimens are poorly preserved and are not figured.

Baculites? sp.

Plate 6, Fig. 11; Plate 9, Fig. 2

Description

Four specimens of large *Baculites?* sp. are preserved in the University of Kansas Geological Museum. Specimen KU 11405 is labeled "*Stramentum haworthi*, Cretaceous, Kansas." It consists of a flattened, sutureless chamber, 62 to 55 mm in width and 220 mm long. The test is smooth and several barnacles are attached to it. Both ends of the specimen are sawed off.

Specimen KU 7294 consists of two fragmentary *Baculites?* to which the metatypes of *Stramentum haworthi* Williston are attached. The *Baculites?* are 45 and 46 mm wide and are smooth. Some fragments of shell are present, and they may be a portion of the *Baculites?* test. The specimens from "near Gove City, Kansas," were collected by Haworth.

A fourth specimen has a greatest width of 43 mm and is 110 mm long, and both ends are broken away. The specimen has no collection number and no locality information. Two specimens of *Ostrea congesta* Conrad are attached to its surface.

Discussion

A similar *Baculites?* sp. occurs in the Niobrara Formation of Colorado near Denver (W. A. Cobban, personal communication). The specimens are large fragments (a foot or more in length and up to 60 mm wide), smooth-shelled, and are characterized by the presence of a *Sciponoceras*-like aperture. This feature makes their identification as *Baculites* questionable. They occur well above the *Clioscaphites vermiformis* zone in rocks that may be of Campanian age (W. A. Cobban, personal communication). The colorado specimens seem to be confined to a thin bed in the upper Smoky Hill Member. Scott and Cobban (1964, p. 5) refer similar *Stramentum* bearing *Baculites* to the Campanian.

None of the Kansas specimens are complete, and none of the specimens have the aperture preserved. One of the Kansas specimens (KU 7294) came from near Gove City. The other specimens, KKU 11405 and KU no number, have no locality information.

Superfamily Scaphitacea
Family Scaphitidae
Subfamily Scaphitinae
Genus *Scaphites* Parkinson, 1811

Type species: *Scaphites aequalis* Sowerby, 1813

Diagnosis

The test consists of a coil of septate whorls and the living chamber (last in adult state) is partly uncoiled. The umbilicus is small. The sculpture consists of straight ribs beginning in the umbilicus and increasing in height toward the margin of the venter. At this position the ribs split into two or more ventral ribs. There may be intercalated ventral ribs. The lobes of the suture are normally bifid in the adult stages.

Scaphites? sp.

Plate 8, Fig. 10

Discussion

A small fragment of the outer whorl of an ammonite is preserved in an old collection of the University of Kansas Geological Museum (no number). The specimen is from near Pyramid Rocks and came from the Smoky Hill Member. The specimen cannot be located at the present time and probably has been lost. It consists of a chalk impression of an external cast. The specimen shows no suture line and is incomplete. Smooth *Baculites,* similar to those from the *Clioscaphites chouteauensis* zone occur with the *Scaphites?; B.* sp. cf. *B. codyensis* (KU 11403) also came from the same locality.

A picture of the specimen was sent to W. A. Cobban and he (personal communication, June 10, 1958) stated in part:

"The ammonite shown in the photograph is a scaphite. It is part of an adult. The close coiling of the body chamber around the septate coil suggests *Clioscaphites* or its immediate ancestor *Scaphites depressus* Reeside (see Prof. Paper 239, pl. 13, fig. 6; pl. 15, figs. 1, 7). Your specimen is not as tightly coiled nor as densely ribbed as *Clioscaphites montanensis* (pl. 16). The degree of coiling and ribbing most closely resembles that of *S. depressus.*"

The references cited are in Cobban, 1952.

A fragmentary specimen, similar to the illustrated one, is in the Fort Hays Kansas State College Museum (13041-3). The specimen came from the upper part of the Pyramid Rocks.

Scaphites depressus occurs in rocks of middle and late Niobrara age (Cobban, 1952, p. 11).

Genus *Clioscaphites* Cobban, 1952

Type species: *Clioscaphites montanense* Cobban, 1952

Diagnosis

The genus is characterized by close coiling, in which the dorsal portion of the living chamber of the adult shell is in contact with the septate portion of the shell. The suture is trifid or asymmetrically bifid in the first lateral lobe.

Clioscaphites vermiformis Meek and Hayden, 1862

Not illustrated

Scaphites vermiformis Meek and Hayden 1862. Acad. Nat. Sci. Phila., v. 14, p. 22. Morrow 1931, unpublished M. S. thesis, Univ. Kans., p. 47, pl. 5, fig. 5.

Clioscaphites vermiformis Meek and Hayden. Cobban 1952. U. S. Geol. Surv. Prof. Paper 239, p. 35, pl. 18, fig. 7-27.

Description

The species is characterized by the closely coiled shell, a curved living chamber, the presence of a row of ventrolateral tubercles, and the presence of trifid lobes in the suture pattern.

Discussion

A single specimen referred to this species was figured by A. L. Morrow in his master's thesis. The specimen has been lost and cannot be located at the present time. The specimen consisted of a fragment of the outer whorl and clearly displayed the ventrolateral tubercles. It was discovered in the Smoky Hill Member in the vicinity of Monument Rocks in western Gove County (in T. 14 S., R. 31 W.). Morrow mistakenly ascribed the location of "Monument Rocks" or "Pyramid Rocks" to Trego County.

The species is indicative of Santonian age and occurs in the Niobrara Formation and equivalent rocks elsewhere in the Western Interior.

Clioscaphites chouteauensis Cobban

Plate 6, Figs. 4-5; Plate 9, Fig. 9

Clioscaphites? chouteauensis Cobban 1952. U. S. Geol. Survey Prof. Paper 239, p. 38, pl. 20, figs. 8-11.

Description

Flattened molds and casts in chalk. Preservation of details is excellent. The greatest height of flattened casts is 65 mm. Secondary ribs are present and abundant, and the costae are dense and fine near the aperture.

Discussion

The specimens are associated with smooth *Baculites* and *Inoceramus* spp. in a thin fossiliferous zone in northwestern Rooks County. The Fort Hays College Museum (FHKSC 11897 to 11900) has many specimens. They are preserved as flattened impressions in chalk.

Suborder Ammonitina
Superfamily Acanthoceratidae
Family Collignoniceratidae
Subfamily Texanitinae
Genus *Bevahites* Collignon, 1948

Type species: *Bevahites quadratus* Collignon, 1948

Diagnosis

Bevahites is characterized by a squarish to compressed whorl cross section. The ventrolateral tubercles are paired and close together. There may be more lateral tubercles than umbilical tubercles, because many intercalated ribs, which do not extend to the umbilicus, may occur. The previously known range of this genus was late Santonian to middle Campanian of Zululand, Madagascar, and Texas.

Bevahites? sp. A

Plate 6, Fig. 1

Pachydiscidae? Morrow 1935. Jour. Paleontology, v. 9, n. 6, pp. 463-73.

Description

The specimen has coarse strong ribs originating from umbilical nodes and the ribs become rounded nodes at the ventrolateral margin of the shell. Shorter ribs between the longer ribs, are either paired or single, have a ventrolateral node, but do not extend to the umbilical margin. The inner whorls are ornamented with coarse umbilical nodes and ribs. The complete specimen has a diameter of approximately 60 centimeters. The venter is indistinct on the cast; however, ventrolateral tubercles seem to be present.

Discussion

The Niobrara specimen is very large, but, it shows some features in common with the Pachydiscidae. The specimen is a plaster cast made in an external mold found impressed in the chalk; hence no suture lines are preserved in the specimen. W. A. Cobban (personal communication, April 2, 1958) stated that the specimen resembled *Bevahites*. The author concurs with this provisional assignment of the specimen. *Bevahites* had not previously been reported from the United States at that time. It has been found in late Santonian to middle Campanian rocks of Madagascar and Zululand. The Kansas specimen is larger than other previously described species, more than twice their diameter. However, many features that characterize the genus *Bevahites* seem to be present. The relative age of the Kansas specimen cannot be determined precisely. The specimen resembles *Bevahites costatus* Collignon closely, and may belong to that species. *B. costatus* occurs in early Campanian rocks of Madagascar.

The specimen was discovered by A. L. Morrow in NW¼ sec. 15, T. 15 S., R. 32 W., Logan County. Morrow considered the specimen to be closely related to *Pachydiscus*, probably an undescribed genus.

Bevahites? sp. B

Plate 6, Figs. 2, 3

Description

A large flattened, fragmentary outer whorl. The paired ventrolateral tubercles are close together. There are no visible lateral tubercles. The ribs are straight, and only primary ribs are apparent. The specimen consists of two fragments, the larger has a greatest preserved length of 195 mm, and a greatest width of 100 mm. The smaller fragment has a greatest preserved length of 185 mm and a greatest width of 100 mm. The whorl cross section is unknown. The shell is partly covered by small oysters. The ribs are about 20 mm. apart, measured crest to crest. No umbilical tubercles can be seen, the umbilical region may be obscured or partially broken away.

Discussion

The specimen came from the *Clioscaphites chouteauensis* zone of northwestern Rooks County and is therefore of late Santonian age. The Rooks County specimen differs from the specimen found by Morrow, in that my specimen lacks secondary ribs and may lack umbilical nodes. The specimen is FHKSC Museum 12029-2.

APTYCHI

At least three "genera" of bivalved aptychi occur in the Niobrara Formation of Kansas. Aptychi are generally considered to be the opercula of ammonoids, however, only a few aptychi are known to definitely belong to established genera of ammonoids. The associations of the Niobrara "genera" is not known. The Niobrara "genera" are true aptychi, in that they consist of paired, calcareous plates. In accordance with the Treatise of Paleontology, aptychus names ars not italicized.

Spinaptychus Trauth, 1927

Type species: Spinaptychus spinosus Cox, 1926

Diagnosis

The genus Spinaptychus is characterized by the presence of perforated tubercles on the exterior surface of the shell. The shell is thin and has growth lines and folds on its interior surface. The shells are bivalved. The type species, and the only other known species, occur in Santonian rocks of England, and Campanian? rocks of Palestine, respectively.

Discussion

Fischer and Fay (1953) described a new species of aptychus from the Smoky Hill Member, which they assumed to belong to a member of the Texanitinae. The specimen of *Texanites* referred to by Fischer and Fay (1953, p. 90), "The University of Kansas collections contain a *Texanites* from the Niobrara Formation of Trego and Ellis Counties Kansas," is not from the Niobrara Formation, as its lithology is that of a hard limestone and not the Niobrara Formation chalk. Presumably Fischer and Fay were not referring to Morrow's specimen of "*Pachydiscus*" inasmuch as they discount that specimen as being the bearer of Spinaptychus. The "*Texanites*" specimen was mislabelled sometime in the past, probably when the collection was reorganized, and may be from Comanchean rocks of Texas (T. Matsumoto, personal communication).

Spinaptychus sternbergi Fischer and Fay, 1953

Plate 8, Figs. 11-13

Spinaptychus sternbergi Fischer and Fay 1953. State Geol. Surv. of Kansas., Bull. 102, pt. 2, pp. 77-92, pls. 1-2.

