

**KANSAS GEOLOGICAL SURVEY  
OPEN-FILE REPORT 58-4**

Stratigraphy and Paleontologic Studies of the Niobrara Formation  
(Cretaceous) in Kansas

by

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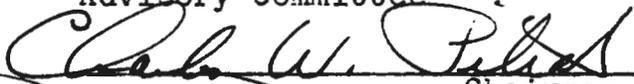
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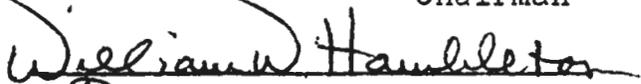
STRATIGRAPHIC AND PALEONTOLOGIC STUDIES OF THE  
NIOBRARA FORMATION (CRETACEOUS) IN KANSAS

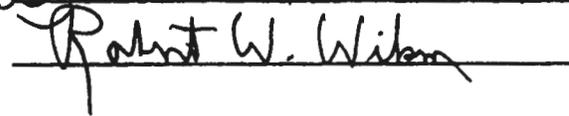
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Advisory Committee

  
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## ABSTRACT

The Niobrara Formation of Kansas is correlated with the Coniacian and Santonian stages of Europe. There is no known direct proof for Campanian age of the uppermost Smoky Hill Member in Kansas at the present time. Index fossils used for the age determination include Actinocamax, Behavites ?, Baculites, Spinptychus, and Inoceramus.

The vertebrate and invertebrate fauna of the Niobrara Formation is listed, and the macroinvertebrate fauna is reevaluated. The genus Pseudoperla Logan is synonymous with Ostrea Linne. Inoceramus grandis has been redefined to include I. niobrarenensis, I. eccentrica, and possibly I. concentricus. Inoceramus platinus is a large flat valved inoceramid present in the Niobrara Formation. Radiolites maximus Logan is placed in the genus Durania. The presence of Behavites ?, a texanitid, two species of Baculites, including Baculites cf. B. codyensis and Clioscapites vermiformis, are recorded. A new type of aptychus is recorded and described, but not named. The genus Platylithophycus Johnson and Howell is referred to the sepioid cephalopods. Twenty-two of the forty-three species previously reported or described from the Niobrara Formation are retained as valid. Seven forms previously unknown in the Niobrara Formation of Kansas are recorded. No new species are described.

The environment of deposition is interpreted as a relatively calm, density stratified, epeiric sea in which the near

bottom waters became stagnant and foul, thus limiting the abundance and variety of benthonic life. The sediments were colored grey by the accumulation of organic matter. The grey color of the sediments is lost during weathering, and the sediments become stained to bright colors by the oxidation of iron sulfides contained in the chalk.

It was not possible to use the thicknesses and intervals of the bentonite beds to determine stratigraphic positions within the upper portion of the Smoky Hill Member.

The chalk is composed of calcium carbonate (50 to 98%), quartz, clay minerals and minor amounts of gypsum, and iron sulfide. Organic matter is present in the grey chalk. The calcium carbonate is composed mainly of coccoliths; however some chemically precipitated rods and needles may be present. Such rods or needles would be difficult to distinguish from rhabdoliths or coccoliths in thin sections.

## INTRODUCTION

### Purpose and Scope

The purpose of this investigation is to interpret the environment of the Niobrara Sea, to examine the validity of the subdivision of the formation into chalk and "shale" beds and to revise the macroinvertebrate fauna of the Niobrara Formation.

The fauna of the Niobrara Formation was, for the most part, described prior to 1900, and consequently older concepts of taxonomy were applied in defining species. This situation is most obvious in the genus Inoceramus, of which 13 species have been identified or described from the Niobrara Formation, and Ostrea congesta, which has been split into 12 species.

The subdivision of the Niobrara Formation has long been a problem. Several authors have attempted to use marker beds in order to determine relative stratigraphic position within the Niobrara Formation. These marker beds have not been reexamined or reevaluated within recent years, and they are of rather doubtful value within the Smoky Hill Member.

Prior to the present study the paleoecology of the Niobrara Sea of Kansas had not been described in detail by anyone who had done field work within the outcrop area of the formation in Kansas.

### Area of Study

The study is confined to the outcrop area of the Niobrara

Formation within the state of Kansas (Fig. 1), and was begun as a project of the State Geological Survey of Kansas. Field work was conducted in Wallace, Logan, Gove, Scott, Trego, Ellis, Phillips, and Smith counties. Most of the collecting and field work was done in the Smoky Hill River in Logan, Gove, Trego, and Wallace counties.

#### Methods of Investigation

Collections of fossils were made from outcrops in western Kansas. Specimens of Niobrara fossils from collections belonging to the University of Kansas Geological Museum and the Fort Hays Kansas State College Museum were also studied by the author. William Logan's collection of type specimens from the Niobrara Formation was included among specimens contained in the University of Kansas Geological Museum. A study of variation among the "species" of Inoceramus was made to determine their taxonomic validity.

Some new specimens were described and several older specimens were redescribed. The ecology of the Niobrara Sea was interpreted from the supposed collective environment of the animals whose fossil remains have been found in the Niobrara Formation. Physical factors such as sediment grain size, content of organic matter, and sediment composition were also taken into consideration for the environmental interpretation.

The probable origin of bright colored chalk was studied



by means of thin sections, chemical analyses and measured stratigraphic sections.

Field work and areal mapping were undertaken to determine the validity and usefulness of previously published stratigraphic subdivisions of the Niobrara Formation.

Previous Work

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. Primarily Abel considered the vertebrates 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 known faunas suggest shallow depths, unfavorable bottom conditions, and quiet waters in the eastern part of the basin. More favorable conditions were present in the western part of the basin.

Williston (1897, p. 239) described the gradation of "blue" chalk into yellow chalk and ascribed the division of the Niobrara Formation into chalk and shale beds to "a myth that has been persistently adhered to by writers on the Kansas Cretaceous since the time of Mudge". Williston, however, gave no analyses or other evidence to support his statement.

Russell (1929, p. 596-599), Moss (1932, p. 16-18) and Bass (1926, p. 19-26) discussed the use of key beds for

correlation within the Niobrara Formation.

The invertebrate fauna of the Niobrara Formation of Kansas has been described as follows: Brown (1940), fossil pearls; Fischer and Fay (1953), an aptychus; Grinnell (1876), Uintacrinus; Johnson and Howell (1948), Platylithophycus, a supposed alga; Loetterle (1937), Foraminifera and ostracodes; Logan (1898, 1899b, 1899a), macroinvertebrates; Miller (1957, 1957b), squids; Morrow (1934, 1935), Foraminifera, Ostracoda, and Cephalopoda; Jeletzky (1955), a belemnite supposedly from Kansas. The vertebrate fauna has been described by many authors, including Cope, Marsh, Williston, Stewart and Wieland.

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#### FAUNA OF THE NIOBRARA FORMATION IN KANSAS

The faunal list was compiled from the paleontologic articles and papers by Abel (1922), Logan (1898, 1899a, 1899b), Loetterle (1937), McClung (1898), Morrow (1934, 1935), Williston (1897), Williston and others (1898), Williston and Stewart (1900), Wieland (1909), Lane (1945-48), Lull and Wright (1942), and Wetmore (1956), and specimens examined and described by the author. The list has been taken directly from papers by other authors and the taxonomy has not been corrected or brought up to date. It is merely an uncritical listing of all previously published reported species. Corrections will be discussed in the section dealing with the revision of the

7.  
fauna. A revised list of the macroinvertebrate fauna is given in the conclusions of the revision of the fauna.

Williston (1893, p. 110) 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, strewn the surface in heaps; large and perfect *Haploscaphas*, *Rudistes*, et., can be obtained literally by the wagon load."

Unfortunately fossils are no longer this abundant on the outcrop of the Niobrara Formation. This is probably due to the great amount of collecting done, both by amateurs and professionals.

#### Faunal List

##### Protozoa

*Gaudryina pupoides* d'Orbigny

*Gaudryina rugosa* d'Orbigny

*Robulus navarroensis* Plummer

\**Lenticulina kansasensis* Morrow

\**Lenticulina sublaevis* Morrow

\**Lenticulina macrodisca* Reuss

\**Dentalina communis* d'Orbigny

\**Dentalina reflexa* Morrow

\**Nodosaria alternistriata* Morrow

*Nodosaria zippei* Reuss

\**Vaginulina niobrarensis* Morrow

\*Restricted to Fort Hays Limestone Member

- \*Vaginulina rectilateralis Morrow  
\*Vaginulina knighti Morrow  
\*Vaginulina subcomarginata Morrow  
\*Vaginulina cf. V. texana Cushman  
\*Palmula suturalis Cushman  
\*Frondicularia verneulina d'Orbigny var. bidentata Cushman  
\*Frondicularia undulosa Cushman  
\*Frondicularia dunbari Morrow  
\*Frondicularia extensa Morrow  
\*Frondicularia aclis Morrow  
\*Flabellina cushmani Morrow  
\*Kyphopyxa christneri Carsey  
\*Kyphopyxa undulata Loetterle  
Ramulina globulifera Brady  
\*Bullopora sollasi Chapman  
Gumbelina globulosa Ehrenberg  
Gumbelina globifera Reuss  
Gumbelina plummerae Loetterle  
Gumbelina tessera Ehrenberg  
Ventilabrella eggeri Cushman  
Eouvigerina aculeata Cushman  
Eouvigerina geneae Morrow  
Eouvigerina plummerae Cushman  
\*Buliminella carseyae Plummer  
\*Bulimina elongata d'Orbigny

\*Restricted to Fort Hays Limestone Member

- \*Bulimina reussi Morrow
- \*Neobulimina irregularis Cushman and Parker
- Hantkenina trituberculata Morrow
- Bolivina crenulata Loetterle
- \*Bolivina tegulata Reuss
- Loxostoma applinae Plummer
- \*Loxostoma tegulatum Reuss
- Pleurostomella austiniana Cushman
- \*Pleurostomella nitida Morrow
- \*Valvulineria infrequens Morrow
- Valvulineria plummerae Loetterle
- \*Gyroidina lenticula Reuss
- \*Gyroidina nitida Reuss
- \*Gyroidina depressa Althelm
- Globorotalia subconica Morrow
- Globorotalia umbilicata Loetterle
- Globigerina cretacea d'Orbigny
- Globigerina marginata Reuss
- Globotruncana arca Cushman
- Globigerinella aspera Ehrenberg
- \*Planulina complanata Reuss
- Planulina kansasensis Morrow

Porifera

Sponge spicules (siliceous)

\*Restricted to Fort Hays Limestone Member

## Mollusca

Ostrea congesta ConradOstrea larva LamarckOstrea exogyroides LoganOstrea incurva LoganOstrea attenuata LoganOstrea crenula LoganOstrea lata LoganOstrea jewellensis LoganOstrea leei LoganPseudoperna rugosa LoganPseudoperna torta LoganPseudoperna attenuata LoganPseudoperna orbicularis LoganPseudoperna wilsoni LoganInoceramus truncatus LoganInoceramus flaccidus White\*Inoceramus deformis Meek\*Inoceramus simpsoni MeekInoceramus pennatus LoganInoceramus subtriangularis Logan\*Inoceramus browni CraginInoceramus concentricus LoganInoceramus platinus Logan

\*Restricted to Fort Hays Limestone Member

Inoceramus fragilis Meek and Hayden

Haploscapha grandis Conrad

Haploscapha eccentrica Conrad

Haploscapha niobrarensis Logan

Radiolites maximus Logan

\*Parapholas sphenoides White

Eutrephoceras sp.

Baculites sp.

Ammonite sp. (Pachydiscus?)

Spinaptychus sternbergi Fischer and Fay

Belemnitella praecursor Stolley var. media Jeletzky

Tusoteuthis longus Logan

Niobrarateuthis bonneri Miller

#### Annelida

Serpula intricata White

Serpula tenicarinata Meek and Hayden

#### Echinodermata

Uintacrinus socialis Grinnell

#### Arthropoda

Stramentum haworthi Williston

Stramentum tabulatum Logan

Squama lata Logan

Squama spissa Logan

\*Cytherella bullata Alexander

\*Restricted to Fort Hays Limestone Member

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- \*Cytherella kansasensis Morrow
  - \*Cytherella parallela Reuss
  - \*Morrowina unilacuna Morrow
  - \*Paracypris tenicula Alexander
  - \*Brachycythere sphenoides Reuss
  - \*Cythereis alexanderi Morrow
  - \*Cythereis alexanderi abbreviata Morrow
  - \*Cythereis coryelli Loetterle
  - \*Cythereis niobrarensis Morrow
  - \*Cythereis ozanana Israelsky
  - \*Cythereis subgracilis Morrow

#### Vertebrata

##### Pisces

- Ptychodus mortoni Mantell
- Ptychodus polygyrus Buckland
- Ptychodus martini Williston
- Ptychodus anonymus Williston
- Isurus mantelli Geinitz
- Lamna appendiculata Roemer
- Lamna mudgei Cope
- Lamna macrorhiza Cope
- Corax falcatus Agassiz
- Ichthyriapus hubbsi Hibbard
- Pycnomicrodon kansasensis Hibbard and Graffham
- Protosphyraena recurvirostris Stewart

\*Restricted to Fort Hays Limestone Member

Protosphyraena penetrans Cope  
Martinichthys mcclungi  
Martinichthys ziphioides Cope  
Pachyrhizodus kingi Cope  
Pachyrhizodus latimentum Cope  
Pachyrhizodus sheareri Cope  
Pachyrhizodus caninus Cope  
Pachyrhizodus leptopsis Cope  
Pachyrhizodus leptognathus Stewart  
Pachyrhizodus velox Stewart  
Pachyrhizodus minimus Stewart  
Saurocephalus arapahovius Cope  
Saurocephalus dentatus Stewart  
Saurocephalus pamphagus Hay  
Saurodon phlebotomus Cope  
Saurodon broadheadi Stewart  
Saurodon xiphirostris Stewart  
Saurodon ferox Stewart  
Portheus audax Leidy  
Portheus lowi Stewart  
Portheus brachygnathus Stewart  
Portheus molossus Cope  
Ichthyodectes anaides Cope  
Ichthyodectes ctenodon Cope  
Ichthyodectes hamatus Cope  
Ichthyodectes prognathus Cope

Ichthyodectes multidentatus Cope

Ichthyodectes goodeanus Cope

Ichthyodectes acanthicus Cope

Ichthyodectes perniciosus Cope

Ichthyodectes cruentus Hay

Gillicus arcuatus Cope

Cimolichthys nepoeolica Cope

Cimolichthys semianiceps Cope

Cimolichthys contracta Cope

Cimolichthys merrilli Cope

Ananogmius contractus Cope

Ananogmius aratus ? Cope

Ananogmius evolutus Cope

Ananogmius polymicrodus Stewart

Enchodus petrosus Cope

Enchodus dolichus Cope

Enchodus calliodon Cope

Enchodus gladiolus Cope

Enchodus anceps Cope

Enchodus carinatus Cope

Enchodus semistriatus Marsh

Enchodus dirus Leidy

Enchodus shumardi Leidy

Enchodus amicrodus Stewart

Enchodus minimus Stewart

Leptecodon rectus Williston

Niobrara encarsia Jordan  
Zanclites xenurus Jordan  
Luxilites striolatus Jordan  
Ferrifron rugosus Jordan  
Stratodus apicalis Cope  
Stratodus oxypogon Cope  
Kansius sternbergi Hussakof  
Kansius martini Jordan  
Eurychir lindleyi Jordan

## Reptilia

### Chelonia

Archelon ischyros Wieland  
Protostega copei Wieland  
Cynocercus incisus Cope  
Porthochelys laticeps Williston  
Toxochelys brachyrhinus Case  
Toxochelys bauri Wieland  
Toxochelys latiremis Cope  
Toxochelys serrifer Cope

### Plesiosauria

Polycotylus latipinnis Cope  
Polycotylus dolichopus Williston  
Trinacromerum osborni Williston  
Styxosaurus snowi Williston  
Thallosaurus ischiadicus Williston

Thalassonomosaurus marshi Williston

Thalassonomosaurus nobilis Williston

Elasmosaurus ischiadicus Williston

Elasmosaurus platyurus Cope

Elasmosaurus snowii Williston

Elasmosaurus sternbergi Williston

Squamata

Baptosaurus onchognathus Merriam?

Clidastes cineriarum Marsh

Clidastes liodontus Merriam

Clidastes tortor Cope

Clidastes velox Marsh

Clidastes wymani Marsh

Holosaurus abruptus Marsh

Sironectes anguliferus Cope

Platecarpus clidastoides Merriam ?

Platecarpus coryphaeus Cope

Platecarpus felix Marsh ?

Platecarpus glandiferus Cope

Platecarpus ictericus Cope

Platecarpus latifrons Marsh ?