Description

The specimens of Spinaptychus sternbergi described by Fischer and Fay ranged from 90 to 170 mm in length (dorsoventral), 58 to 105 mm in width, and were inflated from 5 to 11 mm. The early growth stages are triangular and the later growth stages are quadrate in outline. The later growth lamellae (inner surface) are sharply defined and give a rugose appearance to the shell. The outer surfaces do not have well defined growth lines, and have many randomly distributed tubercles. The tubercles are both pitted and unpitted. The larger ones are 2.5 mm in height. The openings on the tubercles are elliptical in the Kansas specimens and are circular on S. spinosus Cox from England. The specimens of S. spinosus from Palestine have elliptical pores, but they differ from S. sternbergi in that they are smaller, as are the English specimens. They are also relatively wider.

Discussion

The type specimen is number 2022 of the Fort Hays Kansas State College Museum. It was discovered in the upper Smoky Hill Member, about 2 miles northeast of Pyramid Rocks, Gove County, by George F. Sternberg (approximately, section 24, T. 14 S., R. 31 W.). Several other specimens from Logan and Gove counties are preserved in the Museum.

Rugaptychus?

Plate 8, Fig. 14

Description

A small, incomplete aptychus found in association with smooth *Baculites*. The greatest preserved length is 19 mm, and the greatest width of both valves is 10 mm. The apex is broken away. Both valves are present and are joined along the harmonic margin. The surface is ornamented with ribs.

Discussion

The ribs are curved and lack the acute bend characteristic of Rugaptychus. The valves may belong to an ammonite other than *Baculites*. They were found also in association with *Clioscaphites*. The specimen (FHKSC 11888-2) is in the Fort Hays College Museum and came from the upper Smoky Hill Member in the northwest corner of Rooks County.

unnamed aptychus A

Plate 8, Figs. 7, 8

Description

Two trianguar fragments (34 mm by 15 mm, and 33 mm by 15 mm). The outer surface is covered by spines ½ to 1 mm in diameter. The spines are ½ mm high and the point is sharply recurved toward the apex of the valve. The harmonic facet is prominent.

Discussion

The valves are from an unknown ammonite. They were found about 7 miles east of Hill City, on the north side of the Solomon River. They are in the Fort Hays College Museum (FHKSC 11914-2).

unnamed aptychus B

Plate 8, Fig. 9

Description

The specimen consists of a pair of well-preserved aptychi, with the internal surface uppermost. The exterior surface is covered by chalk. Each aptychus is approximately 17 mm wide and 12 mm high. The internal surface is covered with well defined, smooth, concentric growth lines. Each valve is subtriangular in outline. Apparently this aptychus belongs to an undescribed genus.

Discussion

A small, previously undescribed pair of aptychi are preserved in the Fort Hays Kansas State Museum (FHKSC 10279). The specimen was discovered by Mr. George F. Sternberg, in the Smoky Hill Member of Logan or Gove Counties in about 1935. Inasmuch as the exterior surface of the specimen is not exposed, the aptychus can not definitely be identified.

Order Belemnitida
Suborder Belemnopseina
Family Belemnitellidae Pavlow

Genus *Actinocamax* Miller, 1826
Type species: *Actinocamax verus* Miller, 1826

Diagnosis

Actinocamax either lacks an alveolar cavity and ventral fissure or these structures are very small. The embryonic bulb is present in the alveolar end of the guard. The guard may have a shallow pseudoalveolus, of no more than one-eighth the total length of the guard. The inner portion of the guard protrudes above the outer portion and has a characteristic concentric lamellar structure. The surface of the guard is ornamented with weakly developed granular protuberences, or longitudinal striae.

Actinocamex walkeri Jeletzky, 1961

Plate 8, Fig. 3

Actinocamax walkeri Jeletzky 1961. Jour. Paleont., v. 35, n. 3, pp. 521-526, pl. 72, figs. 3, 4, text-fig. 3.

Description

Lanceolate subcylindrical, short, stout guard. The anterior portion of the guard is laterally compressed, the posterior portion is compressed dorso-ventrally. The dorsolateral furrows are fine and closely spaced. The greatest preserved length of the guard is 78.6 mm, and the greatest diameter is 12.9 mm.

Discussion

Jeletzky (1961, p. 525) stated that this species is close to *A. manitobensis* in that it lacks granulation, but differs in that the guard is shorter and stouter and lacks longitudinal striae, and the furrows are weakly developed.

The type specimen is FHKSC Museum 7936-3, and is from an unknown locality; it may have come from the Smoky Hill Chalk.

Belemnoids are rather rare fossils in the Cretaceous beds of western Kansas. However, belemnoids can be used for stratigraphic zonation in areas where they are abundant. In particular, belemnoids are used to zone the middle and eastern European chalk beds, and are probably the best index fossil available for that purpose. Williston (1897, p. 242) discovered some belemnoids in the Smoky Hill Member chalk beds, he stated in part: "Belemnites are not common; one will scarcely find a specimen in a day's search anywhere in the beds. I have never observed any difference in their abundance in the different horizons." My field work in the Smoky Hill Member indicated that belemnoids are perhaps rarer than Williston's statement indicates. Williston did not name or describe any of the belemnoid specimens.

Actinocamax sternbergi Jeletzky

Plate 8 Figs. 1, 2

Belemnitella praecursor Miller 1957. Jour. Paleontology, v. 35, n. 3, pp. 515-521, fig. 5.

Description

The guard of this species is slightly lanceolate when seen either from the dorsal or ventral positions. The guard appears to be cylindrical when viewed from the lateral position. The guard is tapered slightly at each end and tapers abruptly to a point at the apical end. A ventral furrow is present. No pseudoalveolus is present. The apical half of the surface of the guard is ornamented with papillate or granular markings. The markings are larger toward the apex and extend around on to the flanks where they become smaller. Similar papillate markings are present on the ventral surface of the guard near the apex. The markings form weak oblique striations posterior to the alveolus on the ventral side.

Discussion

Jeletzky (personal communication, November 21, 1957) considers this form to be of Santonian (?) age. There is no locality information for this specimen, however; it probably is from Logan or Gove Counties, Kansas. The specimen is number 7936-1 of the Fort Hays College Museum.

Actinocamax sp. aff. *A. laevigatus* Arkhangelsky, 1912

Plate 8, Fig. 4

Actinocamax sp. aff. *A. laevigatus* Arkhangelsky, 1912 Jeletzky, 1961. Jour. Paleontology, v. 35, n. 3, pp. 526-629, figs. 4, 5.

Description

Small guard with high conical alveolar end. The guard is long and slender, and lacks a ventroalveolar furrow, and is smooth. FHKSC Museum specimen 10368 has a greatest preserved length of 32 mm, and a greatest dorso-ventral diameter of 3.9 mm. FHKSC Museum specimen 8126 has a greatest preserved length of 38 mm and a greatest dorso-ventral diameter of 3.7 mm.

Discussion

Jeletzky (1961 p. 529) considered this specimen to be of late Santonian age, and quite different from the Campanian *A. laevigatus* of Europe.

Genus Belemnitella d'Orbigny 1845

Type species: *Belemnites musconatus* Schlotheim 1813

Diagnosis

Belemnitella includes those belemnoids with an alveolar cavity of approximately one-third the length of the guard, a short alveolar slit, a pair of dorsolateral furrows, and a blunt end, which may be mucronate. Vascular imprints may be present on the surface of the guard.

Belemnitella praecursor var. *media* Jeletzky, 1955

Not illustrated

Belemnitella praecursor var. *media* Jeletzky 1955. Jour. Paleont. v. 29, n. 5, pp. 876-885, fig. 1.

Description

The following description is abstracted from Jeletzky's (1955) paper. The guard is long, subcylindrical, and tapers from the alveolar edge down to the apex. The dorsolateral grooves are distinct in the lower two-fifths of the guard, and they grade into rounded dorsolateral depressions toward the alveolar portion of the guard. Weak vascular imprints branch off from the dorsolateral grooves in the apical portion of the guard. Weak longitudinal marks and striae are present on the flanks of the guard. The dorsal side is smooth. The alveolus is 43 mm deep and the guard was probably 120 to 125 mm long before it was broken.

Discussion

This species and variety is represented by a single specimen (KU 3079) that Jeletzky (1955) assumed to have come from the Niobrara Formation of Kansas. Jeletzky did not have the original label or access to the specimen catalog. The label states that specimen KU 3979 was collected by G. P. Cooper from Upper Cretaceous rocks of Colorado. This establishes that the specimen is not from Kansas, though it is probably from the Niobrara Formation. The alveolus of the guard is largely filled with yellow chalk containing *Globigerina* and fish scales. This association is characteristic of the Niobrara Formation.

If this specimen came from the Niobrara Formation, it would indicate that part of the Niobrara Formation is of latest Santonian or early Campanian age, at least in Colorado.

Suborder Mesoteuthina Naef
Family Palaeololinginidae Naef
Genus *Tusoteuthis* Logan 1898
Type species: *Tusoteuthis longa* Logan, 1898

Diagnosis

Tusoteuthis is characterized in having a lanceolate, moderately convex gladius, composed of corneous material. The gladius is widest in its central portion, pointed anteriorly, and is lanceolate, or leaf shaped. The guard is cylindrical and has a hollow central portion.

Discussion

Logan considered *Tusoteuthis* to be closely related to "*Teuthopsis*" Zittel; however, the genus is now considered synonymous with *Paleololigo* Naef. *Tusoteuthis* differs from *Phylloteuthis* in that the latter is characterized by striations passing outward from the midrib, at an oblique angle, toward the gladius. *Tusoteuthis* is either smooth or characterized by concentric markings. The shapes of the gladii are similar.

Williston (1897 p. 242) stated that remains of coleoids are not rare in the Smoky Hill Member, although they nearly always occur as unrecognizable fragments. Williston mentioned a nearly complete specimen collected by Mr. H. T. Martin presumably this is the type specimen of *Tusoteuthis* Logan.

Tusoteuthis longa Logan, 1898

Plate 5, Fig. 6

Tusoteuthis longus Logan 1898. Univ. Kans. Geol. Survey, v. 4, pt. 8, pp. 497-98, pl. 110, fig. 1.

Description

The guard of the type specimen is cylindrical, approximately 200 mm long, and 25 mm in diameter. The gladius is slightly convex, lacks a median keel, and has concentric striations parallel to its outline. The gladius is approximately 400 mm long and 160 mm across its widest part. The specimen is fragmentary, large portions of the gladius having been broken away as is part of the guard. Logan stated that the contents of the ink sac were preserved on the under side of the gladius.

A second squid, probably belonging to this or a closely allied species is in the University of Kansas Geological Museum. The specimen is incomplete and consists of a fragmentary gladius and a portion of the guard. The specimen is 41 mm long, the gladius is approximately 22 mm long and is lanceolate in outline. The greatest width of the gladius is probably about 11 mm. The portion of the guard preserved is 12 mm long and about 1.8 mm wide.