Platecarpus mudgei Cope

Platecarpus oxyrhinus Merriam ?

Platecarpus planifrons Cope

Platecarpus simus Marsh ?

Tylosaurus dyspelor Cope

Tylosaurus micromus Marsh

Tylosaurus nepaeolicus Cope

Tylosaurus proriger Cope

Pterosauria

Nyctodactylus gracilis Marsh

Pteranodon comptus Marsh

Pteranodon ingens Marsh

Pteranodon longiceps Marsh

Pteranodon nanus Marsh

Pteranodon occidentalis Marsh

Pteranodon umbrosus Cope

Pteranodon velox Marsh

Ornithischia

Claosaurus agilis Marsh

Hierosaurus sternbergi Wieland

Aves

Hesperornis crassipes Marsh

Hesperornis gracilis Marsh

Hesperornis regalis Marsh

Baptornis advenus Marsh

Ichthyornis agilis Marsh

Ichthyornis anceps Marsh

Ichthyornis dispar Marsh

Ichthyornis tener Marsh

Ichthyornis validus Marsh

Ichthyornis victor Marsh

Apatornis celer Marsh

Plants

Coccoliths and rhabdoliths

Platylithophycus cretaceum Johnson and Howell

Pinus questedi Brown

wood fragments

REVISION OF MACROINVERTEBRATE FAUNA

The macroinvertebrate fauna of the Niobrara Formation is limited in both variety and numbers. The most abundant faunal elements are Inoceramus and Ostrea congesta. All other macroinvertebrate fossils are rare by comparison. The synonymies are restricted to papers concerning specimens from Kansas, or to papers affecting the taxonomy of Kansas specimens.

Phylum Mollusca Linnaeus

Class Pelecypoda Blainville

Order Dysodonta Neumayr

Family Pernidae Zittel

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 (one mm. 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 inoceramids of the Niobrara Formation of Kansas.

Inoceramus deformis Meek, 1871

Plate 3, Figs. 5, 6.

Inoceramus deformis Meek 1871. Ann. Rept. U. S. Geol. Surv. Terr. for 1870, p. 296. White 1876. U. S. Geol. & Geog. Surv. West 100 Meridan: 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 seven inches in diameter), very convex, and marked by strong, concentric undulations. The shell is thin (2mm.) 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 are prominent, and the hinge line is relatively short. The valves are probably nearly equal in size. Concentric markings cover the entire valve.

#### 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 probably 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, 2, 3; Plate 2, Figs. 1-9.

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. Surv. Terr.,

v. 2, p. 24, pl. 67, Logan 1898. Univ. Kans. State

Geol. 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, p. 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.

DESCRIPTION.

Inoceramus grandis is characterized by a convex right valve and a relatively long hinge line. The beak is confined to the anterior portion of the hinge. The central portion of the shell is ornamented with strong, concentric undulations occupying a definite area. 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 lid, or left valve, is probably flat, ovate, smooth on the interior, and marked by prominent concentric ridges on the outer surface. The left valves vary in thickness from 2 to 6 mm.

#### 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. Hall's illustration is probably of a specimen 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 Haploscapha. 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, the valves are relatively more convex, and the species (I. deformis) is restricted to the Fort Hays Member. Hall's specimen came from a "light yellowish-grey limestone, probably of the cretaceous (sic) formation" in the Front Range area. Only Inoceramus deformis has been found in that region.

Inoceramus grandis ranges throughout both the Fort Hays and Smoky Hill Members of the Niobrara Formation. The shells are much distorted and flattened during preservation. This, combined with the intraspecific variability of Inoceramus grandis has led to the description of too 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 (up to 35 cm. wide by 28 cm. high), thick (up one cm.), and subovate in outline. Only right valves have been previously described for this species. Some specimens have two valves seemingly connected along the hinge line. However, the two valves are both right valves; they are both asymmetrical toward the postero-ventral margin. To date the right and left valves have not been found in the same specimen. Inasmuch as the lower valve is concave, and tends to be cup shaped, the upper valve may be flat. Specimens of "I. concentricus" Logan (not I. concentricus Parkinson) are rather abundant in the Niobrara Formation, and it may be that this "species" is really the lid, or left valve, of I. grandis.

The writer has not found any specimens of I. grandis with a lid or upper valve. Conrad (1873, p. 455-56) 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 convex left valve, which is smooth, and a flat or slightly convex right valve, which has strong concentric markings. Woods, (1912, p. 7-11). This species differs from I. grandis in that the beak of I. involutus is strongly developed and spirally curved and that the right valve is smooth and flat. However, the presence of a convex valve, and a flat lid, with strong concentric markings in both species causes them to resemble each other. This resemblance is probably caused by adaptation to a similar mode of life, rather than a phylogenetic relationship.

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. 12S., R. 18W., an area in which only 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. The writer has discovered many specimens of I. grandis in the Fort Hays Member.

Inoceramus inconstans Woods, 1911

Inoceramus inconstans Woods 1911. Paleo. Soc., v. 2, pt. 7, p. 285-291, figs. 41-50.

Inoceramus simpsoni Meek: Logan 1898. Univ. Kans. State Geol. Survey, v. 4, pt. 8, p. 487, pl. 97.

DISCUSSION.

Logan reported this species in the Fort Hays Member, although he said that it was rare. No specimens of this species from the Niobrara Formation of Kansas are preserved in the University of Kansas collections, nor have any been found in recent years. The type of I. simpsoni according to Meek (1860, p. 312) came from the "North Platt (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, cryptocrystalline limestone and not a chalk. The specimen is actually Inoceramus inconstans Woods, which is probably in synonymous with I. deformis, and resembles specimens from the Cretaceous of England, as well as specimens of I. deformis from rocks of Fort Hays age in Colorado.

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, p. 485-6, pl. 90.

## DISCUSSION.

Logan reported this species from the lower Smoky Hill Member in Kansas. There are no specimens of this species in the University of Kansas Geological Museum, nor have any been found in recent years. Logan's illustrated specimen appears to be an internal cast, probably it is a picture of White's type specimen.

White's specimen (the type) was from "strata of Cretaceous period, 5 miles above Pueblo, Colorado." It was found in a fine-grained, calcareous sandstone. Specimens of Inoceramus deformis Meek, were also collected from the same locality (White, 1876, p. 179). Rocks of the Graneros Formation, Greenhorn Formation, Carlile Shale, and the Fort Hays Member are exposed in this area.

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

Inoceramus platinus Logan, 1898

Plate 3, Figs. 3, 4.

Inoceramus platinus Logan 1898. Univ. Kans. State Geol.

Survey v. 4, pt. 8, p. 491.

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 (one 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 inoceramid ornamentation.

DISCUSSION.

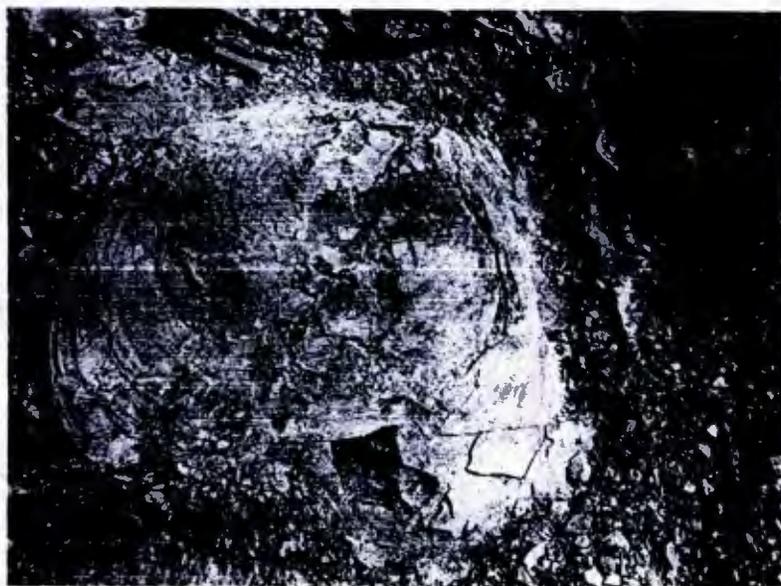
Inoceramus platinus was described by Logan, however the specimen he figured for the illustration of the type is Inoceramus subconvexus Logan from the "Benton limestone" on Salt Creek, south Mitchell County, or near Ellsworth, Kansas. This (KU 5783) is the type specimen of I. subconvexus and

was collected by Logan from one of the two previously mentioned localities. Inoceramus platinus Logan has never been previously illustrated. The type specimen is listed as Ku 4204 in the catalog of the University of Kansas Geological Museum. The type specimen could not be located.

This species is very abundant in the Smoky Hill Member, 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 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, A.M.N.H. no. 18956, and is from near Elder, 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 one mm. or less in thickness.

A third specimen was discovered by the author in NW $\frac{1}{4}$  sec. 6, T. 15S., R. 32W. (Figure 2). This specimen measured 54 inches wide by 50 inches high, and the shell material of the valve was less than one mm. thick. However it was too fractured to be removed from the chalk. None of the specimens

Figure 2. Inoceramus platinus Logan



Inoceramus platinus Logan from NW $\frac{1}{4}$ , sec. 6, T. 15S.,  
R. 32W. in Smoky Hill Member, Logan County. The  
specimen was not collected. It measured 54 by 50  
inches.

referred to this species has been previously illustrated.

Table 1. 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 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.

Nomena nuda

Plate 3, Figs. 1, 2.

"Inoceramus truncatus" Logan 1898. Univ. Kans. State Geol. Surv. v. 4, pt. 8, p. 492, pl. 114.

#### DESCRIPTION.

The type specimen 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 eight to twelve mm. thick, smooth on the interior surface and fine concentric growth lines and pits ornament the exterior surface of the valve.

#### DISCUSSION.

Logan described Inoceramus truncatus from a fragment of what is apparently a large, flat, 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. It is impossible to tell the exact relationship of this specimen from Logan's type specimen and somewhat confusing description. Apparently no specimens of this species have been discovered in recent years.

Logan stated this species was closely related to I. platinus and was confined to the lower Smoky Hill Member. It is possible this species is a thicker shelled variety of I. platinus, however the type specimen is too incomplete for positive determination.

Nomena nuda

Plate 1, Fig. 9.

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

DISCUSSION.

The type specimen of I. subtriangularis (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 line 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. The exact relation of the fragmentary valve cannot be determined, and it is referred to *nomena nuda*.

*Nomena nuda*

Plate 1, Fig. 10, Plate 2, Fig. 2.

"Inoceramus pennatus" Logan 1898. (in part), Univ. Kansas State Geol. Survey, v. 4, pt. 8, p. 488, pl. 120, fig. 2.

DISCUSSION.

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 enough to be identifiable. It probably belongs to a thin shelled species of Inoceramus, if it is a pelecypod. The species is referred to *nomena nuda*, because of the uncertainty of its relationships.

*Nomena nuda*

not illustrated

"Inoceramus browni" Cragin 1889. Cont. to the paleontology of the plains, Washburn Coll. Lab. Nat. Hist., Bull. 2, n. 1, p. 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 synonomous with Inoceramus deformis Meek, however this can not be proved. The species is therefore referred to nomena nuda.

Family Ostreidae Lamarck

Genus Ostrea Linne, 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, symmetrical 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 Pseudoperma Logan, 1899, is considered synonomous with Ostrea Linnaeus, 1758.

Ostrea congesta Conrad, 1843

Plate 1, Figs. 5, 6, 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.

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

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.

Pseudoperna wilsoni Logan 1899. Field Mus. Nat. Hist., Geol.  
Surv. v. 1, n. 6, p. 215-16, pl. 26, fig. 4, 5.

#### 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 one 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 in function, 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.

Logan, 1899a, described several unattached and therefore, undistorted specimens of O. congesta as several species of Pseudoperna, a new genus. P. wilsoni Logan is number P. 5945 of the Chicago Museum of Natural History. The location and collection numbers of Logan's other type specimens is not known. The specimens illustrated by Logan as Pseudoperna all have the typical toothless hinge line with the single large resilifer, and the monomyarian shell that characterizes Ostrea; therefore this genus is considered to be synonymous with Ostrea. The variations used by Logan to define his "species" of Pseudoperna and Ostrea are only variations in shape and size caused by the varying positions and conditions of growth. The shells of oysters are greatly influenced during their growth by crowding, or lack of crowding, as well as other environmental factors. Recent oysters (Abbott, 1954, p. 375) have somatic variations related to physical factors of their

environment.

Ostrea congesta is a variable species and all the forms described by Logan may be seen within its intraspecific variation.

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 larva Lamarck, 1835

not illustrated

Ostrea larva Lamarck 1835. Histoire Naturelle des Animaux sans Vertebres, v. 6, p. 216 (Paris).

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 beak. The margins of the shells interlock along the 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. No specimens have been found in recent years and none of the specimens in the University of Kansas collection can be located. The catalog lists KU 4112 as O. larva, from the Niobrara Formation of western Kansas.

Ostrea cf. O. leei Logan, 1899

Plate 1, Fig. 4.

Ostrea leei Logan 1899. Kans. Univ. Quart., v. 6, n. 4, p. 94.

DESCRIPTION.

The Niobrara specimen closely resembles Ostrea blacki White from the Cretaceous of Texas and the two may be identical. The Kansas specimen consists of a single, convex lower valve. The upper valve, which is missing, apparently was flattened or concave. The edge of the shell is crenulated, and shallow plications extend toward the umbo across the upper surface of the shell.

DISCUSSION.

The Kansas University Geological Museum (KU 7107) has a small specimen identified as Ostrea lugubris, collected in Wallace County by Mudge. The zone of O. lugubris, however is confined to the Carlile Shale (Turonian) and the specimen has been misidentified. Ostrea cf. O. leei differs from O. lugubris, in that the Niobrara specimen is larger (height 50 mm., width 47 mm.) and the shell is not crenulated on the inner surface.

Logan's type specimen of Ostrea leei is not available for comparison. Logan (1899a) did not give the location or collection number of his type specimen.

Order Heterodonta Neumayr

Family Pholadidae Leach

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."

DISCUSSION.

A redescription or reevaluation of this genus is not warranted at this time, inasmuch as the author does not have any specimens.

Parapholas sphenoides White, 1876

not illustrated

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

Parapholas sphenoides (White) 1879. Ann. Rept. U.S. Geol.

Surv., for 1877, p. 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. sphenoides). Logan neither described nor figured the Niobrara specimens. Logan's specimens have not yet been located in the University of Kansas collection. 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 by the author.

Order Pachyodontida

Family Radiolitidae Gray

Subfamily Sauvagesinia Douville

Genus Durania Douville, 1908

type species: Biradiolites cornupastoris

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. 5, 6, 7, 8.

Radiolites maximus Logan 1898. Univ. Kans. State Geol. Surv.,  
v. 4, pt. 8, p. 494-495, pl. 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 six centimeters to ten 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 by the author are 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  $80^{\circ}$  to approximately  $45^{\circ}$ .

The wall cells are polygonal (and 1mm. 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 4169, is listed as coming from Wallace County (Mudge collection), specimen F.H.K.S.C.M. 10336 is from Gove County, and specimen KU 4078 is from Logan County. Specimen F.H.K.S.C.M. 4092 was collected by Mr. Sternberg in sec. 24, T. 13S., R. 28W., 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. George F. Sternberg (personal communication, 1957) has discovered specimens of Durania in the "Benton Group" of Kansas.

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.

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

Class Cephalopoda Cuvier

Order Nautiloidea Owen

Family Nautilidae Spath

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

Genus Eutrephoceras Hyatt, 1894

type species: Eutrephoceras dekeyi Morton, 1833

## DIAGNOSIS.

Eutrephoceras includes 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 4, Figs. 1, 2.

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

## DISCUSSION.

The genus Eutrephoceras is represented by a single, incomplete specimen from the Smoky Hill Member in NE $\frac{1}{4}$ , sec. 2 T. 3S., R. 20W. 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."

## Order Ammonoidea Zittel

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, 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, fig. 1, 7) paper has the only previously described and illustrated ammonites from the Niobrara Formation of Kansas.

Suborder Lytoceratina Hyatt

Superfamily Turrilitacea Meek

Family Baculitidae Meek

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.

Plate 4, Figs. 3,4.

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

## DESCRIPTION.

One specimen (KU 11403) from sec. 34, T. 14S., R. 31W. has a width of 22mm. 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.

A second specimen was discovered in SW $\frac{1}{4}$ , sec. 34, T. 14S., R. 31W. by the author. This specimen is much flattened, shows no suture lines, and no nodes. The specimen is approximately 21 mm. across at its smaller end and 29 mm. across at its larger end. The entire specimen is approximately 122 mm. long. The specimen may represent the living chamber portion of the shell, and apparently is the same species as the one collected by Morrow, although it may be a small specimen of the species referred to as Baculites? in this paper. The specimen is preserved in the University of Kansas Geological Museum, no collection number.