Discussion

The type specimen was discovered in the Smoky Hill Member "from the Hesperornis beds of the Niobrara Cretaceous on the Smoky Hill river (sic) by Mr. Martin" (Logan, 1898, p. 497). The type specimen is number KU 4208, of the University of Kansas Geological Museum. A plaster cast of a better-preserved specimen is in the Museum. It consists of a complete gladius, and a small portion of the guard. The specimen number has been removed from the label. Probably this is a cast of the specimen in the National Museum. The smaller specimen differs from the type specimen of *T. longa* in that it is much smaller than *T. longa* and the gladius bears concentric markings parallel to its outline. The second specimen may be a young form of *Tusoteuthis longa* and is provisionally classed as such in this paper. Both specimens are incomplete and cannot be studied in detail.

Family Kelaenidae
Genus *Niobrarateuthis* Miller, 1957
Type species: *Niobrarateuthis bonneri,* Miller, 1957

Diagnosis

The gladius is elliptical, composed of corneous material, and the greatest width is near the anterior end. The guard is long and cylindrical, its posterior end bearing as median keel.

Discussion

Niobrarateuthis differs from *Palaeololigo* Naef in that *Palaeololigo* has a relatively shorter guard, a more pointed gladius at the posterior end, and has a definite medial asymptote that extends along the guard. The surface markings on the gladii of the two genera are similar. *Niobrarateuthis* differs from *Tusoteuthis* Logan (1898, p. 97) in that *Tusoteuthis* has a lanceolate gladius and lacks a prominent keel. *Phylloteuthis* Meek and Hayden (1876 p. 505) differs from this genus for it possessed a gladius that is more angular posteriorly, with the widest part of the guard in the posterior half and with a guard marked by parallel striations that pass obliquely outward and backward from the midrib.

Niobrarateuthis bonneri Miller 1957

Plate 8, Fig. 5

Niobrarteuthis bonneri Miller 1957. Jour. Paleontology, v. 31, n. 4, pp. 809-811, fig. 1-2.

Description

The guard is 22 to 24 mm in diameter; the anterior portion is broken off and a length of 370 mm remains. The keel is 115 mm long and is continuous with the posterior portion of the guard. The surface of the guard is marked with parallel striations originating at the center line of the guard and inclined obliquely to the posterior, forming an angle of approximately 70 degrees to the center line. The interior of the guard appears to be composed of tubules oriented parallel to the main axis of the guard.

The gladius is 190 mm long and 133 mm wide at its greatest breadth. It is crushed, consisting of a mass of fragments that together retain the original outline. Faint concentric markings parallel to the outline are visible on the surface. However, it is not certain that these marks were present on the gladius of the living animal for they may be brush strokes made during preparation when the specimen was varnished.

Discussion

It is not possible to divide the gladius into conus, lateral part of conus, and lateral asymptote, because the fragmented condition of the fossil hides these features. No lateral plaque seems to be present. The broken upper portion of the keel stands about 20 mm above the outer edge of the gladius and presumably arched up over the keel. It is now crushed.

The holotype consists of a complete but crushed gladius and an incomplete guard, the anterior end being broken away from the guard. The median keel also is partly broken away. However, the outline of the gladius is complete. There is no indication of the presence of any soft parts, such as an ink sac.

The type specimen was found in the Smoky Hill Member, exposed in the S½ section 8, T. 15 S., R. 34 W., Logan County, Kansas. Other specimens have been discovered by Mr. George F. Sternberg, Fort Hays Kansas State College Museum (personal communication, 1957), "about 22 miles southeast of Oakley, Logan County, Kansas, a half mile to the northeast of the Old Maston house" in 1936. Mr. Sternberg discovered a third specimen "slightly higher up and a half mile north" of the second specimen.

The holotype is specimen 7959 of the Fort Hays Kansas State

College Museum (Miller, 1957a). Another specimen, 11842, from an unknown location is also in the College Museum.

Coleoidea, incertae sedis

Genus *Platylithophycus* Johnson and Howell, 1948

Type species: *Platylithophycus cretaceum* Johnson and Howell, 1948

Discussion

The genus *Platylithophycus* was based by Johnson and Howell on a fragment of calcareous organic material that they supposed to have been secreted by an alga. They stated in part: "Little can be discerned from the specimen in the way of microstructure. Hence it cannot be definitely classified. The classification is based on superficial appearance." Apparently Johnson and Howell thought their holotype, Carnegie Museum No. 25758, was the only specimen. Mägdefrau (1952 p. 305) suggested *Platylithophycus* was not an alga. The original specimen was discovered by George F. Sternberg, of the Fort Hays Kansas State College Museum, and was sold piecemeal by him to various institutions. The largest fragment was sold by Sternberg to the University of Nebraska, where Maxim K. Elias studied the specimen, previous to Johnson and Howell's paper. According to Sternberg, the original specimen was fairly large (1½ to 2 feet long), of an oval outline, and the edges were turned in toward the underside. Sternberg stated that Elias had intended to describe the specimen as a squid "*Coccoteuthis cretaceus*" a new genus and species. Elias made thin sections of the specimen and photographed them (pl. 5 fig. 10) and compared them with photographs of thin sections (pl. 5, fig. 9) of the cuttlebone of the Recent squid. The microstructure is remarkably similar. It is the author's opinion that the specimen is a squid, though the familia identity of the specimen cannot be determined with certainty from the fragments available.

Platylithophycus cretaceum Johnson and Howell

Plate 8, Figs. 15, 16

Platylithophycus cretaceum Johnson and Howell 1948. Jour. Paleo. v. 22, n. 5, pp. 632-33, pl. 93.

Description

Johnson and Howell's (1948) original description was based on the assumption that the remains were of algal origin, so their description does not apply. In their specific description, they stated that the "frond" consisted of small hexagonal plates, which in turn were made of tiny crystals that radiated outward from the center of the plate. Elias' thin sections show that the hexagonal plates have a definite microstructure resembling closely the microstructure of Recent cuttlebone. The specimen will not be redescribed as the author has neither Dr. Elias' permission, nor the specimen.

Discussion

Four fragments of the original specimen are preserved in the University of Kansas Geological Museum (KU 11402). The specimen was collected by Sternberg from "three miles northeast of Monument Rocks, Gove County, Kansas." This is the vicinity of T. 14 S., R. 31 W.

Phylum Annelida
Class Chaetopoda
Order Polychaeta
Family Serpulidae
Genus *Serpula* Linnaeus, 1758
Type species: *Serpula vermicularis* Linnaeus, 1758

Diagnosis

The genus *Serpula* includes polychaete worms with a long slender, subcylindrical calcareous test. The test may or may not be attached, it may be irregularly contorted, nearly straight or coiled. The individuals may occur gregariously or singly.

Serpula intrica White, 1876

Not illustrated

Serpula intrica White 1876. U. S. Geol. and Geog. Surv. Terr. West 100th Merid., v. 4, p. 205, pl. 15, fig. 5a. Logan 1897. Univ. Kansas Geol. Surv., v. 4, pt. 8, p. 484, pl. 100, fig. 1.

Discussion

Logan recorded the presence of this species in the Smoky Hill Member. He discovered a single coiled specimen along the Smoky Hill River, south of Gove City. The specimen cannot be located in the University of Kansas Geological Museum and is presumed lost.

Logan quoted White's (1876) description of the type specimen, and used a reproduction of White's figure of the type to illustrate the Kansas specimen. Little can be stated with regard to the presence of this species in Kansas.

Serpula semicoalita Whiteaves, 1889

Plate 5, Fig. 3

Serpula semicoalita Whiteaves 1889. Cont. to Can. Paleont., v. 1, pt. 2, p. 185, pl. 26, fig. 1.

Serpula plana Logan 1898. Univ. Kans. Geol. Surv., v. 4, pt. 8, p. 443, pl. 119, fig. 2.

Description

The test of Logan's type of S. *plana* is subcylindrical, up to 5 mm diameter, has a gradual taper from the aperture toward the apex. The aperture is circular, and approximately 3 mm inside diameter. The test does not have a keel.

Growth lines are present on the test. The tests are slightly curved or nearly straight, and although the tests cross each other, they do not double back over themselves.

The test is composed of a double wall. The outer wall is thinner (approximately 0.1 mm) and the inner wall is thicker (0.5 to 1.0 mm). Both walls have growth lines.

Discussion

Logan's type specimen (KU 4276) of S. *plana* is labelled as coming from the "Niobrara Cretaceous" of western Kansas. The words "Niobrara," "western Kansas," and "4276" are entered on the label with a different pen and penmanship than the words "*Serpula plana* Logan," "Type," "Cretaceous," and "W. N. Logan." It is probable that the reference to the Niobrara Formation was added at a later date by someone other than Logan. Logan (1898) recorded this species from the Fairport Shale Member of the Carlile Shale and not the Niobrara Formation.

S. *plana* does not have a keel as does S. *tenuicarinata;* this serves to distinguish the two species. The Niobrara forms of S. *semicoalita* are smaller than the forms from the Carlile Shale.

The type specimen of S. *semicoalita* described by Whiteaves is from the Niobrara Formation in Manitoba, Canada. It is not improbable that the species also occurs in the Niobrara Formation of Kansas.

Serpula tenuicarinata Meek and Hayden, 1857

Plate 5, Figs. 1, 2

Serpula tenuicarinata Meek and Hayden 1857. Proc. Acad. Nat. Sci. Phila., v. 9, p. 134. Logan 1898. Univ. Geol. Surv. Kans., v. 4, pt. 8, p. 484, pl. 86, fig. 4.

Description

The species is characterized by the presence of a carina along the dorsal portion of the test. The wall of the test is very thin, less than 0.5 mm. The wall seems to consist of a very thin outer layer marked by growth lines, and a thicker, smooth-walled, inner layer.

The greatest outside diameter of the test is 4 mm. The majority of the tests are smaller, and seem to average about 2 mm. in diameter.

Discussion

Logan's figured specimen (KU no number) came from Trego County, Kansas. The species is distributed throughout the Smoky Hill Member. Another specimen (KU 4078) from Trego County is also in the University of Kansas Geological Museum.

Phylum Echinodermata
Class Crinoidea
Subclass Articulata
Order Uintacrinida
Type species: *Uintacrinus socialis* Grinnell, 1876

Diagnosis

Uintacrinus includes at least two species of stemless crinoids with a globular calyx composed of many small plates. The calyx has 10 slender, long arms that bear pinnules. The base is probably dicyclic and is composed of a centrale surrounded by basals or infrabasals and basals. Five radials encircle the basal plates. The remaining plates of the dorsal cup are two primary brachials and the second axillary, which are separated by interbrachials. Secundibrachs branch from the axillary brachial. Interbrachials also occur between the secundibrachs. A tegmen is present.

Uintacrinus socialis Grinnell, 1876

Plate 9, Fig. 5

Uintacrinus socialis Grinnell 1876. Amer. Jour. Sci., v. 12, pp. 81-83, pl. 5, fig. 1-2b. Meek 1876. U. S. Geol. and Geog. Surv. Terr., Bull., v. 2, n. 4, pp. 375-378, fig. a, b. Clark 1893. U. S. Geol. Surv., Bull. 97, pp. 21-24, pls. 1, 2. Williston & Hill 1894. Kansas Univ. Quart., v. 3, n. 1, pp. 19-21. Bather 1896. Zool. Soc. London, Proc. for 1895, pp. 974-1004, pls. 54-56. Logan 1898. Univ. Kans. Geol. Surv., v. 4, pt. 8, pp. 481-483, pls. 21, 112. Springer 1900. Mus. Comp. Zool., Mem., v. 25, n. 1, pp. 1-89, pls. 1-8.

Discussion

The anatomy of *Uintacrinus socialis* has been described by many authors, among whom Springer (1900), Bather (1896), and Clark (1893), have published detailed descriptions. *Uintacrinus westfalicus* Schluter, 1878, was described from Santonian rocks of Europe. The two species are closely related, and may be synonymous. The species have been distinguished in that *U. socialis* has broader brachial plates and seven interradial plates encircle the eighth or eighth and ninth interradial plates and *U. westfalicus* supposedly has only five interradial plates. However, the number of interradial plates seem to vary in both species, and the differences overlap. *U. anglicus* seems to be a distinct and valid species (Rachel Gulliver, personal communication, November 1967).

The author does not propose to repeat the previously published detailed anatomy of this species.

Phylum Arthropoda
Class Crustacea
Subclass Cirripedia
Order Thoracica
Family Stramentidae
Genus *Stramentum* Logan, 1897
(*Loricula* Sowerby, 1843)
Type species: *Policipes haworthi* Williston, 1896

Diagnosis

Stramentum includes those barnacles with a capitulum composed of a single whorl of nine or possibly ten valves. The capitulum consists of paired scutals, laterals, tergals, carinolaterals and a split carinal plate. Neither Logan (1897) nor Withers (1935) recorded the presence of a rostral valve in S. *haworthi.* The author has not observed a rostral valve in any of his specimens.

Stramentum haworthi (Williston), 1896

Plate 9, Fig. 7

Pollicipes haworthi Williston 1896. Univ. Geol. Surv. Kans., v. 2, p. 243, pl. 36.
Stramentum haworthi (Williston) Logan 1897. Kans. Univ. Quart., ser. a, v. 6, n. 4, p. 188. Withers 1935. Catalogue of fossil Cirripedia: Brit. Mus. Nat. Hist., v. 2, pp. 320-21, pl. 42.
Stramentum tabulum Logan 1898. Univ. Geol. Surv. Kans., v. 4, pt. 8, p. 498, pl. 111.

Description

S. *haworthi* has been redefined by Withers as follows: Nearly central umbo, upper and lower occludent margins form an obtuse angle, and the apex of the tergolateral margin is obliquely inclined to the main axis. The growth lines of the tergum are straight. The penduncle plates are divided into three median and two carinal rows on each side. The median plates have convex upper margins. The carinal plates have nearly straight upper margins.

Discussion

Withers (1935, p. 321) combined Logan's species S. *tabulum* and Williston's species S. *haworthi* on the basis that Logan described a new species because the carina was missing from a young specimen. Logan defined S. *tabulum* as having eight capitular plates and a smaller size than S. *haworthi.*

Most of the Niobrara barnacles in the University of Kansas collection seem to be attached to a smooth-shelled *Baculites?* sp. and are pseudo-planktonic, not benthonic.

The holotype is number 8323 in the University of Kansas Geological Museum.

Genus *Squama* Logan, 1897
Type species: *Squama spissa* Logan, 1897

Diagnosis

Squama includes those stramentids with a capitulum of 12 valves; paired scutals, upper laterals, tergals, carinolaterals, a carina, subcarina, rostral and subrostral valves are present. The peduncle is comparatively narrow and has ten rows of intersecting plates. *Squama* presumably differs from *Stramentum* in that *Squama* has a narrower peduncle, and three additional capitular plates, subcarinal, rostral, and subrostral.

Squama spissa Logan, 1897

Not illustrated

Squama spissa Logan 1897. Kans. Univ. Quart., ser. a, v. 6, n. 4, p. 187.
Withers 1935. Cat. Foss. Cirrip., Brit. Mus. Nat. Hist., p. 310, pl. 39.
Squama lata Logan 1897. Kans. Univ. Quart., ser. a, v. 6, n. 4, p. 188.

Discussion

The type specimens of S. *spissa* and S. *lata* are missing and there are no known specimens in any collections. Withers (1935, p. 309) combined Logan's two species on the basis that:

"From his (Logan's) descriptions and figures it seems very probable that the second species, S. *lata* is founded on an individual of S. *spissa* in which the capitulum is incomplete. The only distinction given, except that of size, is the absence of S. *lata* of subcarina, rostrum, and subrostrum, although a valve which might be the rostrum is indicated even in his own figure of S. *lata*."

Inasmuch as there are no known specimens of this genus at the present time nothing further can be done.

Subclass Malacostraca
Order Decapoda
Family Palinuridae
Genus *Linuparis* White, 1847
Type species *Palinurus trigonus* DeHaan, 1850

Diagnosis

Linuparis has an elongate, subcylindrical carapace. A rostrum may or may not be present. The carapace does not form separate orbits for the eyes. The walking appendages are of equal length.

Linuparis? sp.

Plate 9, Fig. 4

Description

The specimen is incomplete and poorly preserved. It consists of the right side of the cephalothorax and several abdominal somites. Several of the walking legs are preserved. The entire specimen is 23 mm long, the cephalothorax is approximately 10 mm long and 5 mm high. The specimen is smaller than previously described species of *Linuparis* found in Cretaceous rocks of North America.

Discussion

The Kansas specimen (KU 7295) is from the lower Smoky Hill Member "in the vicinity of Castle Rock" (eastern Trego County, near the Smoky Hill River, T. 13 S., R. 24 W.?). It is not possible to identify this specimen specifically and it is only provisionally assigned to this genus.

Conclusions

The following listed species are considered to be valid and to represent the macroinvertebrate fauna of the Niobrara Formation of Kansas, as known at this time. Starred species are restricted to the Fort Hays Member.

Pelecypoda

- *Ostrea congesta* Conrad
- *Ostrea falcata* Morton
- *Ostrea exogyroides* Logan
- *Ostrea rugosa* (Logan)
- **Inoceramus deformis* Meek
- *Inoceramus involutus* Sowerby
- *Inoceramus grandis* (Conrad)
- *Inoceramus simponsi* Meek
- *Inoceramus platinus* Logan
- **Parapholas sphenoideus* White
- *Pecten bonneri* n. sp.
- *Pteria* sp. cf. *P. petrosa* (Conrad)
- *Lucina* sp.
- *Durania maxima* Logan

Nautiloidea

- *Eutrephoceras* sp.

Ammonoidea

- *Bevahites?* sp. A
- *Bevahites?* sp. B

Baculites spp.
Baculites sp. cf. *B. codyensis* Reeside
Baculites? sp.
Scaphites? sp.
Clioscaphites vermiformis Meek and Hayden
Clioscaphites chouteauensis Cobban
Spinaptychus sternbergi Fischer and Fay
aptychus (four varieties)

Sepioidea
Tusoteuthis longa Logan
Niobrarateuthis bonneri Miller
Platylithophycus cretaceum Johnson and Howell

Belemnoidea
Actinocamax walkeri Jeletzky
Actinocamax sternbergi Jeletzky
Actinocamax laevigatus Jeletzky

Annelida
Serpula intrica White?
Serpula semicoalita Whiteaves
Serpula tenuicarinata Meek and Hayden

Crinoidea
Uintacrinus socialis Grinnell

Arthropoda
Stramentum haworthi (Williston)
Squama spissa Logan
Linuparis? sp.

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APPENDIX A—CHEMICAL ANALYSES

The chemical analyses were prepared by Walter Hill under the direction of Russell Runnels, formerly Chief Geochemist of the Kansas Geological Survey.

The percentage of $CaCO_3$ is determined by adding the amounts of CaO and D. L. O. I. 600°/1000° C. (loss on ignition from 600 to 1000 degree centigrade). The D. L. O. I. 105°/550° C. is interpreted to represent the loss of organic matter during ignition from 105 to 550 degrees centigrade.

Silicon dioxide, titanium dioxide, potash, sodium oxide, and aluminum oxide, probably are present in detrital minerals such as quartz, zircon, feldspar, and the clay minerals.

Iron oxide and sulfur are probably present as pyrite, and some iron oxide, along with some of the other metalliferous oxides, may be present as other opaque minerals.

Phosphorous pentoxide may be a constituent of vertebrate bones and fish scales.

Manganese oxide is present in the Fort Hays Member, the crinoidal limestone, and one other Smoky Hill Member sample. No conclusion is drawn from this occurrence, although manganese is normally present within the lattice structure of crinoids.

The organic matter visible in the thin sections was subjectively estimated by assuming the amount of brown and grey blotches to be representative of the relative amounts of carbonaceous material. The amounts are further subjectively classified as "none," "little," "some" and "much" for increasing amounts, in that order.

Sources of Analyzed Specimens

Specimens used for chemical analyses were derived from the following locations:

Fort Hays Member

Locality

1. sec. 26, T. 14 S., R. 22 W.
2. NW¼ sec. 26, T. 13 S., R. 19 W.
3. SE¼ sec. 5, T. 15 S., R. 23 W.

Smoky Hill Member

4. sec. 1, T. 14 S., R. 33 W.
5. sec. 14, T. 16 S., R. 33 W.
6. N½ sec. 35, T. 14 S., R. 33 W.
7. SW¼ sec. 34, T. 14 S., R. 31 W.
8. N. center, S½ sec. 25, T. 15 S., R. 33 W.
9. NE¼ NE¼ sec. 19, T. 15 S., R. 32 W.
10. sec. 32, T. 13 S., R. 26 W.
11. center E½ sec. 11, T. 14 S., R. 29 W.
12. SW¼ sec. 34, T. 14 S., R. 31 W.
13. NE¼ sec. 32, T. 15 S., R. 26 W.
14. NE¼ SW¼ sec. 10, T. 14 S., R. 33 W.

The samples from locality 8 are listed as 8a-g. The samples were collected from a 36 foot bluff, sample (a) from the base, sample (b) from six feet above the base, sample (c) 12 feet above the base, sample (d) 18 feet above the base, sample (e) 24 feet above the base, sample (f) 30 feet above the base, and sample (g) is from 36 feet above the base, or the top of the bluff. Rock thin sections were cut from these samples, and some of them are illustrated on plate 7.

Sample 14 is a fragment of *Uintacrinus* limestone.

TABLE 3. Chemical Analyses.