## DISCUSSION.

Several specimens of Baculites sp. have been found in the Smoky Hill Member of Kansas. Baculites codyensis Reeside has been found in the upper Niobrara Formation of Montana and the middle Niobrara Formation of Utah. It is rather small, 8 or 9 mm. in diameter, and has close set arcuate nodes. Baculites aquilaensis Reeside occurs in the Pierre Shale and Telegraph Creek Formation of the Western Interior. This species is larger

than B. codyensis (22-25 mm. in diameter) has arcuate ribs that appear on early portions of the shell, and is smaller than younger species of Baculites.

W.A. Cobban (personal communication, April 21, 1958) wrote the author in part;

"The baculite, KU 11403 from the chalk monuments in secs. 33 and 34, T. 14S., 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 Clioscapites 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 specimen is too poorly preserved to warrant specific description and is number KU 11403 in the University of Kansas Geological Museum collection. Morrow (1935, p. 473) discussed this specimen and noted its resemblance to B. ovatus Say. B. ovatus is found in the Pierre Shale and Telegraph Creek Formation and is much larger than the Niobrara specimen.

Baculites ? sp.

Fig. 11

DESCRIPTION.

Four specimens of large Baculites ? sp. are preserved in the University of Kansas Geological Museum. Specimen KU 11405 is labelled "Stramentum haworthi, Cretaceous, Kansas". It consists of a flattened, sutureless chamber, 62 to 55 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 are from "near Gove City, Kansas", and were collected by Haworth.

A fourth specimen is 42 to 43 mm. wide, 110 mm. long, 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 (a foot or more in length and up to 50 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 Clioscaphtes 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.

None of the Kansas specimens are complete, and none of the specimens have the aperture preserved. Two of the Kansas specimens (KU 7294 and possibly the specimen described as Baculites sp. from SW $\frac{1}{4}$  sec. 34, T. 14S., R. 31W.) are probably from within or close to the Clioscaphtes vermiformis zone.

This means the species occurs in rocks of upper Santonian age in Kansas. The other specimens, KU 11405 and KU no number, have no locality information. The Kansas specimens may occur in younger rocks than the Colorado specimens, although not enough reliable locality information is available to be certain of this at the present time.

Superfamily Scaphitacea Meek

Family Scaphitidae Meek

Subfamily Scaphitinae Meek

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 stage) 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 nodes at the ventro-lateral ends of the primary ribs. There may be intercalated ventral ribs. The lobes of the suture are normally bifid in the adult stages.

Scaphites? sp.

Plate 5, Fig. 7.

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 become lost. It consists of a chalk impression of an external cast. The specimen shows no suture line and is incomplete.

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 Clioscaphtes 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 Clioscaphtes montanensis (pl. 16). The degree of coiling and ribbing most closely resembles that of S. depressus".

The references cited are in Cobban, 1951.

Scaphites depressus occurs in rocks of middle and late Niobrara age (Cobban, 1951, p. 11).

Genus Clioscaphtes Cobban, 1952

type species: Clioscaphtes 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.

Clioscaphtes 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.

Clioscaphtes 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 of this species was figured by A.L. Morrow in his master's thesis. The specimen has become 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. 14S., R. 31W.). 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.

Suborder Ammonitina Hyatt

Superfamily Acanthoceratidae Hyatt

Family Collignoniceratidae Wright and Wright

Subfamily Texanitinae Collignon

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 are more lateral tubercles than umbilical tubercles, because many intercalated ribs, which do not extend to the umbilicus, occur. The previously known range of this genus was upper Santonian to middle Campanian of Zululand and Madagascar.

Bevahites ? sp.

Plate 6, Fig. 9.

Pachydiscidae? Morrow 1935. Jour. Paleontology, v. 9, n. 6,  
p. 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, however, 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 has not previously been reported from the United States. It has been found in upper 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 lower Campanian rocks of Madagascar, however the Kansas specimen was associated with Clioscaphtes vermiformis and therefore is Santonian age.

The specimen was discovered by A.L. Morrow in NW $\frac{1}{4}$  sec. 15, T. 15S., R. 32W., Logan County. Morrow considered the

specimen to be closely related to Pachydiscus, probably an undescribed genus.

#### Aptychi

At least two "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.

#### 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, 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 Spinptychus. The "Texanites" specimen was mislabelled sometime in the past, probably when the collection was reorganized. The specimen may be from Comanchean rocks of Texas (T. Matsumoto, personal communication).

Spinptychus sternbergi Fischer and Fay, 1953

Plate 6, Figs. 6, 7.

Spinptychus sternbergi Fischer and Fay 1953. State Geol.

Surv. of Kans., Bull. 102, pt. 2, p. 77-92, pls. 1-2.

DESCRIPTION.

The specimens of Spinptychus sternbergi described by Fischer and Fay ranged from 90-170 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. 14S, R. 31W.). Several other specimens from Logan and Gove counties are preserved in the Museum.

#### Aptychus

Plate 6, Fig. 5.

#### 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 (number 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 referred to a genus and the author has not named the specimen.

Order Dibranchiata Owen

Suborder Belemnnoidea Naef

Family Belemnitellidae Pavlow

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". The writer's field work in the Smoky Hill Member, indicates that belemnoids are perhaps rarer than Williston's statement indicates. Williston did not name or describe any of the belemnoid specimens.

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.

Actinocamax cf. A. manitobensis Whiteaves, 1889

Plate 5, Figs. 1, 2.

Actinocamax manitobensis Whiteaves 1889. *Contr. Can. Paleont.*, v. 1, pt. 2, p. 151-196, pls. 21-31.

Belemnitella praecursor Miller 1957. *Jour. Paleont.*, v. 31, n. 5, p. 908-912, fig. 1 a, d, (in part).

## DESCRIPTION.

The guard of this species is slightly lanceolate when seen either from the dorsal or ventral position, however the guard is cylindrical when seen from the lateral position. The guard is tapered slightly at each end, and the guard tapers abruptly to an apex in the last fourth of its length. A shallow pseudoalveolus is present. A deeply incised ventral furrow is present. The surface of the guard is ornamented with faint longitudinal striations near the apex. The rest

of the specimen is smooth and lacks ornamentation.

#### DISCUSSION.

The specimen is number 7936-2 in the Fort Hays Kansas State Museum. Jeletzky (personal communication, Feb. 12, 1958) considers this form to be of upper Turonian or Coniacian age. The locality for the specimen is not known; it probably came from Trego or Gove Counties, Kansas.

Actinocamax cf. A. groenlandicus Birkelund, 1956

Plate 5, Figs. 3, 4.

Actinocamax groenlandicus Birkelund 1956. Medd. om Gron.,

v. 137, n. 9, p. 5-11, pl. 1, fig. 1 a-c, 2, 3 a-c.

Belemnitella praecursor Miller 1957. Jour. Paleont., v. 31,

n. 5, p. 908-12, fig. 1 b, c, (in part).

#### 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.

Genus Belemnitella d'Orbigny, 1845

type species: Belemnites mucronatus 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 dorso-lateral 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, p. 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 dorso-lateral grooves are distinct in the lower two-fifths of the guard, and they grade into rounded dorso-lateral 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 120-125 mm. long before it was broken.

#### DISCUSSION.

This species and variety is represented by a single specimen (KU 3979) 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 specimen was labelled according to Jeletzky, "Belemnites, U.K., Colorado". The label actually 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, however it may be from the Niobrara Formation, or one of its equivalents. The alveolus of the guard is largely filled with crystalline calcite, however a portion of the alveolus is filled with yellow chalk containing Globigerina and fish scales. This association is characteristic of the Niobrara Formation.

It is not certain this specimen came from the Niobrara Formation. However if it did, it would indicate that part of the Niobrara Formation is of uppermost Santonian or lower Campanian age, at least in Colorado.

Suborder Teuthoidea Naef

Superfamily Mesoteuthoidea Naef

Family Palaeololiginidae Naef

Four genera assigned to the dibranchiate family Palaeololiginidae Naef have been described from North America. Three of these, Tusoteuthis Logan, Phylloteuthis Meek and Hayden, and Niobrarateuthis Miller, were discovered in the Niobrara Formation. The fourth genus, Ptiloteuthis Gabb (1869) found in the Cretaceous of California, was described as a squid but subsequently has been shown by Rehn (1939) to be an insect wing (Miller, 1957a). The genera Tusoteuthis, Niobrarateuthis and Phylloteuthis are more closely allied to each other than any one of them is to Paleololigo, and they should perhaps be grouped into a separate family.

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

Genus Tusoteuthis 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" Zittle; 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.

Tusoteuthis longus Logan, 1898

Plate 5, Fig. 5.

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

## DESCRIPTION.

The guard of the type specimen is cylindrical, approximately 20 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. longus in that it is much smaller than T. longus and the gladius bears concentric markings parallel to its outline. The second specimen may be a young form of Tusoteuthis longus and is provisionally classed as such in this paper. Both specimens are incomplete and cannot be studied in detail.

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 a 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 5, Fig. 6.

Niobrarateuthis bonneri Miller 1957. Jour Paleontology,  
v. 31, n. 4, p. 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 approx-

imately 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 south  $\frac{1}{2}$ , section 8, T. 15S., R. 34W., 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, Hays, Kansas (Miller, 1957a).

Sepiodea, 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. Magdefrau (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, "Cocconeuthis cretaceum" 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, however the familial and generic identity of the specimen cannot be determined with certainty from the fragments available.

Platylithophycus cretaceum Johnson and Howell

Plate 5, Figs. 8, 10.

Platylithophycus cretaceum Johnson and Howell 1948. Jour.

Paleo. v. 22, n. 5, p. 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 a 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 in the vicinity of T. 14S., R. 31W.

Phylum Annelida Lamarck

Class Chaetopoda Blainville

Order Polychaeta

Family Serpulidae Savigny

Genus Serpula Linnaeus, 1758

type species: Serpula vermicularis Linnaeus, 1758

DIAGNOSIS.

The genus Serpula includes those 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 intricata White, 1876

not illustrated

Serpula intricata White 1876. U.S. Geol. and Geog. Surv.

Terr. West 100th Merid., v. 4, p. 205, pl. 15, fig. 5 a.

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 must be 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 6, Fig. 4.

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 "Fort Benton Group", and not from the Niobrara Formation. It seems probable, therefore, that Logan's type specimen came 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.

Hattin (1952, p. 28) put S. plana Logan and S. semicoalita Whiteaves in synonymy. The type specimen 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 6, Fig. 3.

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 Bruguiere

Class Crinoidea Miller

Subclass Articulata Miller

## Order Uintacrinida Zittel and Broili

Genus Uintacrinus Grinnell, 1876type 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. The first eight are fixed. Interbrachials also occur between the secundibrachs. A tegmen is present.

Uintacrinus socialis Grinnell, 1876

Plate 6, Fig. 8.

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

p. 481-483, pl. 21, 112. Springer 1900. Mus. Comp.  
Zool., Mem., v. 25, n. 1, p. 1-89, pl. 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. however, U. socialis has broader brachial plates and seven interradial plates encircle the eighth or eighth and ninth interradial plates. In U. westfalicus there are only five interradial plates.

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

Phylum Arthropoda Siebold and Stannius

Class Crustacea Pennant

Subclass Cirripedia Burmeister

Order Thoracica Darwin

Suborder Lepadormorpha Pilsbry

Family Stramentidae Withers

Genus Stramentum Logan, 1897

(Loricula Sowerby, 1843)

type species: Pollicipes 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. Hattin (1952, p. 97-100) records the presence of a tenth valve, the rostral, in S. canadensis Whiteaves. 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 6, Fig. 2.

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, p. 320-21, pl. 42.

Stramentum tabulum Logan 1898. Univ. Geol. Surv. Kans.,

v. 4, pt. 8, p. 498, pl. lll.

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 tergo-lateral margin is obliquely inclined to the main axis. The growth lines of the tergum are straight. The peduncle 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. (Figure 11).

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 twelve valves; aired scutals, upper laterals, tergals, carino-laterals, 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 in 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 Latreille

##### Suborder Eucarida Colman

##### Order Decapoda Latreille

##### Suborder Heterochelida Beurlen and Glaessner

##### Family Palinuridae Gray

##### 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 6, Fig. 1.

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. 13S., R. 24W.?). It is not possible to specifically identify this specimen 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. Species followed by a query may not be present in the Niobrara Formation of Kansas.

## Pelecypoda

Ostrea congesta ConradOstrea larva Lamarck ?Ostrea cf. O. leei Logan\*Inoceramus deformis MeekInoceramus grandis ConradInoceramus platinus Logan\*Parapholas sphenoides White ?Durania maxima Logan

## Nautiloidea

Eutrephoceras sp.

## Ammonodea

Bevahites ? sp.Baculites sp.Baculites ? sp.Scaphites ? sp.Clioscapites vermiformis Meek and HaydenSpinaptychus sternbergi Fischer and Fay

aptychus

## Sepioidea

Tusoteuthis longus LoganNiobrarateuthis bonneri MillerPlatylithophycus cretaceum Johnson and Howell

## Belemnoidea

Actinocamax cf. A. manitobensis WhiteavesActinocamax cf. A. groenlandicus Birkelund

## Annelida

Serpula intricata White ?Serpula semicoalita WhiteavesSerpula tenuicarinata Meek and Hayden

## Crinoidea

Uintacrinus socialis Grinnell

## Arthropoda

Stramentum haworthi WillistonSquama spissa LoganLinuparis ? sp.

## 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<sub>3</sub> content, is more dense, and is white or lighter colored than the Smoky Hill Member. The two members are easily distinguished in subsurface well cuttings. They can be distinguished at outcrops by the absence of any underlying grey 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. Its outcrop belt trends southwest from northcentral Kansas (Figure 1). The Niobrara is divided into two members, the Smoky Hill Member and the underlying Fort Hays Member

(Figure 3).

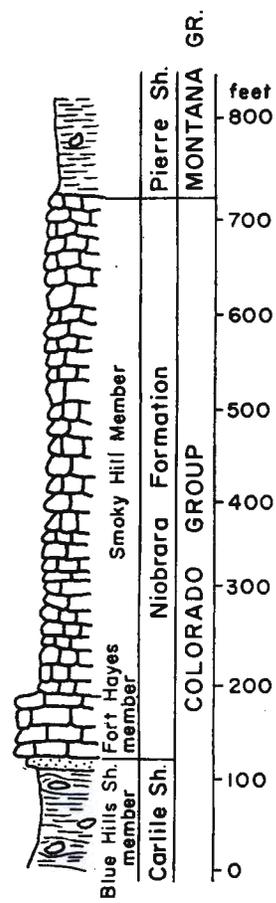
The Fort Hays Member is a light-grey to very light-yellow chalk; it is massively bedded and has thin, light to dark-grey, chalky-clay partings. The Fort Hays Member forms the basal 50 feet of the Niobrara Formation.

The Smoky Hill Member is a grey 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 as foraminiferal tests (mainly Gumbelina) 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 larger particles consist of quartz, mica flakes, and heavy minerals.

#### 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.

Fig. 3. Generalized stratigraphic column.



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 (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 of measured sections were cited or included in Russell's paper (Miller, in press).

The author has measured the thicknesses and intervals of bentonite beds in the 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 from one to six feet, and the majority of the bentonites are one inch thick. Stratigraphic sections less than one mile apart are impossible to correlate by this method. It seems likely, therefore, that this method of correlation is of little use in the Smoky Hill Member, even though Bass (1926) was able to employ it successfully in the Fort Hays Member, and both Bass and Moss (1932) seem to have applied this method to the lower Smoky Hill Member.

Williston (1897, p. 239) discussed a subdivision of the Niobrara Formation into the Ornithostoma, Hesperornis, and Rudistes beds. 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 pterodactyl, 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 a weathering and not a stratigraphic characteristic. Weathering of the Niobrara Formation is discussed in the next section.

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 lower Smoky Hill Member, and 3 species confined to the upper Smoky Hill Member. This is only a gross breakdown 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 have not been thoroughly collected; also some of the forms that may be useful for zonation have been overspeciated. A zonation based on "soft" and "resistant" beds, or on "shale" and chalk, or on grey and brightly colored chalk is 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 seems to be unreliable at least locally in the Smoky Hill Member.

#### 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. The upper part of Meek and Hayden's "Lower Series" 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 lower Santonian stages (lower Senonian) of Europe.

Cobban (personal communication, December, 1957) wrote the author 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 hippocrepsis 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 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 hippocrepsis, 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 occur in the Niobrara Formation of Kansas. Their exact relationship in Kansas is doubtful.

Jeletzky (personal communication, December 1957) wrote that he considers Uintacrinus to be indicative of upper Santonian age on a global scale. He cited a recently discovered occurrence of Uintacrinus in upper Santonian rocks of Australia and the previously known occurrence of Uintacrinus in Europe.

Miller, Sternberg, and Walker (1957), stated the range of Uintacrinus in the Smoky Hill Member was from sec. 10, T. 14S., R. 33W., near Russell Springs in Logan County to sec. 1, T.

14S., R. 25W., Castle Rock area, Gove County. This indicates that Uintacrinus occurs at or very near the top of the Smoky Hill Member and within 50 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 of the specimens lowers the base of the range of Uintacrinus as previously defined in Kansas. Williston (1893, p. 110) 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."

Uintacrinus occurs approximately 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 upper part of the Santonian stage. However, the base of the Uintacrinus zone may occur in older rocks, at least in Kansas or Uintacrinus may locally occur in rocks older than those rocks occupied by the faunal assemblage characteristic of the Uintacrinus zone.

Recent studies of the correlation of the Niobrara Formation have tended toward a younger age designation for the Smoky Hill Member (Figure 4). The correlation of the Niobrara Formation

Fig. 4. Correlation chart of Niobrara Formation of Kansas.

European stages	Cobban + Reeside (1954)	Jeletzky (1955) <sup>1</sup>	Cobban + Reeside (1958) <sup>2</sup>	This paper
Campanian	Pierre Shale		Pierre Shale	Pierre Shale
				
Santonian				
Coniacian	Smoky Hill Member	Smoky Hill Member	Smoky Hill Member	Smoky Hill Member
	Fort Hays Member	Fort Hays Mem.	Fort Hays Member	Fort Hays Member
Turonian				
	Carlile Shale	Carlile Shale	Carlile Shale	Carlile Shale

1. Inferred from Jeletzky's paper, as he did not publish a chart.

2. Personal Communication, W. A. Cobban (1958).

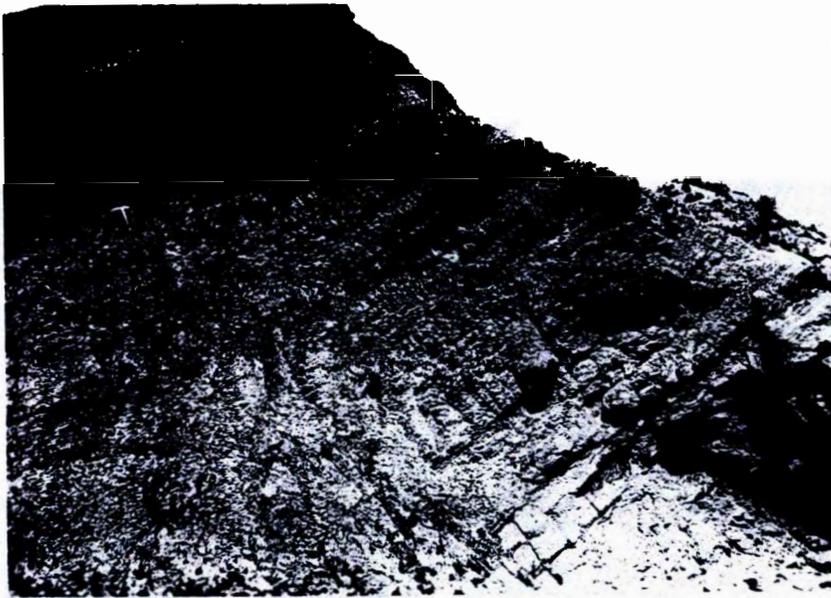
of Kansas has been complicated by a scarcity of ammonites and other fossils considered to be age index species. The known or inferred ranges of the index fossils found in the Niobrara Formation of Kansas are plotted in Figure 5. The Niobrara Formation is roughly subdivided into north-south geographic bands for this purpose. These bands roughly correspond to a stratigraphic zonation of the chalk, as the formation dips gently to the westward. This procedure is necessary as there are no suitable marker beds in the Niobrara Formation, and relative stratigraphic levels within the formation are difficult to establish. This subdivision seems to indicate Coniacian age for the lower part (Fort Hays Member and lowermost Smoky Hill Member) and Santonian age for the upper part of the lower and middle Smoky Hill Member. The upper part may be of uppermost Santonian or of lower Campanian age, although there is no direct proof for this statement. The uppermost Smoky Hill Member in Kansas must be considered Santonian until direct proof of a different age is obtained.

The Niobrara Formation is unconformably overlain by the Pierre Shale (Montana Group)(Figure 6). The Pierre Shale consists of as much as 1,400 feet of thin bedded, black to dark grey, shale with marine fossils. The shale weathers to light brown and grey, and contains selenite crystals and thin beds of bentonite (Moore, et al, 1951, p. 23). The Pierre Shale rests unconformably upon the Smoky Hill Member of the Niobrara Formation. The unweathered contact is marked by a very slight

Figure 5. Ranges of index fossils within Niobrara Formation of Kansas.

Index Fossils	Fort Hays Member	Smoky Hill Member				
		Castle Rock	Monument Rocks	Elkader	Russell Springs	Wallace
<u>Inoceramus deformis</u>	_____					
<u>Inoceramus platinus</u>		_____	_____	_____	_____	_____
<u>Inoceramus grandis</u>	_____					
<u>Eutrephoceras</u> sp.					_____	
<u>Durania maxima</u>		_____	_____	_____	_____	_____
<u>Ostrea congesta</u>	_____					
<u>Actinocamax</u> spp.		_____	_____	_____		
<u>Bevahites</u> ? sp.			_____			
<u>Clioscaprites vermiformis</u>			_____			
<u>Baculites</u> cf. <u>B. codyensis</u>			_____			
<u>Spinptychus sternbergi</u>		_____	_____	_____		
<u>Uintacrinus socialis</u>		_____	_____	_____	_____	_____

Fig. 6. Pierre Shale contact



Contact of Pierre Shale and Niobrara Formation in south of center, near west line, sec. 21, T. 15S., R. 32W. The contact is indicated by the geologic pick.

change in intensity of hue, not easily seen by people with normal color vision. A zone of rounded, fine, and very fine, sand grains is included within the basal foot of the Pierre Shale. There is also an abrupt change from chalk, which effervesces violently with dilute hydrochloric acid, to a noncalcareous shale that does not react with dilute hydrochloric acid. Locally the base of the Pierre Shale consists of a tooth and bone conglomerate derived from the Niobrara Formation. The hiatus between the Pierre Shale and the Niobrara Formation may be represented by part of the Eagle Sandstone, Telegraph Creek Formation and equivalent rock units in Wyoming, the Dakotas, and elsewhere. However, it seems probable that the upper Smoky Hill Member may be in part equivalent to the Eagle Sandstone and some younger rocks.

The Niobrara Formation unconformably overlies the Carlile Shale ( Figure 7). The upper Carlile Shale is a black, fissile, marine shale with zones of large septarian concretions. A fine-grained sandstone, the Codell Sandstone Member, occurs locally at the top of the formation (Miller, 1958, p. 215) seems to represent an old beach sand and may have been deposited during a time of a relative lowering of the Western Interior sea level.

The Carlile Shale is overlain by the Fort Hays Member of the Niobrara Formation and the contact is marked by an abrupt change from a dark, fissile, shale with a low carbonate content of 12% (Matsumoto and Miller, 1958, p. 352), or a fine grained,

Fig. 7. Carlile Shale contact



Contact of Carlile Shale and Niobrara Formation in SW $\frac{1}{4}$ , sec. 36, T. 14S., R. 22W. The massive chalk beds of the Fort Hays Member lie directly on the Blue Hill Shale Member at this locality.

silty sandstone with a maximum thickness of 25 feet (Moore, et al, 1951, p. 24), to the grey to light yellow, massively bedded, chalk of the Fort Hays Member.

## ENVIRONMENT OF DEPOSITON

### Discussion of Faunal Evidence

Foraminifera -- The foraminiferal fauna of the Niobrara Formation consists largely of planktonic genera such as Gumbelina 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.

Bathysiphon

Pelosina

Ammodiscus

Glomospira

Haplophragmoides

Lituola

Spiroplectammina

Textularia

Verneuilina

\*Gaudryina

Pseudoclavulina

Clavulinoides

Pseudogaudryinella

Heterostomella

Arenobulimina

Marssonella

Dorothia

Manorella

\*Robulus

\*Lenticulina

Saracenaria

Marginulina

\*Dentalina

\*Nodosaria

Chrysalogonium

Pseudoglandulina

Citharina

Palmula

Neoflabellina

\*Frondicularis

Pseudofrondicularia

\*Kyphopyxa

Lagena

Globulina

\*Ramulina

Vitriwebbina

Nonionella

Bolivinopsis

\*Gumbelina

Rectogumbelina

\*Ventilabrella

Bolivinooides

Bolivinitella

\*Eouvigerina

Pseudouvigerina

\*Buliminella

\*Bulimina

\*Neobulimina

Virgulina

\*Loxostomum

\*Pleurostomella

Nodosarella

Ellipsonodosaria

\*Valvulineria

\*Gyroidina

Allomorpha

Hastigerinella

Schackoina

\*Globotruncana

Globorotalia

\*Globorotalites

Anomalina

\*Planulina

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

Vaginulina

Bullopورا

Hantkenina

Bolivina

Globigerina

Arenaceous Foraminifera (except Gaudryina) are apparently 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 dwarfing 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 pH or acidity, and (5) lack of light. The foraminiferal fauna of the Niobrara Formation in Kansas seemingly is dwarfed, when compared with "normal" species of the same geologic age from the Gulf Coast Cretaceous. Some specific examples are given in Table 2.

Table 2. Measurements of some Cretaceous Foraminifera in millimeters.

Species	Length (or Diameter)	
	Niobrara Formation of Kansas	Gulf Coast, measure- ments, after Cushman, 1946, except for <u>Globigerina</u>
<u>Robulus navarroensis</u>	0.5 to 0.7	1.0 (or more)
<u>Gumbelina globifera</u>	0.27 to 0.33	0.3 to 0.5
<u>Gumbelina plummerae</u>	0.4 to 0.45	0.5 to 0.65
<u>Globigerina "cretacea"</u> (Measurements after Frizzell, 1954)	0.2 to 0.26	0.36 to 0.44

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 dwarfism, in Foraminifera.

An examination of the causes of foraminifer dwarfing listed by Lalicker (1948), would indicate that dwarfing of the Niobrara foraminifers may be caused by unfavorable chemical composition and physical conditions of the water, such as a low oxygen content and possibly excessive acidity. Said (1951, 1953) records the presence of dwarfed 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 dwarfed 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 shallow epeiric seas, such as the Black Sea.

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 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, which is rare, are the only benthonic mollusca discovered to date. The specimens 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.

Recent oyster banks (Allee and Schmidt, 1951, p. 249) in deep waters (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 inoceramids 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, non-reef water (Bergquist & Cobban, 1957, p. 873). Rudists, in general, are characteristic of warm, clear, shallow, normally saline seas. The superabundance of Inoceramus and oysters and the lack of other typical benthonic Cretaceous mollusc genera (such as Exogyra, Tellina, Avicula, Turritella, Pyropsis, and Rostellites), in the Niobrara Formation, that are present in the underlying Cretaceous Formation, 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 dwarfed in warmer seas.

Naef (1912, p. 192) stated:

"Wir betrachten sie (belemnites) als nektonische Formen der meresoberfläche und kustenzonen, von der sich nur besonders spezialisierte Typen losmachen konnten, 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.

Other authors, Bubnoff (1922), Diener (1912), and Frech (1915) consider 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, Uintacrinus westphalicus Schluter (1878), (Zittel, 1913, p. 236) occurs with Marsupites and Bourgeticrinus.

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 by the author (NE $\frac{1}{4}$  SW $\frac{1}{4}$  sec. 10, T. 14S., R. 33W., 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 sq. ft.), 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 benthic 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 Uintacrinus were reduced (possibly by unfavorable physical factors) then it too would have had a suppressed larval form and would have tended to live in large benthonic groups, although it, like Antedon, was a free-swimming form capable of wide-spread distribution.

It is probable that the Uintacrinus slabs composed of specimens smaller than the average may represent individuals dwarfed by an unfavorable environment, rather than an

accumulation of juvenile individuals.

Arthropoda -- Two genera of barnacles (Souama and 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 and occur in both members. They are rather rare and most specimens seem to be attached to shells of a large species of Baculites.

Fish -- Many genera of fish have been found in the Niobrara Formation. Some were bottom feeders (Ptychodus), others such as Portheus, 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 effects 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, 1946, p. 312). This formed a stratification of feeding areas and ecologic niches, although all the genera were dependent on the surface for air.

The plesiosaurs apparently were surface or near-surface swimmers and probably fed on fish.

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 turtle do today.

Birds -- Hesperornis is a well-known non-flying form and apparently was a fast-swimming fish eater like the modern loons and grebes. Ichthyornis was analogous to the Recent shore birds, may actually be 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 Upper 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 up 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.

The abundance of organic matter colored the chalk grey. The general lack of bottom living animals, including scavengers, permitted an excellent state of preservation for the vertebrate fossils, as the bones were not disrupted and scattered by scavengers.

The greater number of benthonic Foraminifera and Ostracoda 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.

The Niobrara Sea presumably was shallow, density stratified, marine, clear, relatively calm, and had slow sediment accumulation rates. The slow rate of sediment accumulation was probably the result of the sediments being deposited in 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.

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 grains 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 grey 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  $\text{SiO}_2$  and more  $\text{MnO}_2$  (content) than the Smoky Hill Member. The organic matter content (D.L.O.I., Differential loss on ignition,  $105^\circ/550^\circ\text{C}$ ) 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, it does not undergo color changes caused by 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, 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  $\text{CaCO}_3$  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 appendix A. The Smoky Hill Member tends to have no  $\text{MnO}_2$  or a low  $\text{MnO}_2$  content which contrasts with the Fort Hays Member. The grey chalk samples

tend to have a higher content of organic matter than the brightly colored chalk. The grey 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 bluff in north center, South  $\frac{1}{2}$  sec. 25, T. 15S., R. 33W. The grey chalk at the base of the bluff becomes yellowish grey 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  $\frac{1}{2}$  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 rhabdololiths, 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, rhabdololiths, 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 (rhabdololiths) were  $1/1000$  to  $1/2000$  inch long. McClung (1898, p. 424) published illustrations of the coccoliths and rhabdololiths.

Calvin (1895, p. 213-236) described the composition of the Niobrara 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 greyish chalk capped by brightly colored chalk (Figures 8 and 9). Subsurface sections of the Smoky Hill Member are entirely grey chalk (Appendix D). Samples from United Carbon no. 1 Wheeler sec. 21, T. 17S., R. 41W., Greeley County were examined and Smoky Hill Member chalk was recorded from 110-150 feet as yellow chalk and from 150-720 feet as grey chalk; Fort Hays Member (white) chalk was recorded from 720-770 feet. Samples from Shell no. 1 Hardin, sec. 24, T. 6S., R. 40W., Sherman County were examined. Grey Smoky Hill Member chalk was recorded from 1310-1810 feet. White Fort Hays Member chalk was recorded from 1810-1850 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 grey chalk and the yellow chalk does not extend downdip, it appears that the brightly colored chalk is not a sedimentational feature, and must develop from the grey 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

Fig. 8. Relation of grey and yellow chalk in subsurface cross-section.

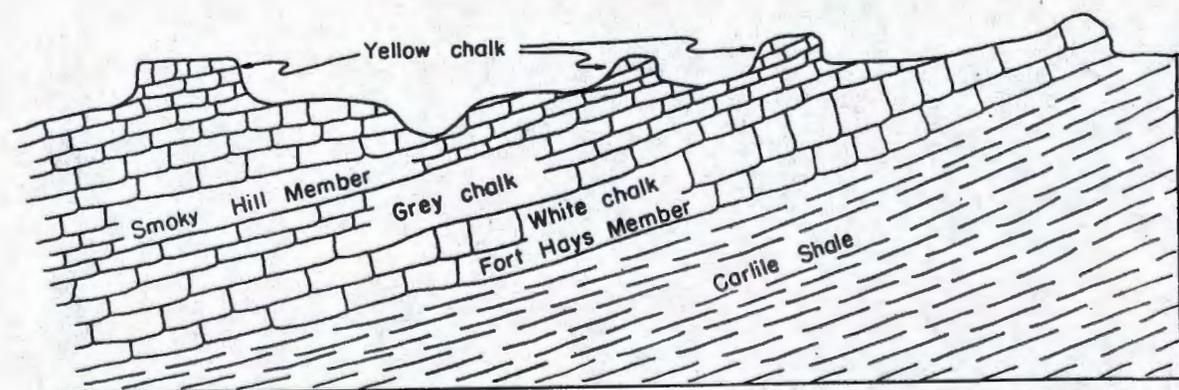


Fig. 9. Weathering Forms of Chalk



A. Chalk blocks in SW $\frac{1}{4}$ , sec. 11, T. 15S., R. 33W., Logan County. The blocks are developed on a pediment of Chalk Creek.