Number	CaO	D. L. O. I. 600°/1000°	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	SrO
1.	52.64	41.49	2.37	0.01	0.80	0.42	0.04
2.	52.99	41.09	2.33	0.18	0.41	1.15	0.05
	53.29	41.11	2.51	0.11	0.63	1.20	....
3.	52.26	41.26	2.53	0.05	0.40	0.51	0.35
4.	54.33	42.22	1.28	0.15	0.31	0.66	0.05
	54.40	42.17	1.46	0.19	0.23	0.92	....
5.	28.20	21.98	30.25	0.78	8.01	3.49	0.006
	28.35	22.25	30.28	0.63	8.52	3.52	....
6.	39.62	31.35	16.37	0.23	4.91	1.73	0.05
7.	35.77	27.62	19.54	0.30	5.05	2.33	0.77
	40.60	30.65	14.17	0.81	3.43	1.88	....
8a.	35.60	27.71	21.62	0.70	6.51	1.99	0.02
8b	43.61	34.63	10.20	0.22	2.94	1.54	0.47
	44.60	34.72	9.96	0.29	2.74	1.53	....
8c.	39.98	29.49	14.54	0.15	4.21	1.92	0.05
	29.55	29.48	14.64	0.22	3.95	2.07	....
8d.	39.84	30.12	14.80	0.32	4.31	2.22	0.05
8e.	41.12	31.55	15.12	0.14	4.03	2.40	0.06
8f.	36.00	27.59	20.52	0.67	5.57	2.85	0.04
	36.42	27.80	20.72	0.27	6.21	2.74	....
8g.	44.20	34.14	12.74	0.20	3.63	1.99	0.05
	44.56	34.19	13.07	0.04	2.73	2.06	....
9.	48.35	33.37	3.42	0.10	0.91	3.09	....
	48.03	33.83	3.61	0.03	1.07	3.10	0.83
10.	47.63	37.32	8.27	0.09	2.40	1.45	0.05
11.	25.32	20.16	29.99	0.59	8.37	3.52	0.006
	25.32	20.09	30.22	0.70	8.36	3.43	....
12.	46.08	33.59	7.64	0.17	2.04	1.39	0.51
	46.50	33.92	7.69	0.08	2.38	1.49	....
13.	34.00	26.60	23.45	0.45	6.69	2.73	0.02
	34.22	26.33	23.85	0.72	6.51	2.70	....
14.	55.02	43.27	0.29	0.02	nil	0.37	0.12

TABLE 3. Chemical Analyses (*continued*).

Number	MgO	MnO_3	K_2O	Na_2O	P_2O_5	SO_3	S
1.	0.39	0.21	0.02	0.02	0.03	trace	0.02
2.	0.45 0.54	0.14	0.06 0.06	0.02 0.02	0.14	trace	trace ....
3.	0.41	0.25	0.06	0.03	0.03	0.08	trace
4.	0.34 0.43	nil	0.03	0.02	0.04	trace	trace ....
5.	1.21 1.70	nil	1.21	0.17	0.15	0.01	0.03 ....
6.	1.16	nil	0.55	0.09	0.05	0.22	0.14
7.	1.17 0.07	.... nil	0.91 0.47	0.08 0.06	0.10	2.13 2.89	trace ....
8a.	0.83	nil	0.82	0.04	0.08	0.15	0.10
8b.	0.71 0.66	nil	0.16	0.01	....	....	....
8c.	0.55 0.39	nil	0.39 0.53	0.01 0.04	0.09	1.39 0.98	.... 0.02
8d.	0.52	nil	0.35	0.01	0.07	0.45	0.14
8e.	0.51	nil	0.49	0.01	0.03	0.26	0.15
8f.	0.70 0.77	nil	0.78 0.66	0.06 0.06	0.08	0.15	nil ....
8g.	0.52 0.73	nil	0.76 0.27	0.02 0.01	0.08	nil	nil ....
9.	0.34 0.19	.... nil	0.07 0.08	0.01 0.01	.... 0.05	1.37	.... nil
10.	0.35	nil	0.18	0.02	0.07	0.05	0.07
11.	1.94 1.89	0.09	1.18 1.20	0.09 0.12	0.11	0.24	0.18 ....
12.	0.65 0.60	nil	0.24 0.12	0.06 0.05	0.05	1.16 2.61	.... trace
13.	0.95 1.10	nil	0.90 0.97	0.05 0.05	0.12	0.14	0.03 ....
14.	0.69	0.08	0.06	0.01	0.04	0.07	nil

TABLE 3. Chemical Analyses (*concluded*).

Number	D. L. O. I. 550°/600° C	D. L. O. I. 105°/550° C	Total	Organic matter
1.	0.47	0.31	99.22	none
2.	0.40	0.67	100.07	none
	0.29	0.73	100.76	…
3.	0.56	0.48	99.26	none
4.	0.27	0.48	100.20	none
	0.19	0.53	100.06	…
5.	1.35	2.54	99.36	much
	1.09	2.55	100.44	…
6.	1.35	2.43	99.50	much
7.	1.82	3.03	99.85	much
	0.77	2.17	99.74	…
8a.	1.59	1.83	99.49	much
8b.	1.28	2.83	98.98	some
	0.53	3.56	99.61	…
8c.	2.18	4.27	99.22	much
	1.55	4.99	98.53	…
8d.	1.56	4.66	99.28	much
8e.	1.09	1.78	99.20	much
8f.	1.84	2.60	99.45	some
	1.71	2.47	100.10	…
8g.	1.04	0.60	99.97	none
	0.84	0.98	99.61	…
9.	0.62	2.19	93.86	…
	0.40	1.44	99.48	much
10.	0.55	0.75	99.18	some
11.	1.76	5.53	98.89	much
	1.34	5.59	98.70	…
12.	1.46	3.23	98.22	…
	1.00	3.38	100.38	some
13.	1.61	1.81	99.52	some
	0.89	2.77	100.39	…
14.	0.15	0.31	100.41	none

APPENDIX B—LOCALITY LIST

Localities from which lithologic samples and fossils were collected are tabulated. The localities from which fossils were colllected have been given Kansas University locality register numbers. No locality register numbers were given to the localities from which only lithologic samples were obtained.

1. Ellis County
   NW¼ sec. 26, T. 13 S., R. 19 W. (Fort Hays Member)
2. Gove County
   E½ sec. 23, T. 14 S., R. 26 W. KU 11396 (Smoky Hill Member)
   cent. W½ sec. 32, T. 13 S., R. 26 W. KU 11391 (Smoky Hill Member)
   NW¼ sec. 8, T. 15 S., R. 31 W. KU 11394 (Smoky Hill Member)
   SW¼ sec. 34, T. 14 S., R. 31 W. (Smoky Hill Member)
   cent. E½ sec. 11, T. 14 S., R. 29 W. (Smoky Hill Member)
   NE¼ sec. 32, T. 15 S., R. 26 W. (Smoky Hill Member)
3. Graham County
   sec. 1, T. 8 S., R. 22 W. KU 11395 (Fort Hays Member)
4. Lane County
   sec. 14, T. 16 S., R. 29W. (Smoky Hill Member)
5. Logan County
   cent. S. line sec. 26, cent. N. line sec. 35, T. 14 S., R. 33 W.
   KU 11393 (Smoky Hill Member)
   NW¼ sec. 6, T. 15 S., R. 32 W. KU 11388 (Smoky Hill Member)
   NE¼ SW¼ sec. 10, T. 14 S., R. 33 W. (Smoky Hill Member)
   sec. 1, T. 14 S., R. 33 W. (Smoky Hill Member)
   N½ sec. 35, T. 14 S., R. 33 W. (Smoky Hill Member)
   N cent. S½ sec. 25, T. 15 S., R. 33 W. (Smoky Hill Member)
   NE¼ NE¼ sec. 19, T. 15 S., R. 32 W. (Smoky Hill Member)
6. Rooks County
   sec. 33, T. 7 S., R. 19 W. KU 11398 (Fort Hays Member)
7. Smith County
   sec. 3, T. 5 S., R. 13 W. KU 11397 (Fort Hays Member)
   N½ sec. 32, T. 4 S., R. 15 W. KU 11399 (Fort Hays Member)
8. Trego County
   SW ¼ sec. 36, T 14 S., R. 22 W. KU 11390 (Fort Hays Member)
   NE¼ sec. 33, T. 13 S., R. 24 W. KU 11389 (Smoky Hill Member)
   NW¼ sec. 26, T. 14 S., R. 23 W. KU 11392 (Fort Hays Member)
   sec. 26, T. 14 S., R. 22 W. (Fort Hays Member)
   SE¼ sec. 5, T. 15 S., R. 23 W. (Fort Hays Member)

EXPLANATION OF PLATE 1

Inoceramus grandis (Conrad)

FIG.

1. Right valve, KU 11263, one of the Logan's type specimens of *H. niobrarensis* (× 1/4).
2. Right valve, KU 10701 (× 1/4).
3. Right valve, KU 11236, one of Logan's type specimens of *H. niobrarensis* (× 1/3).
4. Right and left valves attached, FHKSCM 11916 (× 1/7)
5. Left valve, KU no number, from the Fort Hays Member near Kirwin Dam (× 1/2).
6. Exterior of right? valve, KU 5802. Logan's type specimen of *I. concentricus* (× 4/5).
7. Right valve, FHKSCM 12028, with portion of left valve still attached (× 1/5).
8. Right and left valves, FHKSCM 11959. The valves are fragmentary and appressed. The exterior of the left valve is uppermost, and a portion of the right valve is exposed at the top (× 1/2).
9. Right valve, KU 5758. One of Logan's type specimens of *I. pennatus* (× 3/4).
10. Right valve, KU 11263. One of Logan's type specimens of *H. niobrarensis* (× 1/5).
11. Right valve, KU 11406 (× 1/4).
12. Left valve, KU 10701 (× 1/4).

PLATE 1

EXPLANATION OF PLATE 2

Inoceramus involutus Sowerby

FIG.

1. Right and left valves, FHKSCM 12023. The left valve is crushed and the beak is covered by oysters. The right valve is partially broken in the center and peeled back (× ⅓).
2. Left valve, FHKSCM 12023 (× ⅓).

Inoceramus grandis (Conrad)

3. Fragmentary right and left valves, FHKSCM 11885, of a large individual's interior (× 1/9).
4. Right valve, KU 10702, that may belong to this species (× ⅛).

Inoceramus involutus Sowerby

5. Interior of KU 5782, Logan's type specimen of *I. truncatus* (× ¼).
6. Exterior of KU 5782, Logan's type specimen of *I. truncatus* (× ¼).

Ostrea congesta Conrad

7. Several valves, KU 11395, attached to an *Inoceramus* (× ⅗).
8. Cluster of individuals, KU 10701, attached to valve of *I. grandis* (× ⅓).

Pteria sp. cf. *P. petrosa* (Conrad)

9. Crushed and fragmentary left valve, FHKSCM 11919 (× 1).

Ostrea falcata Morton

10. Right valve of FHKSCM 11960 (×1½).
11. Left valve of FHKSCM 11960 (× 1½).

Pecten bonneri new species

12. Interior of left valve of type, FHKSCM 11908-2 (× 1).
13. Interior of right valve of type, FHKSCM 11908-2 (× 1).
14. Exterior of left valve of type, FHKSCM 11908-2 (× 1).
15. Exterior of right valve of type, FHKSCM 11908-2 (× 1).