B. Chalk blocks in sec. 1, T. 14S., R. 26W., Gove County. The dark area at the top of the blocks is lichens. The stratification is largely caused by bentonite beds.

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 homogeneous 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, later authors have used the distinction of yellow chalk and grey shale beds when describing measured sections of the Smoky Hill Member.

It seems likely that the yellow chalk develops by weathering of grey chalk once it becomes exposed. Possibly, as Williston suggested, the grey chalk was preserved as such beneath the water table and turned to yellow chalk after the water table was lowered and exposed the grey chalk to weathering agents. The present contact of the grey 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 (Figure 10). The yellow chalk buried under the sediments of the Ogallala Formation may represent an older, weathered, outcrop.

Weathering agents produce yellow chalk from grey chalk by removal of organic matter and oxidation of pyrite.

Fig. 10. Weathering "zones" in chalk



Chalk Monuments in cent. SW $\frac{1}{4}$ , sec. 34, T. 14S., R. 31W,  
Gove County. The apparent stratification here is largely  
caused by weathering phenomena.



Fig. 11. Baculites ? sp. Specimen from Niobrara Formation of Kansas (KU 11405). Barnacles (Stramentum haworthi Williston) are attached to its surface. Natural size.

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#### APPENDIX A - CHEMICAL ANALYSES

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

The percentage of  $\text{CaCO}_3$  is determined by adding the amounts of  $\text{CaO}$  and D.L.O.I.  $600^\circ/1000^\circ \text{C}$  (loss on ignition from 600 to 1000 degrees centigrad). The D.L.O.I.  $105^\circ/550^\circ \text{C}$  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.

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

Magnesium oxide is probably included as ions in the calcite lattice structure.

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.

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. 14S., R. 22W.  
 2. NW $\frac{1}{4}$ , sec. 26, T. 13S., R. 19W.  
 3. SE $\frac{1}{4}$ , sec. 5, T. 15S., R. 23W.

##### Smoky Hill Member

4. sec. 1, T. 14S., R. 33W.  
 5. sec. 14, T. 16S., R. 33W.  
 6. N $\frac{1}{2}$ , sec. 35, T. 14S., R. 33W.  
 7. SW $\frac{1}{4}$ , sec. 34, T. 14S., R. 31W.  
 8. N. center, S $\frac{1}{2}$ , sec. 25, T. 15S., R. 33W.  
 9. NE, NE $\frac{1}{4}$ , sec. 19, T. 15S., R. 32W.  
 10. sec. 32, T. 13S., R. 26W.  
 11. cent. E $\frac{1}{2}$ , sec. 11, T. 14S., R. 29W.  
 12. SW $\frac{1}{4}$ , sec. 34, T. 14S., R. 31W.  
 13. NE $\frac{1}{4}$ , sec. 32, T. 15S., R. 26W.

14. NE, SW, sec. 10, T. 14S., R. 33W.

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

Table 3, Chemical Analyses (continued)

Number	MgO	MnO <sub>3</sub>	K <sub>2</sub> O	Na <sub>2</sub> O	F <sub>2</sub> O <sub>5</sub>	SO <sub>3</sub>	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	0.18 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 (continued)

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 0.29	0.67 0.73	100.07 100.76	none
3.	0.56	0.48	99.26	none
4.	0.27 0.19	0.48 0.53	100.20 100.06	none
5.	1.35 1.09	2.54 2.55	99.36 100.44	much
6.	1.35	2.43	99.50	much
7.	1.82 .77	3.03 2.17	99.85 99.74	much
8a.	1.59	1.83	99.49	much
8b.	1.28 0.53	2.83 3.56	98.98 99.61	some
8c.	2.18 1.55	4.27 4.99	99.22 98.53	much
8d.	1.56	4.66	99.28	much
8e.	1.09	1.78	99.20	much
8f.	1.84 1.71	2.60 2.47	99.45 100.10	some
8g.	1.04 0.84	0.60 0.98	99.97 99.61	none
9.	0.62 0.40	2.19 1.44	93.86 99.48	much
10.	0.55	0.75	99.18	some
11.	1.76 1.34	5.53 5.59	98.89 98.70	much
12.	1.46 1.00	3.23 3.38	98.22 100.38	some
13.	1.61 0.89	1.81 2.77	99.52 100.39	some
14.	0.31	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 collected 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

NW $\frac{1}{4}$  sec. 26, T. 13S., R. 19W. (Fort Hays Member)

## 2. Gove County

E  $\frac{1}{2}$  sec. 23, T. 14S., R. 26W. KU 11396 (Smoky Hill Member)

cent. W.  $\frac{1}{2}$  sec. 32, T. 13S., R. 26W. KU 11391 (Smoky Hill Member)

NW  $\frac{1}{4}$  sec. 8, T. 15S., R. 31W. KU 11394 (Smoky Hill Member)

SW  $\frac{1}{4}$  sec. 34, T. 14S., R. 31W. (Smoky Hill Member)

cent. E  $\frac{1}{2}$  sec. 11, T. 14S., R. 29W. (Smoky Hill Member)

NE  $\frac{1}{4}$  sec. 32, T. 15S., R. 26W. (Smoky Hill Member)

## 3. Graham County

sec. 1, T. 8S., R. 22W. KU 11395 (Fort Hays Member)

## 4. Lane County

sec. 14, T. 16S., R. 29W. (Smoky Hill Member)

## 5. Logan County

cent. S. line sec. 26, cent. N. line sec. 35, T. 14S.,

R. 33W. KU 11393 (Smoky Hill Member)

NW  $\frac{1}{4}$  sec. 6, T. 15S., R. 32W. KU 11388 (Smoky Hill Member)

NE, SW  $\frac{1}{4}$  sec. 10, T. 14S., R. 33W. (Smoky Hill Member)

sec. 1, T. 14S., R. 33W. (Smoky Hill Member)

N $\frac{1}{2}$  sec. 35, T. 14S., R. 33W. (Smoky Hill Member)

N cent. S  $\frac{1}{2}$  sec. 25, T. 15S., R. 33W. (Smoky Hill Member)

NE, NE  $\frac{1}{4}$  sec. 19, T. 15S., R. 32W. (Smoky Hill Member)

6. Rooks County

sec. 33, T. 7S., R. 19W. KU 11398 (Fort Hays Member)

7. Smith County

sec. 3, T. 5S., R. 13W. KU 11397 (Fort Hays Member)

N  $\frac{1}{2}$  sec. 32, T. 4S., R. 15W. KU 11399 (Fort Hays Member)

8. Trego County

SW  $\frac{1}{4}$  sec. 36, T. 14S., R. 22W. KU 11390 (Fort Hays Member)

NE  $\frac{1}{4}$  sec. 33, T. 13S., R. 24W. KU 11389 (Smoky Hill  
Member)

NW  $\frac{1}{4}$  sec. 26, T. 14S., R. 23W. KU 11392 (Fort Hays  
Member)

sec. 26, T. 14S., R. 22W. (Fort Hays Member)

SE  $\frac{1}{4}$  sec. 5, T. 15S., R. 23W. (Fort Hays Member)

## APPENDIX C - MEASURED SECTIONS

Sections were measured at the following locations.

## Trego County

1. SW $\frac{1}{4}$ , sec. 36, T. 14S., R. 22W.

## Gove County

2. N $\frac{1}{2}$ , sec. 1, T. 14S., R. 26W.
3. cent. sec. 32, T. 15S., R. 26W.
4. cent. SW $\frac{1}{4}$ , sec. 34, T. 14S., R. 31W.

## Logan County

5. cent. NW $\frac{1}{4}$ , sec. 6, T. 15S., R. 32W.
6. cent. E $\frac{1}{2}$ , sec. 20, T. 15S., R. 32W. (Lake McBride Quad.)
7. cent. W. line, sec. 20, T. 15S., R. 32W. (Lake McBride Quad.)
8. S. of cent., nr. W. line, sec. 21, T. 15S., R. 32W. (Lake McBride Quad.)
9. NE $\frac{1}{4}$ , SW $\frac{1}{4}$ , sec. 21, T. 15S., R. 32W. (Lake McBride Quad.)
10. cent. W. line, sec. 21, T. 15S., R. 32W. (Lake McBride Quad.)
11. SE $\frac{1}{4}$ , SW $\frac{1}{4}$ , sec. 30, T. 15S., R. 32W. (Lake McBride Quad.)
12. SW $\frac{1}{4}$ , sec. 11, T. 15S., R. 33W.
13. cent. N $\frac{1}{2}$ , sec. 25, T. 15S., R. 33W. (Lake McBride Quad.)
14. cent. sec. 26, T. 14 S., R. 33W.

Measured section number one was measured across the

Carlile Shale-Niobrara Formation contact at the Cedar Bluff Dam. Measured sections 6, 8, and 10 were measured across the Niobrara Formation-Pierre Shale contact in a down-faulted block located in the northeastern quarter of the Lake McBride Quadrangle (Miller, in press).

Most of the sections were measured within or near the Lake McBride Quadrangle. This area is well within the Smoky Hill Member of the Niobrara Formation and is ideally suited to test the practicability of using the thicknesses and intervals of the bentonite beds as stratigraphic marker zones.

Measured sections 6, 8, and 10 were taken in the uppermost Smoky Hill Member, and the contact with the Pierre Shale should represent a horizon or a thin zone of transgressive rocks over the limited area in consideration. The measured sections are located within  $\frac{1}{4}$  square mile. A comparison of sections 8 (about 50 feet) and 6 (about 44 feet) does not reveal any similarity of intervals or thicknesses. Section 10 is not long enough to use for satisfactory correlation with the others.

Measured sections 5, 7, 9, 11, 12, 13 and 14 were measured in the Smoky Hill Member chalk outside the faultblock, and probably represent a zone in the basal part of the upper third of the member. The upper portion of each measured section is represented by large blocks of weathered yellow chalk. The chalk apparently weathers differentially, and forms "soft" or "hard" zones. These "soft" and "hard" zones become eroded differentially and seemingly represent correlateable beds.

Similar zones were measured at measured sections 5, 12, and 14. However, the thicknesses and intervals of the bentonite beds do not correspond, and seemingly there is no link between sedimentation and the development of "soft" and "hard" zones under the weathering processes.

Presumably, the thicknesses and intervals of the bentonite beds can not be matched from one area to another within the upper part of the Smoky Hill Member, so this criterion can not be reliably used for correlation in that member.

1. SW $\frac{1}{4}$ , sec. 36, T. 14S., R. 22W.

Fort Hays Member

8.0 ft. massive, light yellow, limestone.

0.2 feet, shaly parting.

2.8 feet blocky, massive, light-yellow limestone.

Blue Hill Shale Member of Carlile Shale

1.6 feet sandy, silty, blueish-grey shale. Weathers reddish-orange.

0.5 feet, very silty sandstone, reddish with ferruginous cement.

0.5 feet very silty blueish-grey shale

0.05 feet reddish, ferruginous cemented sandstone.

0.4 feet very fine grained, silty, sandstone, light grey.

6.8 feet blueish-grey shale, weathers reddish-orange, silty lenses.

11.0 feet covered interval

Total thickness 31.9 feet.

2. N $\frac{1}{2}$ , sec. 1, T. 14S., R. 26W.

Contact with Ogallala Formation

Niobrara Formation

6.0 feet yellow chalk

0.05 feet bentonite

5.4 feet yellow chalk

0.05 feet bentonite

16.1 feet yellow chalk, platy near top.

0.1 feet limonite

12.4 feet yellow chalk

Chalk becomes less punky and less yellow below here.

6.8 feet yellow chalk

0.05 feet bentonite

2.3 feet yellow chalk

0.05 feet bentonite

0.65 feet yellow chalk

0.05 feet bentonite

1.15 feet yellow chalk; hard.

0.05 feet bentonite

2.6 feet yellow chalk

1.4 feet yellowish to greyish chalk

0.2 feet limonite and bentonite

2.5 feet grey chalk

0.1 feet gypsum and limonite

3.4 feet grey chalk

0.1 feet gypsum and limonite

3.4 feet grey chalk  
 0.1 feet gypsum  
 1.2 feet grey chalk  
 0.1 feet gypsum  
 2.0 feet grey chalk  
 0.2 feet resistant ledge; shale?  
 3.3 feet grey chalk  
 0.1 feet bentonite and gypsum  
 5.7 feet grey chalk  
 0.1 feet bentonite and limonite.

Total thickness 74.2 feet

3. cent. sec. 32, T. 15S., R. 26W.

Sanborn Formation

10 feet loess

Niobrara Formation

5.5 feet light grey chalk  
 0.025 feet limonite  
 0.75 feet light grey chalk  
 0.025 feet limonite  
 0.25 feet light grey chalk  
 0.025 feet limonite  
 0.9 feet light grey chalk  
 0.5 feet hard grey chalk  
 1.9 feet grey chalk  
 0.025 feet bentonite  
 Fault, about 1 foot displacement

1.0 feet grey chalk  
0.05 feet limonite  
4.1 feet yellow chalk  
0.05 feet limonite  
3.2 feet yellow chalk  
0.05 feet bentonite and limonite  
0.7 feet yellow chalk  
0.05 feet bentonite  
3.0 feet yellow chalk  
0.2 feet hard yellow chalk  
10.6 feet yellow chalk  
36.4 feet grey chalk  
0.1 feet bentonite and limonite  
10.5 feet grey chalk  
0.1 feet limonite and bentonite  
5.3 feet grey chalk  
0.05 feet bentonite and limonite  
2.2 feet grey chalk  
0.025 feet bentonite  
3.9 feet grey chalk  
0.025 feet limonite and bentonite  
2.8 feet grey chalk  
0.05 feet limonite  
5.3 feet grey chalk  
0.05 feet limonite and bentonite  
4.1 feet grey chalk

0.05 feet limonite and bentonite

9.6 feet grey chalk

Total thickness 123.43 feet.

4. cent. SW $\frac{1}{4}$ , sec. 34, T. 14S., R. 31W.

Niobrara Formation

15 feet light yellow chalk. Contains abundant Inoceramus.

7 feet grey chalk

0.1 feet limonite and bentonite

1.5 feet grey chalk

0.4 feet limonite and bentonite

0.9 feet grey chalk

0.4 feet limonite and bentonite

4.3 feet grey chalk

Total thickness 29.6 feet.

5. cent. NW, sec. 6, T. 15S., R. 32W.

Niobrara Formation

7.5 feet hard yellow chalk (rubbly)

2.6 feet hard, yellow and grey chalk

0.025 feet bentonite

7.1 feet hard, light, yellowish-grey chalk

15.9 feet grey chalk

0.25 feet limonite and bentonite

1.6 feet grey chalk

0.1 feet limonite and bentonite

2.5 feet grey chalk

0.025 feet limonite

3.5 feet grey chalk  
 0.1 feet limonite and bentonite  
 3.3 feet grey chalk  
 0.025 feet limonite and bentonite  
 1.6 feet grey chalk  
 0.1 feet limonite and bentonite  
 2 feet grey chalk

Total thickness 48.23 feet.

6. cent. E $\frac{1}{2}$ , S. 20, T. 15S., R. 32W.

Pierre Shale

0.02 feet white clay  
 4.0 feet dark grey shale (non-calcareous)

Niobrara Formation

1.0 feet grey chalk  
 0.1 feet bentonite (gypsiferous)  
 2.3 feet grey chalk  
 0.1 feet limonite  
 2 feet grey chalk  
 0.1 feet limonite  
 1.7 feet grey chalk  
 0.1 feet bentonite and limonite  
 2.2 feet grey chalk  
 0.1 feet limonite and bentonite  
 2.1 feet grey chalk  
 0.05 feet limonite  
 0.1 feet light grey chalk

0.05 feet gypsum  
1.7 feet grey chalk  
0.4 feet reddish-brown bentonite  
2.7 feet grey chalk  
0.1 feet calcite and limonite  
5 feet grey chalk  
0.02 feet limonite  
0.1 feet grey chalk  
0.05 feet limonite  
6.5 feet grey chalk  
0.02 feet limonite  
0.9 feet grey chalk  
0.1 feet limonite and bentonite  
8 feet grey chalk

Total thickness 43.6 feet.

7. CWL, sec. 20, T. 15S., R. 32W.

Niobrara Formation

4 feet hard yellow chalk  
0.05 feet bentonite  
2.0 feet yellow chalk  
0.05 feet bentonite  
0.1 feet yellow chalk  
0.05 feet bentonite  
3.3 feet yellow chalk  
27 feet yellow chalk with calcite fills in fissures.  
0.05 feet gypsum

0.8 feet yellow chalk  
 0.1 feet limonite, bentonite and gypsum  
 2.5 feet yellow chalk  
 0.1 feet limonite, bentonite and gypsum  
 3.0 feet grey and yellow chalk  
 0.2 bentonite and gypsum  
 1.0 feet grey chalk  
 0.05 feet bentonite and gypsum  
 1.4 feet grey chalk  
 0.1 feet bentonite, limonite, and gypsum  
 7 feet grey chalk, partly covered

Total Thickness 52.85 feet.