PLATE 2

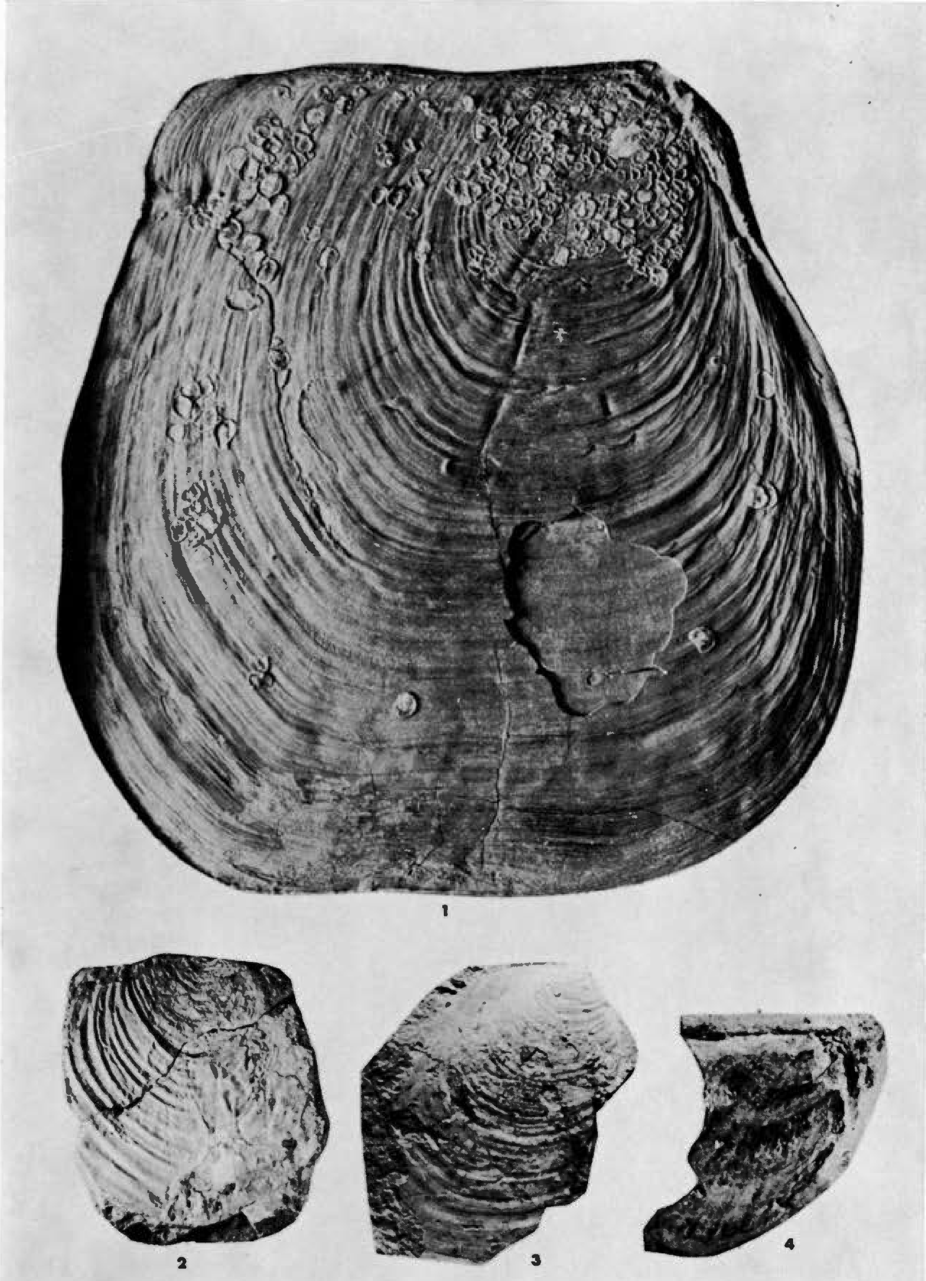
EXPLANATION OF PLATE 3

Inoceramus platinus Logan

FIG.

1. Nearly complete right valve, with attached left valve, FHKSCM 2086 ($\times \frac{1}{7}$).
2. Fragmentary right valve, KU 10748 ($\times \frac{1}{8}$).
3. Fragmetary immature right valve FHKSCM 12030 ($\times \frac{1}{3}$).
4. Logan's type specimen of *I. subtriangulatus*, KU 11262. Original color pattern shows ($\times \frac{1}{3}$).

PLATE 3



EXPLANATION OF PLATE 4

Inoceramus deformis Meek

Fig.

1. Right valve, KU no number, an internal cast from the Fort Hays Member near Osborne, Kansas (× ⅓).
2. Left valve, KU 11392, an internal cast (× ¼).
3. Interior of KU 7995 (× ⅕).

Inoceramus platinus Logan

4. One of Logan's type specimens of *I. pennatus*, KU 5784 (× ¼).

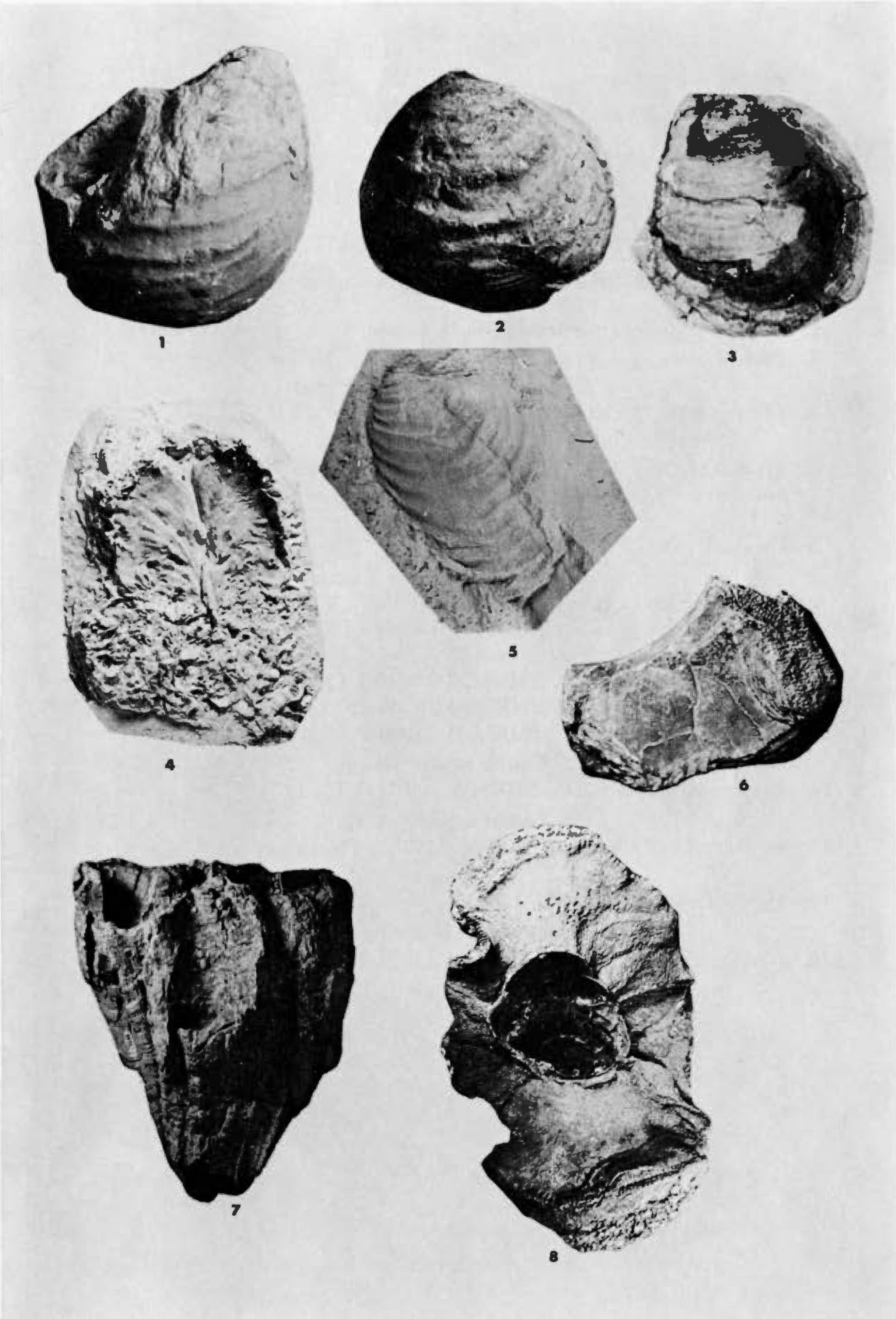
Inoceramus simpsoni Meek

5. Left valve of FHKSCM 11912 (× ⅖).

Durania maxima (Logan)

6. Fragment with vascular markings on the funnel plate, KU 4079 (× ¼).
7. Three valves grown together, FHKSCM 4092 (× ⅕).
8. Recumbent lower valve, FHKSCM 10336 (× ⅕).

PLATE 4



EXPLANATION OF PLATE 5

Serpula tenuicarinata Meek and Hayden

Fig.

1. Clusters of tubes collected by W. N. Logan, KU no number ($\times \frac{3}{4}$).
2. Part of same specimen ($\times \frac{3}{4}$).

Serpula semicoalita Whiteaves

3. Logan's type specimen of S. *plana*, KU 4276 ($\times \frac{3}{4}$).

Inoceramus sp.

4. Portion of right valve, FHKSCM 11892, from the *Clioscaphites chouteaensis* zone ($\times \frac{3}{4}$).

Lucina sp.

5. Crushed valve, FHKSCM 11909 ($\times 1\frac{1}{4}$).

Ostrea exogyroides Logan

6. Interior of lower valve, FHKSCM 12092-3 ($\times 1$).
7. Interior of lower valve, FHKSCM 12092-3 ($\times 1$).
8. Exterior of lower valve, FHKSCM 12092-3 ($\times 1$).
9. Exterior of lower valve, FHKSCM 12092-3 ($\times 1$).
10. Interior of upper valve, FHKSCM 11938 ($\times 1$).
11. Exterior of lower valve, FHKSCM 12092-3 ($\times 1$).

Ostrea rugosa Logan

12. Exterior of upper valve, FHKSCM 11911-3 ($\times 1$).

Pecten bonneri n. sp.