8. South of center near west line, sec. 21, T. 15S., R. 32W.

Pierre Shale

18 feet dark grey, gypsiferous, fissile, shale. Contains  
bone fragments.

Niobrara Formation

1.2 feet grey chalk  
 0.2 feet limonite and bentonite  
 0.8 feet grey chalk  
 0.2 feet limonite  
 2.3 feet grey chalk  
 0.1 feet bentonite and limonite  
 1.8 feet grey chalk  
 0.2 feet bentonite and limonite  
 1.1 feet grey chalk

0.05 feet bentonite and limonite

0.6 feet grey chalk

0.05 feet limonite

1.3 feet grey chalk

0.1 feet bentonite

3.1 feet grey chalk

0.2 feet bentonite

4 feet grey chalk

0.3 feet bentonite

3.1 feet grey chalk

0.05 feet bentonite

1.2 feet grey chalk

0.05 feet limonite

1.3 feet grey chalk

0.1 feet limonite and bentonite

5 feet grey chalk

0.1 feet limonite and bentonite

2.4 feet grey chalk

0.05 feet bentonite and limonite

1.2 feet grey chalk

Total thickness 50.45 feet.

9. NE $\frac{1}{4}$ , SW $\frac{1}{4}$ , sec. 21, T. 15S., R. 32W.

Niobrara Formation

0.6 feet grey chalk

0.05 feet yellow, fissile shale parting

1.9 feet grey chalk

0.35 feet yellow, clayey, shale parting  
6.5 feet grey chalk with small partings  
0.05 feet fissile shale parting  
0.75 feet grey chalk  
0.05 feet yellow, fissile, shale parting  
1.6 feet grey chalk  
0.2 feet fissile, yellow, shale parting with siltstone  
2.65 feet grey chalk  
0.1 feet sandy, bentonite layer  
1.0 feet grey chalk  
0.1 feet bentonite layer  
0.85 feet grey chalk  
0.1 feet bentonite layer  
0.9 feet grey chalk  
0.11 feet sandy bentonite layer  
0.35 feet grey chalk  
0.25 feet sandy bentonite layer  
0.6 feet grey chalk  
0.05 feet sandy, bentonite, and limonite  
1.0 feet grey chalk

10. cent. west line, sec. 21, T. 15S., R. 32W.

Pierre Shale

2-3 feet weathered upper portion  
0.1 feet gypsum  
0.9 feet grey shale  
0.1 feet gypsum

1.0 feet grey shale  
 0.1 feet gypsum  
 1.2 feet grey shale  
 0.05 feet gypsum  
 1.1 feet grey shale  
 0.1 feet gypsum  
 0.4 feet grey shale  
 0.05 feet gypsum  
 0.8 feet medium light-grey shale  
 0.05 feet gypsum  
 0.6 feet medium light-grey shale, local sand lenses at  
 base, irregular contact.

Niobrara Formation

1.1 feet medium light grey chalk  
 0.1 feet white clayey shale  
 0.5 feet grey chalk (fresh color greyish-black)

Total thickness 11.05 feet

11. SE $\frac{1}{4}$ , SW $\frac{1}{4}$ , sec. 30, T. 15S., R. 32W.

Niobrara Formation

8.0 feet yellow, weathered, massive, chalk  
 0.2 feet brittle yellow chalk  
 0.01 feet bentonite  
 0.8 feet grey chalk  
 0.02 feet bentonite  
 0.5 feet grey chalk  
 0.1 feet bentonite

2.5 feet grey chalk  
0.2 feet bentonite  
0.5 feet grey chalk  
0.02 feet bentonite  
0.4 feet grey chalk  
0.05 feet bentonite  
0.3 feet grey chalk  
0.2 feet bentonite  
0.5 feet grey chalk  
0.02 feet bentonite  
0.95 feet grey chalk  
0.2 feet bentonite  
1.1 feet grey chalk  
0.1 feet bentonite  
1.5 feet grey chalk  
0.02 feet bentonite  
10.4 feet grey chalk  
0.05 feet bentonite  
6.8 feet grey chalk  
0.05 feet bentonite  
2.2 feet grey chalk  
0.1 feet bentonite  
2.1 feet grey chalk  
0.1 feet bentonite  
2.2 feet grey chalk  
0.1 feet bentonite

0.95 feet grey chalk  
 0.1 feet bentonite  
 3.1 feet grey chalk  
 0.3 feet limonite and bentonite  
 1.0 feet grey chalk  
 0.05 feet bentonite  
 5.5 feet light yellowish-orange chalk  
 0.2 feet limonite, calcite, and bentonite  
 6.9 feet light yellowish-orange chalk  
 0.1 feet limonite, calcite, and bentonite  
 0.5 feet light grey chalk  
 0.07 feet limonite  
 5.75 feet light grey chalk  
 0.1 feet bentonite  
 6 feet grey chalk

Total thickness 74.92 feet.

12. SW $\frac{1}{4}$ , sec. 11, T. 15S., R. 33W.

Niobrara Formation

19 feet hard yellow chalk. Contains many Inoceramus  
and Ostrea.

5 feet grey chalk  
 0.02 feet bentonite  
 1.5 feet grey chalk  
 0.05 feet bentonite and limonite  
 2.3 feet grey chalk  
 0.02 feet limonite

2.6 feet grey chalk

Total thickness 30.5 feet.

13. cent.  $N\frac{1}{2}$ , sec. 25, T. 15S., R. 33W.

Niobrara Formation

2 feet yellow-orange chalk

0.05 feet limonite

8.9 feet yellow-orange chalk

4.5 feet grey chalk

0.05 feet bentonite

10 feet grey chalk

0.05 feet bentonite

6 feet grey chalk

0.05 feet limonite and bentonite

5.4 feet grey chalk

0.02 feet limonite and bentonite

4.5 feet grey chalk

0.05 feet limonite and bentonite

5.9 feet grey chalk

0.05 feet limonite

0.3 feet grey chalk

Total thickness 42.4 feet.

14. sec. 26, T. 14S., R. 33W.

Niobrara Formation

10 feet hard yellow chalk

9 feet soft yellow chalk

3 feet hard yellow chalk

2.5 feet soft yellow chalk

5.5 feet grey chalk

3.3 feet grey chalk

0.05 feet limonite bed

1.6 feet grey chalk

0.05 feet limonite bed

2.2 feet grey chalk

0.1 feet sandy limonite bed

5.5 feet grey chalk

0.05 feet limonite bed

7 feet light grey chalk

Total thickness 49.9 feet.

## APPENDIX D

## Subsurface sections

Samples from two rotary rig drilled wells were examined. The samples are a uniformly greyish chalk, mottled with lighter grey chalk blotches, except in the weathered zone under the Ogallala Formation, where a zone of oxidized, yellow chalk has developed, and the Fort Hays Member which is a distinctive white chalk in subsurface as well as surface sections.

The predominant lithology at each depth is listed first other lithologies are listed in order of decreasing amount, as is ordinarily the case with rotary drill cuttings. There is some contamination.

Shell #1 Harden: C, NE, SE, sec. 24, T. 6S., R. 40W.

1280-90 - dark, silty shale

1290-1300 - dark, silty shale, with angular quartz grains

1300-10 - dark, shale - Base of Pierre Shale

1310-20 - dark, silty chalk, with lighter calcareous spots, angular quartz grains. Top of Niobrara Formation

1320-1330 - no sample

1330-40 - dark, silty chalk

1340-50 - dark, silty chalk with some light chalk

1350-60 - same

1360-70 - same

1370-80 - same

- 1380-1390 - no sample
- 1390-1400 - rounded quartz grains, light chalk, some  
dark chalk
- 1400-10 - light chalk, quartz grains, dark chalk
- 1410-20 - same
- 1420-30 - same
- 1430-40 - light chalk, dark chalk and quartz
- 1440-50 - light and dark chalk
- 1450-60 - same
- 1460-70 - dark chalk, quartz grains
- 1470-80 - same
- 1480-90 - same
- 1490-1500 - same
- 1500-10 - same
- 1510-20 - light chalk, dark chalk and quartz grains
- 1510-20 - same
- 1520-30 - same
- 1530-40 - same
- 1540-50 - same
- 1550-60 - same
- 1560-70 - dark chalk and quartz grains
- 1570-80 - same
- 1580-90 - same
- 1590-1600 - light chalk, black shale (Pierre Shale  
fragments?) and quartz grains
- 1600-10 - no sample



1860-70 - light shale and chalk fragments

1870-80 - light shale

United Carbon #1 Wheeler: SE, SE, NW, sec. 21, T. 17S.,  
R. 41W. - Greeley Co.

20-30 - yellow siltstone and rounded quartz grains

30-40 - yellow siltstone and rounded quartz grains

40-50 - same

90-100 - yellowish-grey siltstone and rounded quartz  
grains

100-10 - yellowish-grey siltstone, rounded quartz grains  
& some reworked Niobrara Foraminifera - Base  
of Ogallala Formation.

110-20 - yellow chalk, calcite (Inoceramus) fragments  
and rounded quartz grains. Top of Niobrara  
Formation.

120-30 - yellow chalk, calcite fragments and rounded  
quartz grains, with Globigerina

130-40 - same with bits of grey chalk

140-50 - same

150-60 - grey chalk, some rounded quartz grains and  
yellow chalk fragments

160-70 - same

170-80 - grey chalk

180-90 - dark grey chalk

190-200 - same

200-10 - lighter grey chalk

- 210-20 - light grey
- 220-30 - same
- 230-40 - same
- 240-50 - same with dark grey chalk and rounded quartz  
grains & yellow silty chalk
- 250-60 - light grey chalk
- 260-70 - same
- 270-80 - same
- 280-90 - same
- 290-300 - dark chalk
- 300-10 - light chalk and some dark chalk
- 310-20 - same
- 320-30 - light chalk, with some dark chalk
- 330-40 - same
- 340-50 - same
- 350-60 - same
- 360-70 - same
- 370-80 - same
- 380-90 - same
- 390-400 - same
- 400-10 - same
- 410-20 - dark chalk with some light chalk
- 420-30 - same
- 430-40 - same and bentonite shale fragments
- 440-50 - dark chalk and some light chalk
- 450-60 - dark chalk

- 460-70 - same
- 470-80 - same
- 480-90 - same with some light chalk
- 490-500 - same
- 500-10 - same
- 510-20 - black chalk and some lighter dark chalk
- 520-30 - dark chalk and some light chalk
- 530-40 - dark and light chalk with a few chert fragments
- 540-50 - dark and light chalk, chert fragments and  
rounded quartz grains
- 550-60 - dark and light chalk
- 560-70 - light chalk (some dark chalk) and a few chert  
fragments
- 570-80 - same
- 580-90 - bentonite
- 590-600 - bentonite
- 600-10 - dark chalk
- 610-20 - dark chalk and bentonite
- 620-30 - dark chalk
- 630-40 - light chalk and some dark chalk
- 640-50 - same
- 650-60 - same
- 660-70 - same
- 670-80 - same
- 680-90 - dark chalk and some light chalk

- 690-700 - light chalk and some dark chalk
- 700-10 - same
- 710-20 - dark chalk and some light chalk. Base of Smoky  
Hill Member
- 720-30 - dark chalk and bits of white chalk. Top of Fort  
Hays Member
- 730-40 - white chalk and bits of dark chalk
- 740-50 - white chalk and dark chalk
- 750-60 - same
- 760-70 - white chalk and some rounded quartz grains  
Base of Niobrara Formation
- 770-80 - dark shale Top of Carlile Shale.
- 780-90 - dark shale
- 790-800 - dark shale
- 800-10 - same
- 810-20 - same
- 820-30 - same

## Explanation of Plate 1

	Page
<u>Inoceramus grandis</u> Conrad -----	24
Fig. 1. View (X.5) of exterior of left valve. Logan's type specimen of " <u>I concentricus</u> ", KU 5802. Locality Ellis County.	
2. View (X.45) of exterior of right valve. Locality KU 11389.	
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<u>Ostrea</u> cf. <u>O. leei</u> Logan -----	41
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5. Three specimens (X.8) attached to an <u>Inoceramus</u> valve. Specimen at top lacks right valve. KU 1808, M. K. Elias collection. Locality 6 miles south of Phillipsburg.	
6. Group (X.8) of specimens showing variations caused by crowded growth. Locality KU 11395.	
7. Group (X.8) of individuals in close association, but not distorted. Locality KU 11395.	
8. Cluster (X.6) of individuals on shell of <u>I.</u> <u>grandis</u> KU 10701, Bridwell collection. Variations caused by crowded growth are shown. Locality High Ridge, south of Phillipsburg.	

"Inoceramus subtriangularis" Logan ----- 35

9. View (X.45) of Logan's type specimen, KU  
11262. Note presence of color pattern.  
Locality "Gove County".

"Inoceramus pennatus" Logan ----- 36

10. View (X.45) one of Logan's type specimens,  
KU 5784. Locality "Niobrara Chalk, Kansas".



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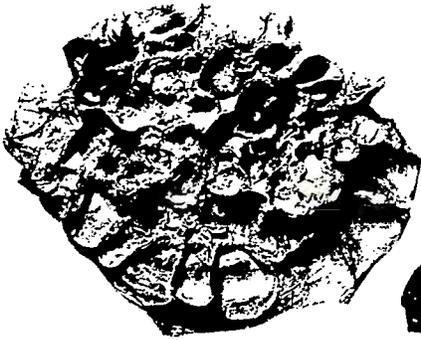
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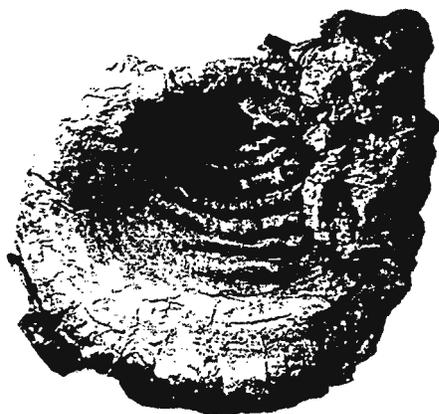


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## Explanation of Plate 2

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<u>Inoceramus grandis</u> Conrad -----	24
Fig. 1. View (X.25) of interior of left valve. KU 11406. Collected by G. F. Sternberg. Locality Logan or Gove Counties.	
2. View (X.55) of young specimen. One of Logan's type specimens of " <u>I. pennatus</u> ", KU 5785. Locality "Gove County".	
3. View (X.6) of interior of left valve, showing pernid hinge teeth. The valve is largely filled with <u>Ostrea congesta</u> . Locality KU 11393.	
4. View (X.6) of specimen from Bridwell Coll. (KU 10701). Specimen shows distortion caused after fossilization. Locality, High Ridge, south of Phillipsburg.	
5. View (X.55) of one of Logan's type specimens of " <u>H. niobrarensis</u> ", KU 11263. Locality "Trego and Logan Counties.	
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8. View (X.4) of one of Logan's type specimens, KU 11263, of " <u>H. niobrarensis</u> ". Locality Trego and Logan Counties.	

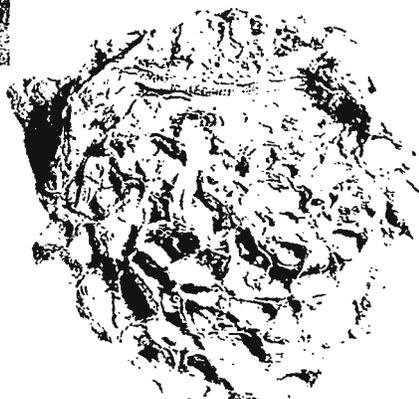
Fig. 9. View of large left valve (X.25) collected by  
G. F. Sternberg (KU 11406). Locality Logan  
or Gove County.



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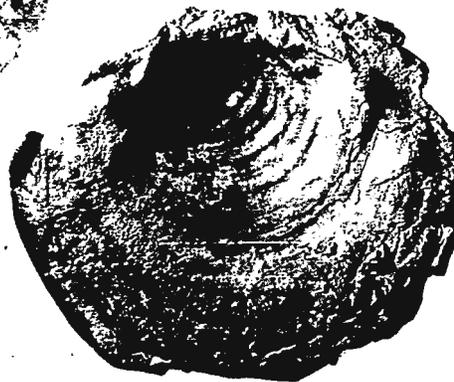
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## Explanation of Plate 3

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"Inoceramus truncatus" Logan ----- 34

Fig. 1. View (X.5) of interior of Logan's type specimen (KU 5782). Locality north of Ellis, along Saline River, Ellis Co.

2. View (X.5) of exterior of Logan's type specimen (KU 5782). Locality as above.

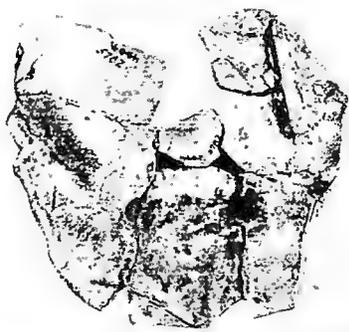
Inoceramus platinus Logan ----- 29

3. View (X.45) of fragmentary valve, KU 10748. Locality southwestern Nebraska.

4. View (X.12) of nearly complete specimen in Fort Hays Kansas State College Museum (no. 2086). Collected by G. F. Sternberg in 1948. Locality 25 miles southwest of Oakley and 7 or 8 miles northwest of Elkader.

Inoceramus deformis Meek ----- 21

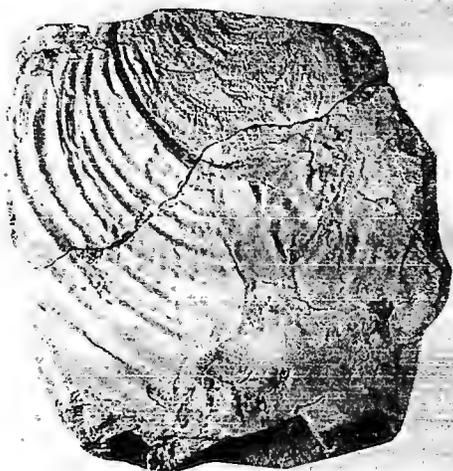
5. View (X.4) of internal cast from Fort Hays Member. Locality KU 11392.
6. View (X.3) of interior of valve collected by R.O. Mitchell (KU 7995). Locality southern Smith County.



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## Explanation of Plate 4

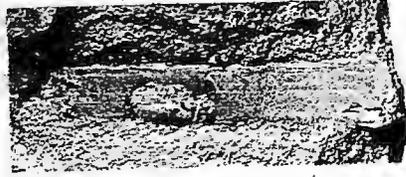
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<u>Eutrephoceras</u> sp. -----	46
Fig. 1. View (X.7) of venter of specimen. Collected by A.L. Morrow from the Smoky Hill Member. Locality NE $\frac{1}{4}$ sec. 2, T. 3S., R. 20W.	
2. Lateral view (X.7) of Morrow's specimen. Locality as above.	
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3. View (X.4) of living chamber of specimen from chalk monument area. Locality KU 11394.	
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8. View (X.25) of above specimen, from opposite side.	



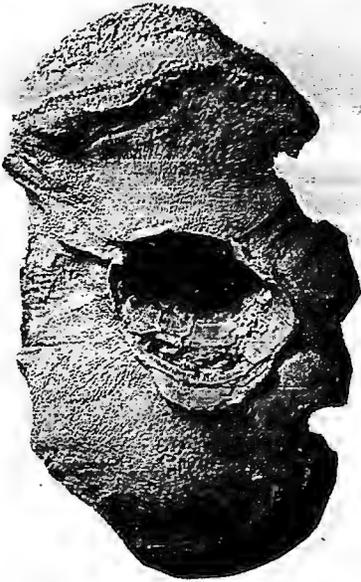
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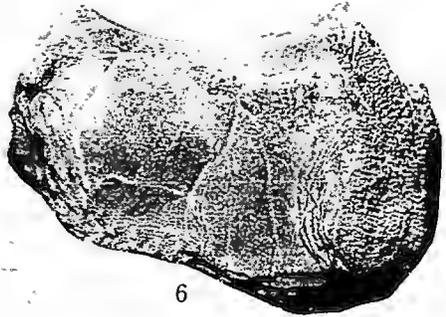
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## Explanation of Plate 5

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|---|------|
| <u>Actinocamax</u> cf. <u>A. manitobensis</u> Whiteaves -----   | 60   |
| Fig. 1. Dorsal view (X.7) of specimen from Smoky Hill Member. Collected B. G.F. Sternberg. Fort Hays Kansas State College Museum, no. 7936-2. Locality Logan or Gove County.  |      |
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| 3. Ventral view (X.7) of specimen from Smoky Hill Member. Collected by G.F. Sternberg. Fort Hays Kansas State College Museum, no. 7936-1. Locality Logan or Gove County.  |      |
| 4. Dorsal view (X.7) of specimen F.H.K.S.C.M. 7936-1, described above.  |      |
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| 5. View (X.14) of portion of gladius and guard of type specimen (KU 4208). Locality "Smoky Hill River, Kansas".   |      |
| <u>Niobrarateuthis bonneri</u> Miller -----   | 67   |
| 6. View (X.25) of gladius and portion of guard of type specimen. Collected by G.F. Sternberg, Fort Hays Kansas State College Museum, no. 7959. Locality south $\frac{1}{2}$ sec. 8, T. 15S., R. 34W., Logan County. |      |

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Recent cuttlebone -----	70
10. Thin section (X 480) of Recent cuttlebone. Slide by M.K. Elias, photo by W. Hoffman.	



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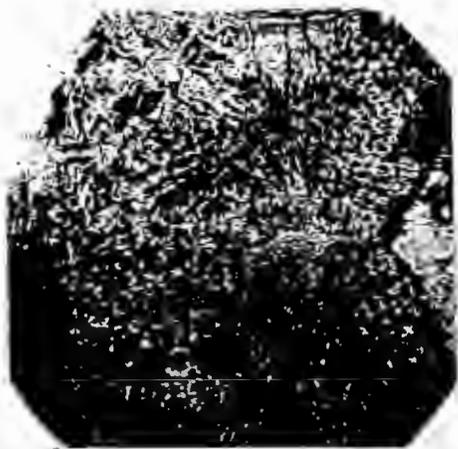
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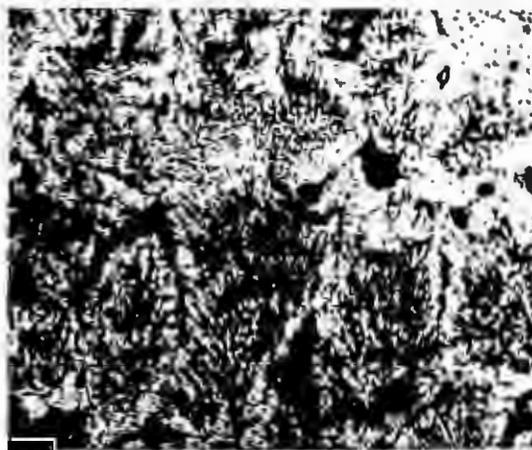
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## Explanation of Plate 6

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<u>Linuparis</u> ? sp. -----	80
Fig. 1. Lateral view (X 1.2) of specimen KU 7295. Locality "vicinity of Castle Rock", Gove County.	
<u>Stramentum haworthi</u> Williston -----	77
2. Lateral view (X.8) of the type specimen, KU 8323. Locality "near Gove City", Gove County.	
<u>Serpula tenuicarinata</u> Meek and Hayden -----	74
3. View (X.8) cluster of tubes. Collected by W.N. Logan, no number. Locality "Trego County, Kansas".	
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 Kansas State College Museum, no. 2022.  
 Collected by G.F. Sternberg. Locality "about  
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8. View (X.5) of slab collected by H.T. Martin.  
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9. Lateral view (X.2) of specimen collected by  
 A.L. Morrow. The specimen is a plaster cast  
 of an impression in the chalk. Locality NW $\frac{1}{4}$   
 sec. 15 T. 15S., R. 32W., Logan County.



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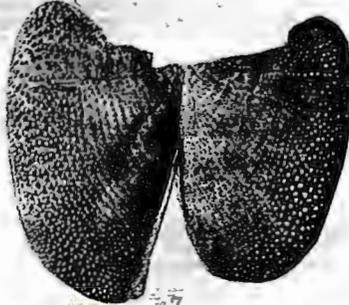
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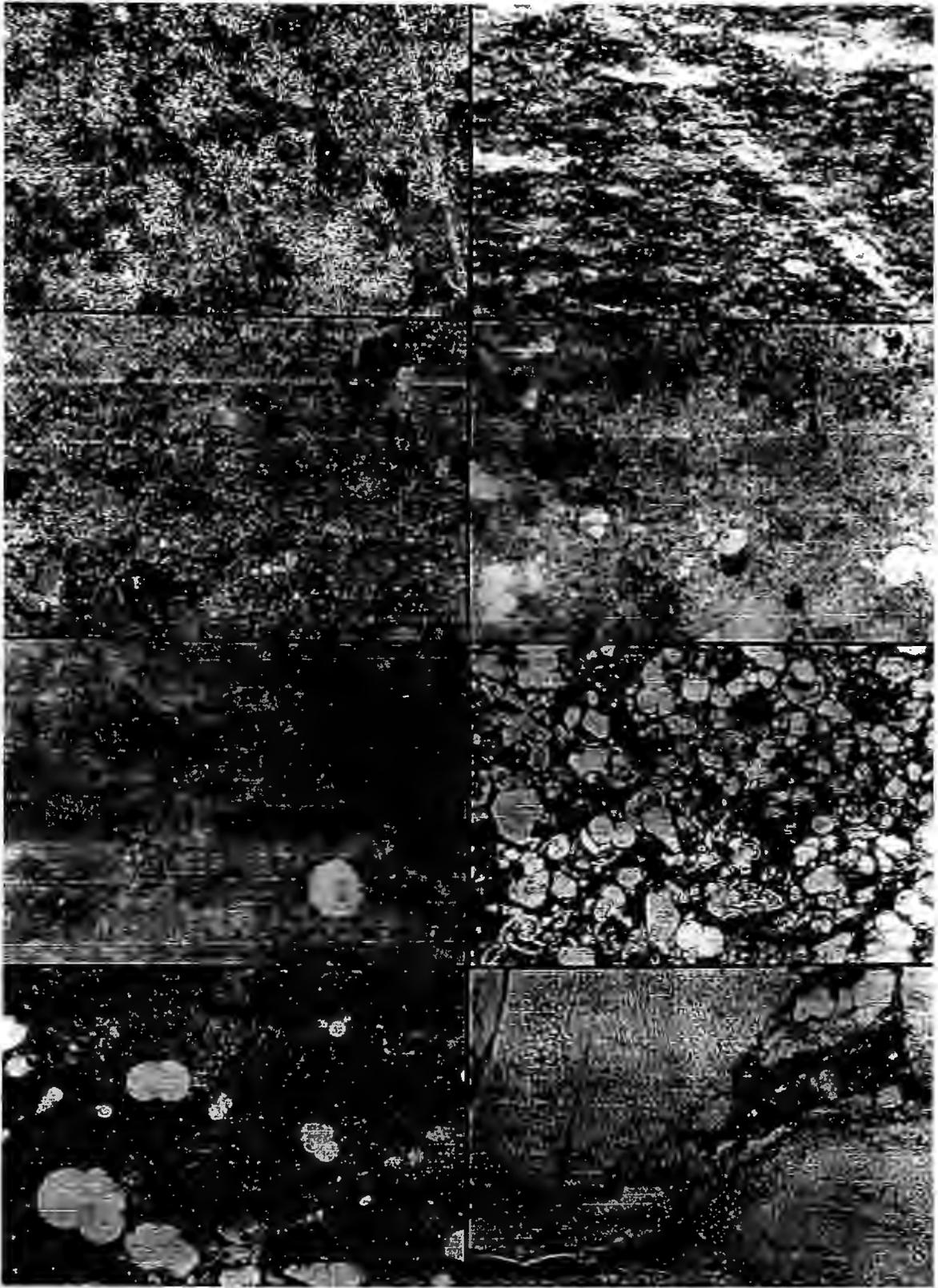
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## Explanation of Plate 7

- Fig. 1. Thin section of grey chalk (X 28) from N cent. S $\frac{1}{2}$ , sec. 25, T. 15S., R. 33W., at base of bluff. Smoky Hill Member
- Fig. 2. Same as above, except sample from 12 feet above base of bluff.
- Fig. 3. Same as above, except sample from 18 feet above base of bluff.
- Fig. 4. Same as above, except sample from 24 feet above base of bluff.
- Fig. 5. Same as above, except sample is yellow chalk from top (36 feet above base) of bluff. There is a lack of streaks and blotches of organic matter.
- Fig. 6. White chalk (X 28) from Fort Hays Member NW $\frac{1}{4}$  sec. 26, T. 13S., R. 19W. Gumbeliná is abundant.
- Fig. 7. Yellow chalk (X 28) from Smoky Hill Member in sec. 1, T. 14S., R. 33W.
- Fig. 8. Uintacrinus fragments (X 28) in crinoidal limestone from Smoky Hill Member in NE, SW $\frac{1}{4}$ , sec. 10, T. 14S., R. 33W.