13. Interior of right valve, FHKSCM 11908-2 ($\times 1$).

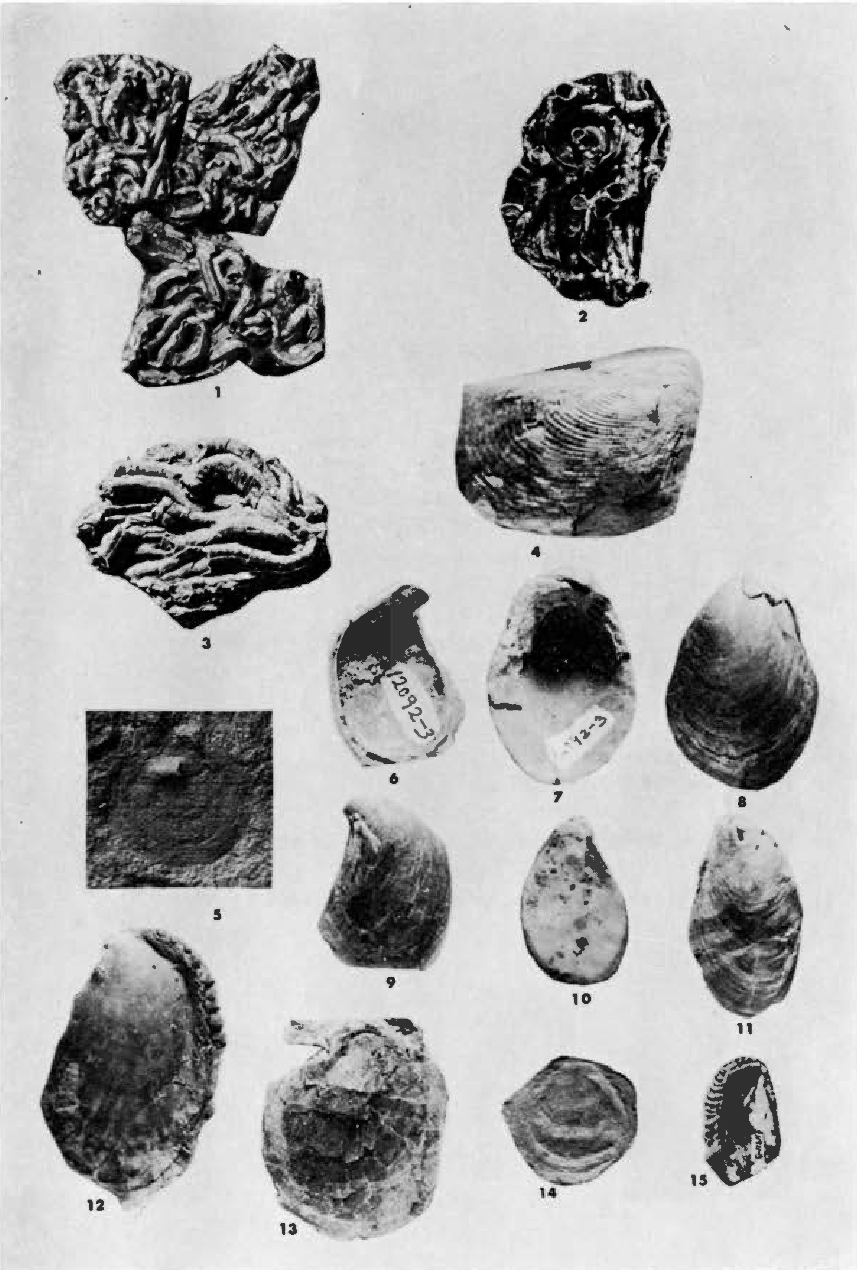
Lucina sp.

14. Crushed valve, FHKSCM 12044 ($\times 1\frac{1}{4}$).

Ostrea rugosa Logan

15. Interior of upper valve, FHKSCM 11911-3 ($\times \frac{2}{5}$).

PLATE 5



EXPLANATION OF PLATE 6

Behavites? sp. A.

FIG.

1. Plaster cast of specimen collected by Morrow, KU no number (× 1/8).

Behavites? sp. B.

2. Internal cast in chalk, FHKSCM 12029-2 (× 1/6).
3. Impression of exterior, FHKSCM 12029-2 (× 1/6).

Clioscaphites chouteauensis Cobban

4. Lateral view of FHKSCM 11784 (× 3/4).
5. Lateral view of FHKSCM 11784 (× 3/4).

Eutrephoceras sp.

6. Venter of specimen collected by A. L. Morrow, KU no number (× 2/3).
7. Lateral view of Morrow's specimen (× 2/3).

Baculites sp. cf. *B. codyensis* Reeside

8. Ribbed baculites, FHKSCM 12032 (× 2/3).
9. Ribbed baculites, FHKSCM 12031 (× 2/3).

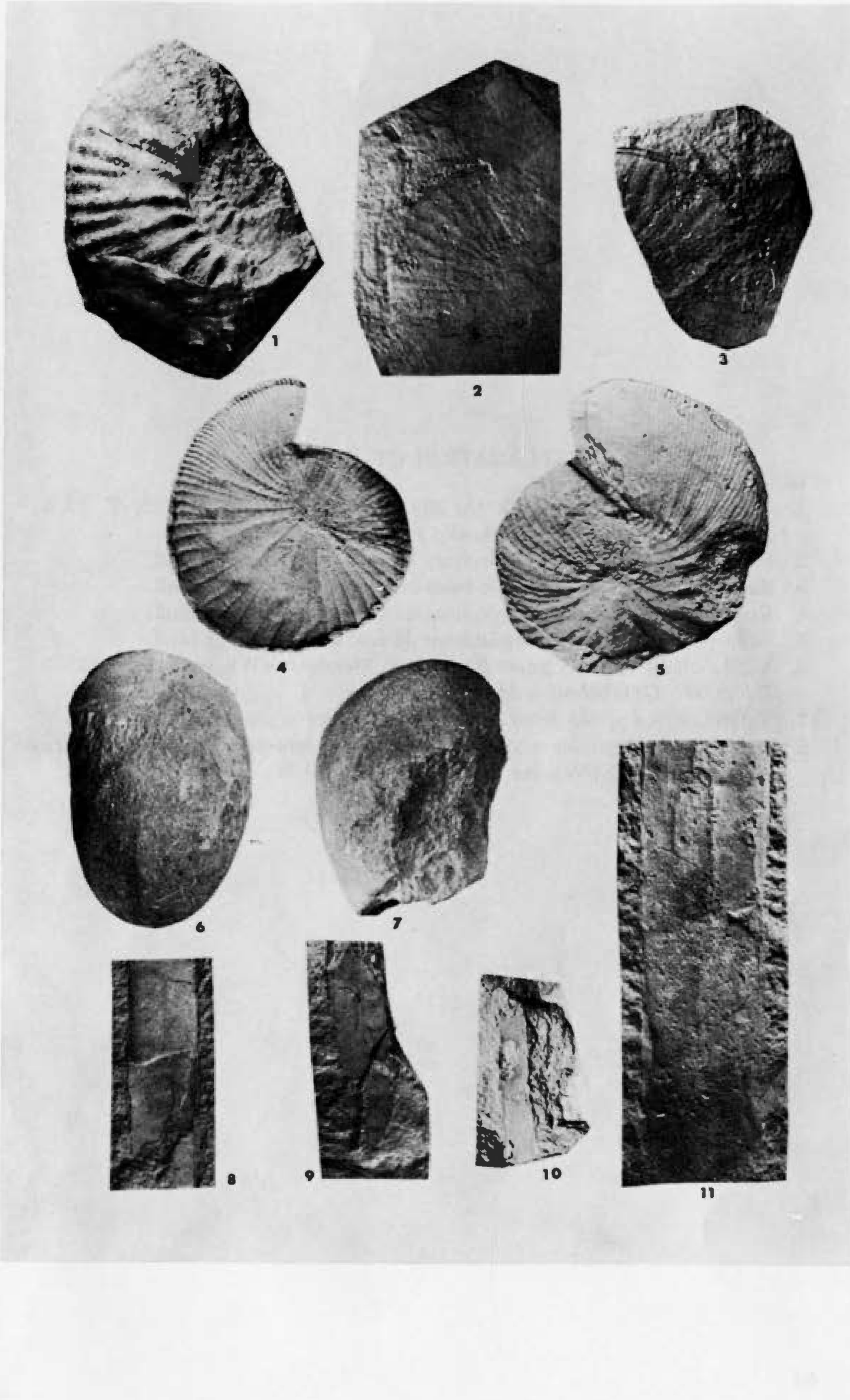
Baculites sp.

10. Smooth baculite with oyster attached, KU no number (× 1/6).

Baculites? sp.

11. Smooth baculite with barnacles attached, KU 11405 (× 1/3).

PLATE 6

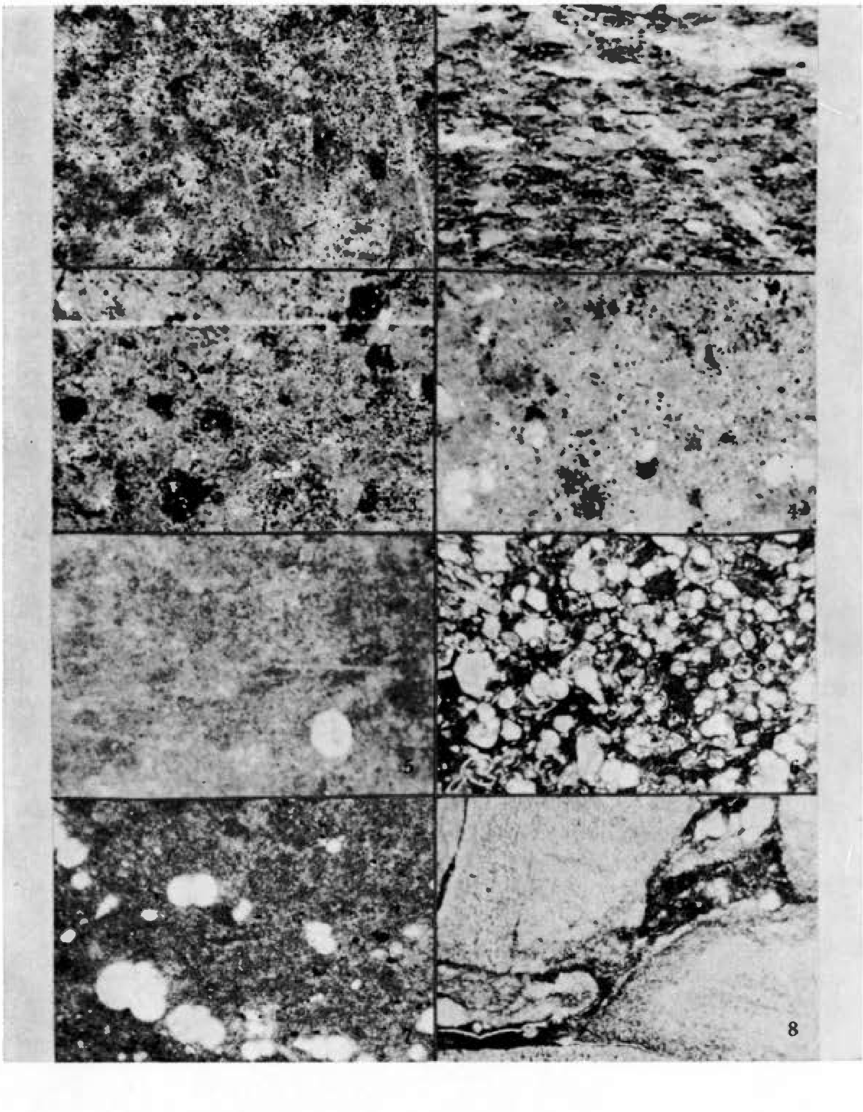


EXPLANATION OF PLATE 7

FIG.

1. Thin section of grey chalk (× 28) from N. cent. S½ sec. 25, T. 15 S., R. 33W., at base of bluff. Smoky Hill Member.
2. Same as above, except sample from 12 feet above base of bluff.
3. Same as above, except sample from 18 feet above base of bluff.
4. Same as above, except sample from 24 feet above base of bluff.
5. Same as above, except sample from 36 feet above base of bluff.
6. White chalk (× 28) from Fort Hays Member NW¼ sec. 26, T. 13 S., R. 19 W. *Gümbelina* is abundant.
7. Yellow chalk (× 28) from Smoky Hill Member in sec. 1, T. 14 S., R. 33 W.
8. Uintacrinus fragment (× 28) in crinoidal limestone from Smoky Hill Member in NE¼ SW¼ sec. 10, T. 14 S., R. 33 W.

PLATE 7



EXPLANATION OF PLATE 8

Actinocamax sternbergi Jeletzky

FIG.

1. Ventral view of type, FHKSCM 7936-1 (× ¾).
2. Dorsal view of type, FHKSCM 7936-1 (× ¾).

Actinocamax walkeri Jeletzky

3. Lateral view of FHKSCM 7936-3 (× ⅔).

Actinocamax laevigatus Jeletzky

4. Lateral view of type, FHKSCM 8126 (× 1).

Niobrarateuthis bonneri Miller

5. Dorsal view of type, FHKSCM 7959 (× ⅛).

Tusoteuthis longa Logan

6. Dorsal view of type, KU 4208 (× ⅛).

Unnamed aptychus A.

7. External view of FHKSCM 11914-2 (× 1½).
8. External view of FHKSCM 11914-2 (× 1½).

Unnamed aptychus B.

9. Internal view of FHKSCM 10279 (× 1).

Scaphites? sp.

10. Fragment of whorl, KU no number (× ⅔).

Spinaptychus sternbergi Fischer and Fay

11. External view of type, FHKSCM 2022 (× ⅕).
12. Internal view of type, FHKSCM 2022 (× ⅕).
13. External view of FHKSCM 11913-2 (× ¼).

Rugaptychus?

14. External view of FHKSCM 11888-2 (× 1½).

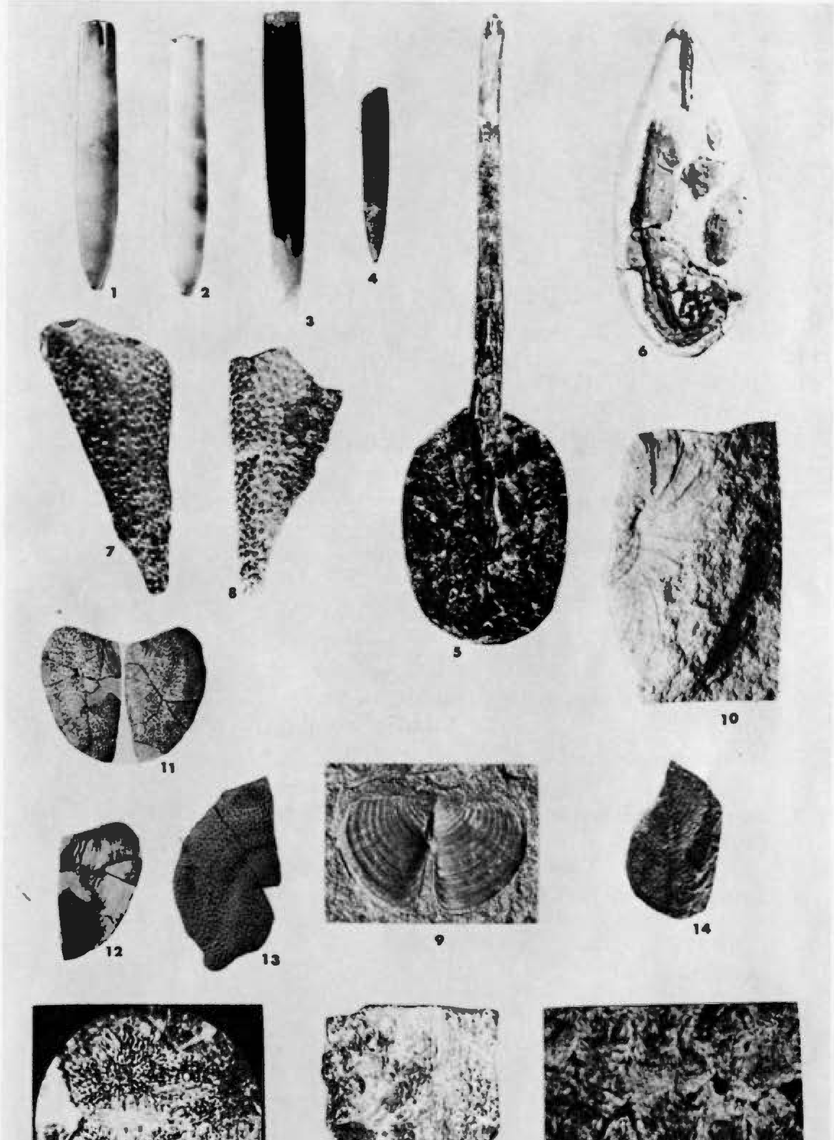
Platylithophycus cretaceum Johnson and Howell

15. Thin section of fragment, showing cuttlebone-like structure (× 80).
16. Fragment of the type, KU 11402 (× ⅔).

Recent cuttlebone

17. Thin section of Recent squid cuttlebone (× 480).

PLATE 8



EXPLANATION OF PLATE 9

Baculites sp. cf. *B. codyensis* Reeside

FIG.

1. Specimen is KU 11403 (× 3/4).

Baculites? sp.

2. Large smooth baculite with barnacles attached, KU 7294 (× 4/5).

Baculites sp.

3. Smooth baculites from *Clioscaphites chouteauensis* zone, FHKSCM 11915 (× 1/7).

Linuparis? sp.

4. Lateral view of KU 7295 (× 2).

Uintacrinus socialis Grinnell

5. Slab collected by the author, KU no number (× 1/6).

Pholas? sp.

6. Collected by Logan, KU no number (× 1).

Stramentum haworthi (Williston)

7. Williston's type specimen, KU 8323 (× 1.2)

Inoceramus involutus Sowerby

8. Exterior of left valve from basal Smoky Hill Member, FHKSCM 13031 (× 1/4).

Clioscaphites chouteauensis Cobban

9. Lateral view of FHKSCM 11784 (× 3/4).

PLATE 9

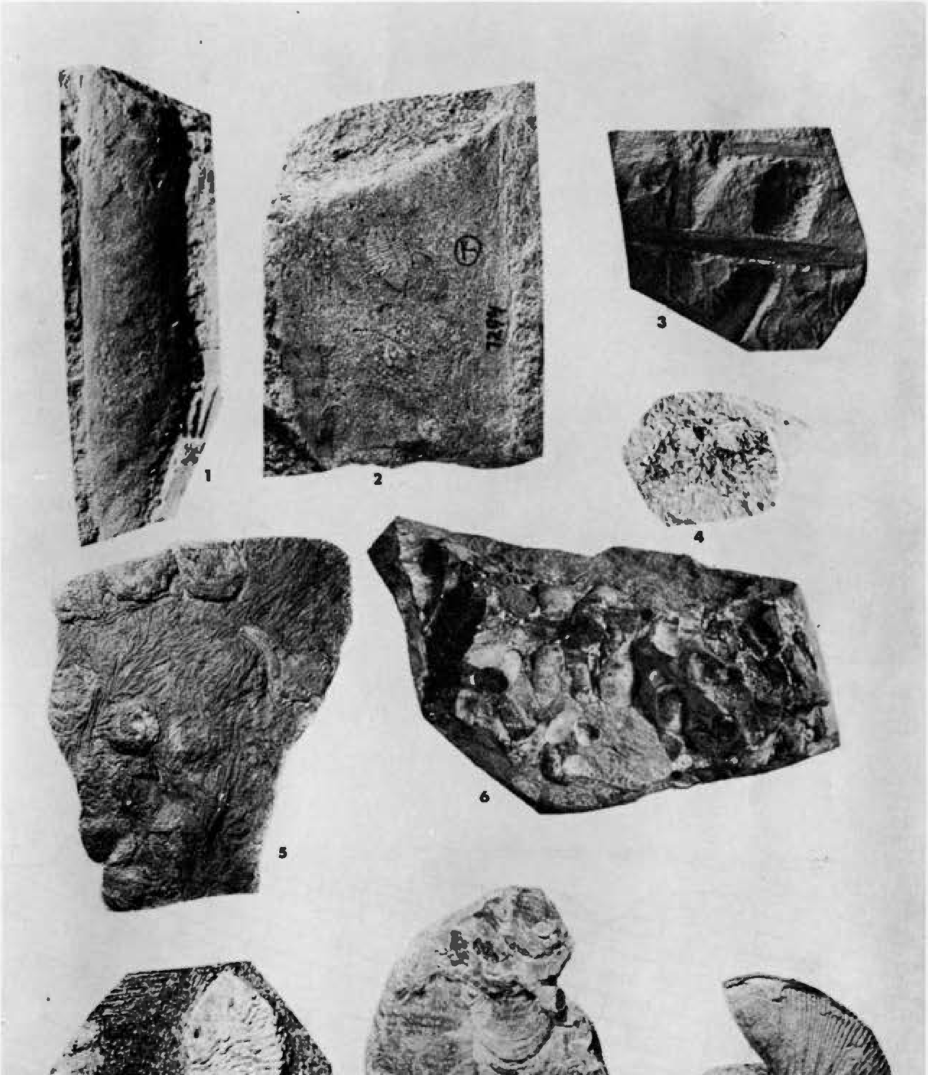


FIGURE 1. Weathering of chalk into hard yellow upper layer at Chalk Monuments in cent. SW¼ sec. 34, T. 14 S., R. 31 W., Gove County.

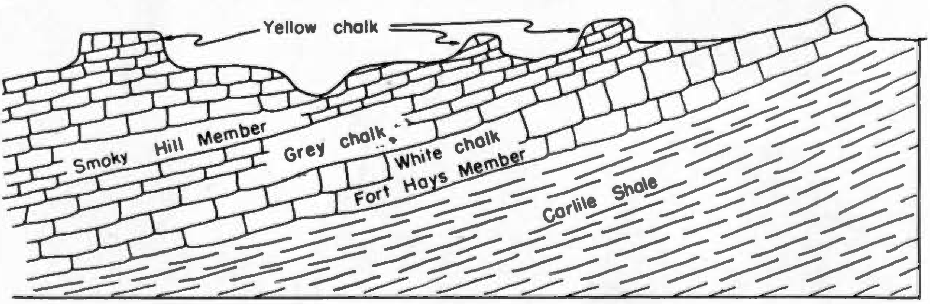


FIGURE 2. Diagrammatic cross-section showing relationship of weathered yellow chalk and unweathered gray chalk.

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