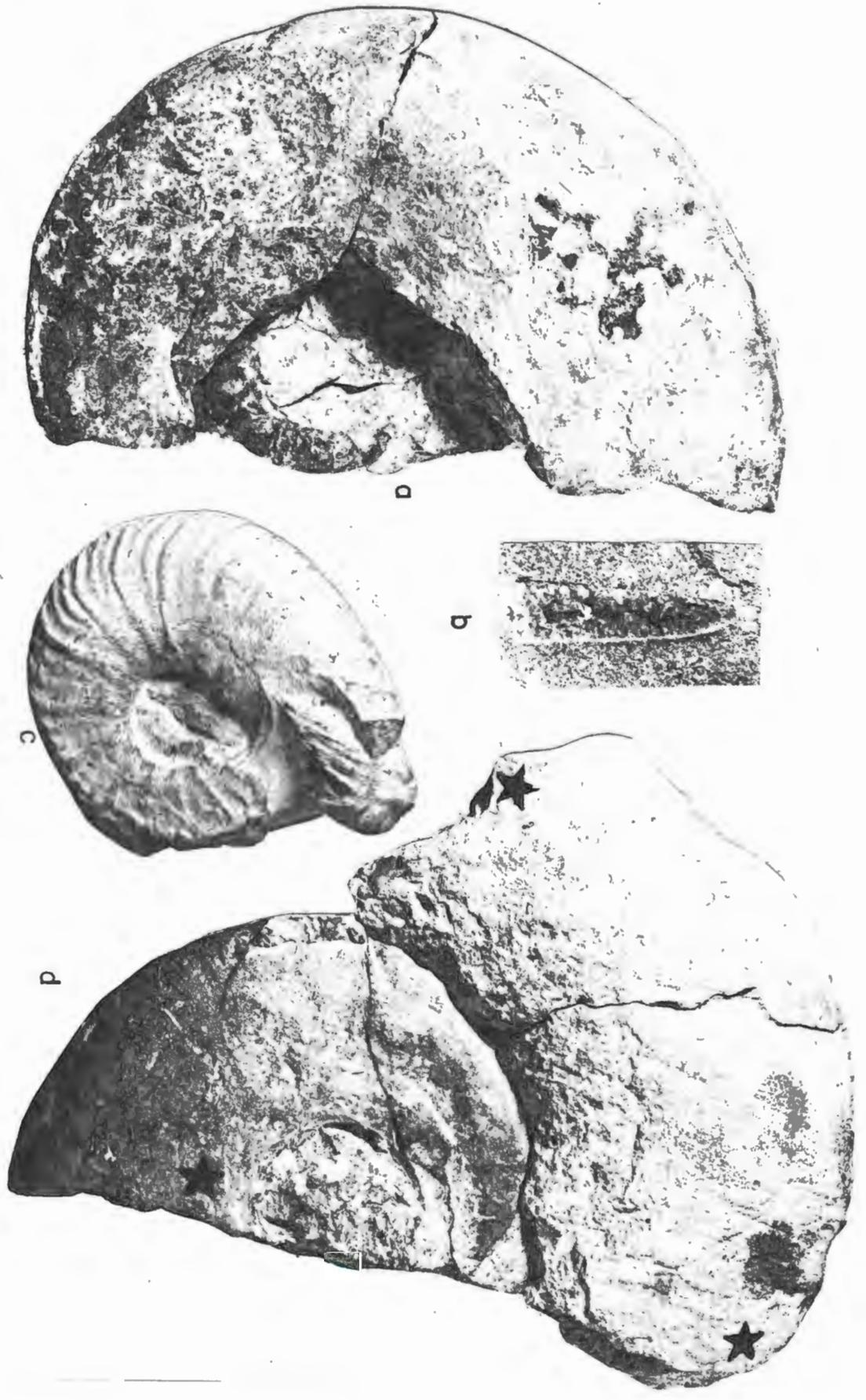


PLATE 5

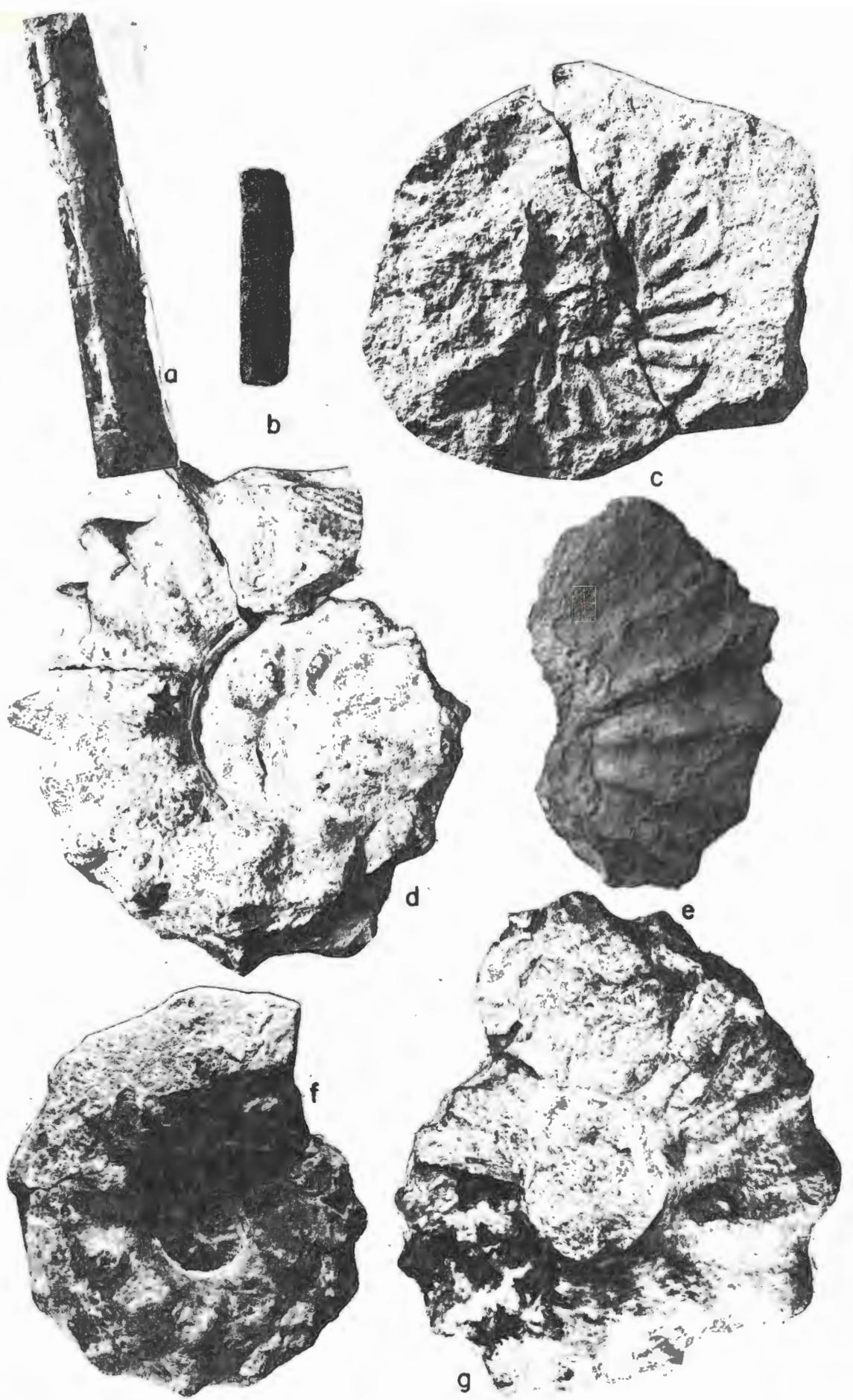


PLATE 6



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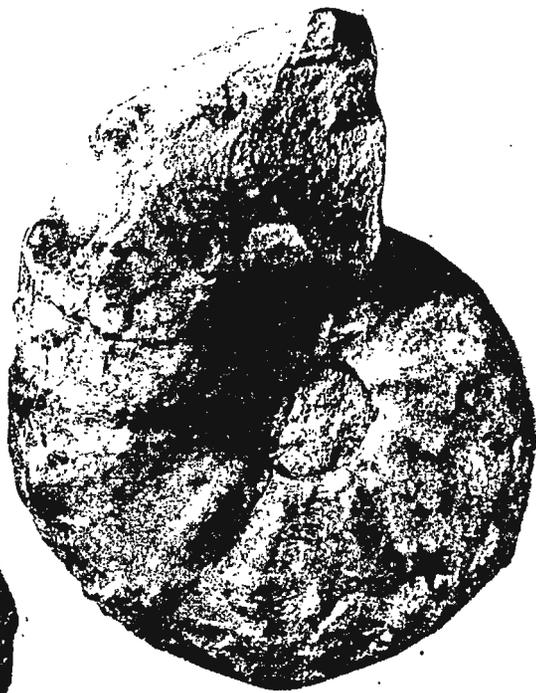
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PLATE 7



a



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b



c



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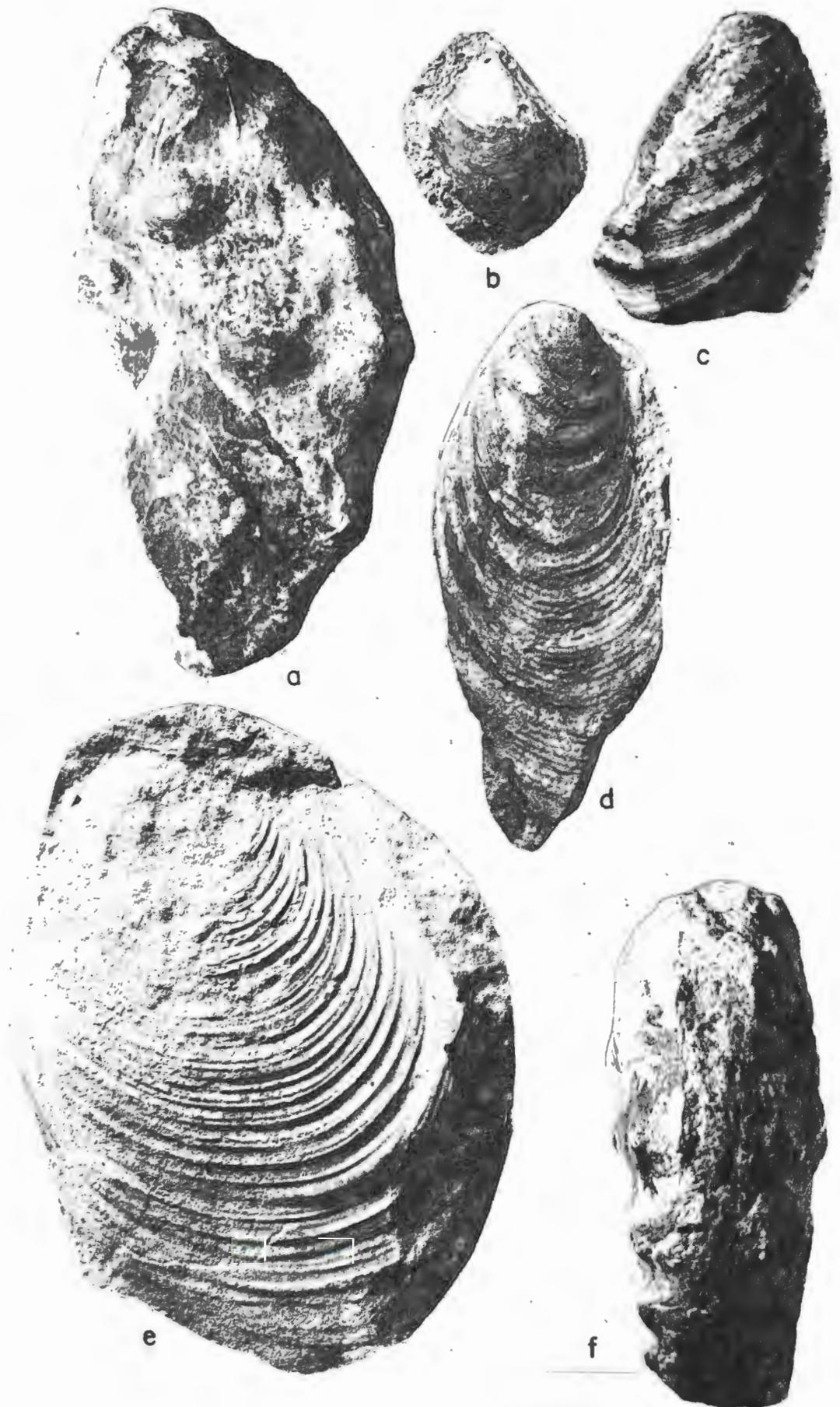


PLATE 2

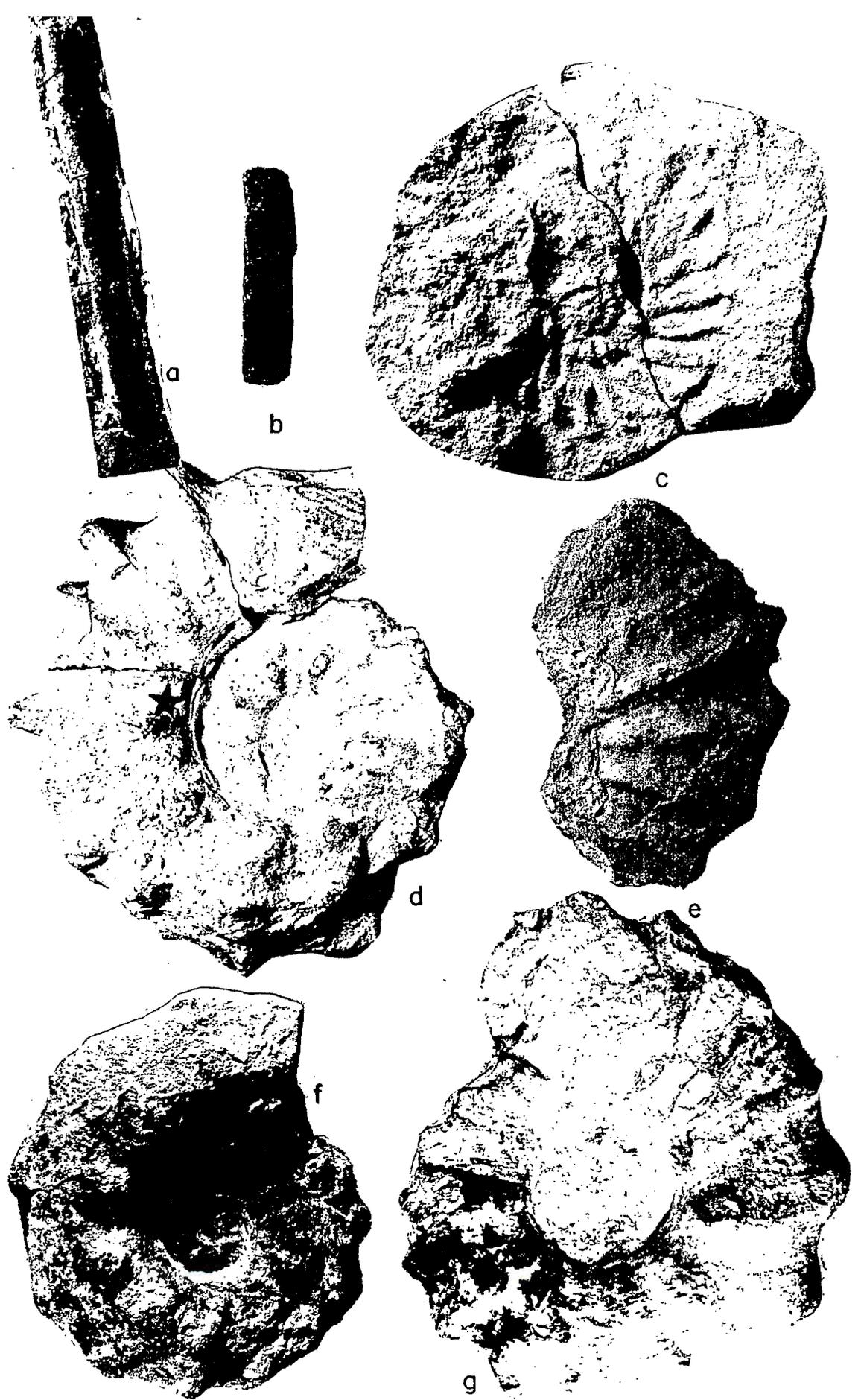


PLATE 6



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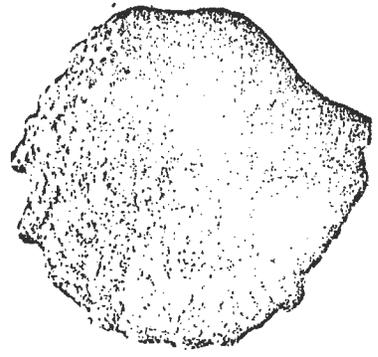
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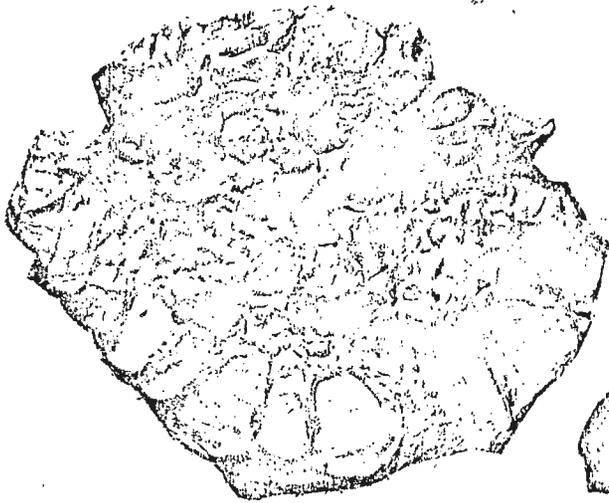
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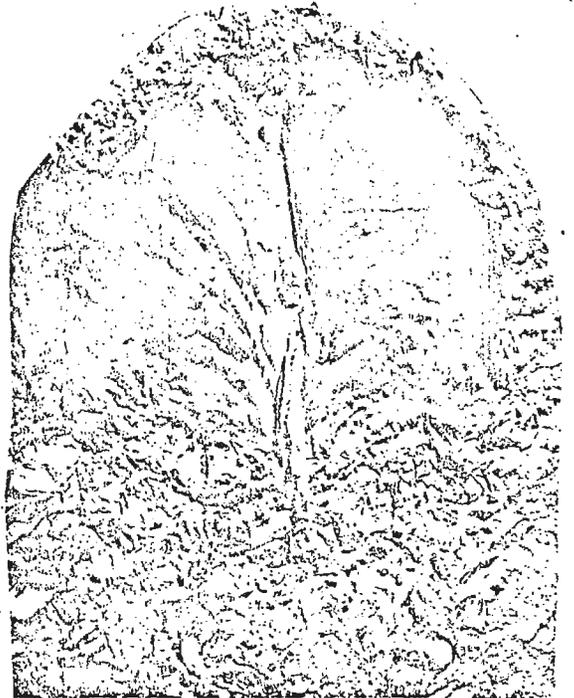
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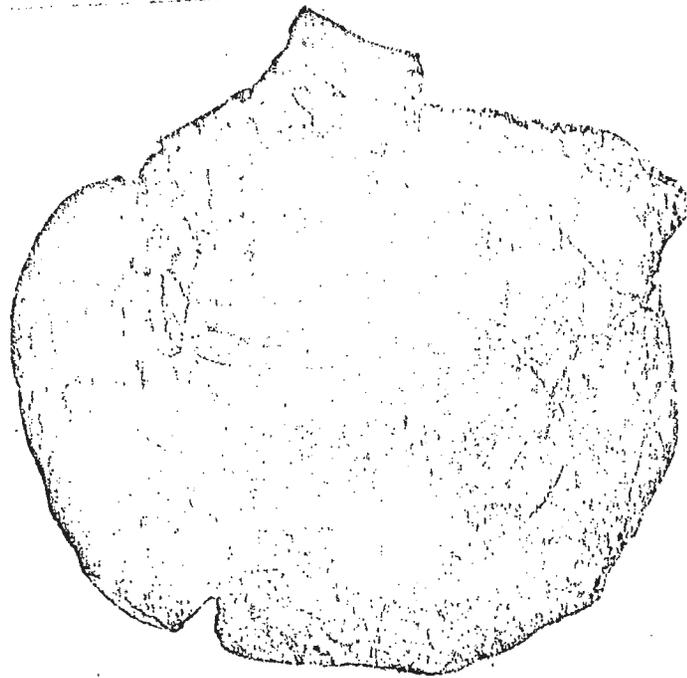
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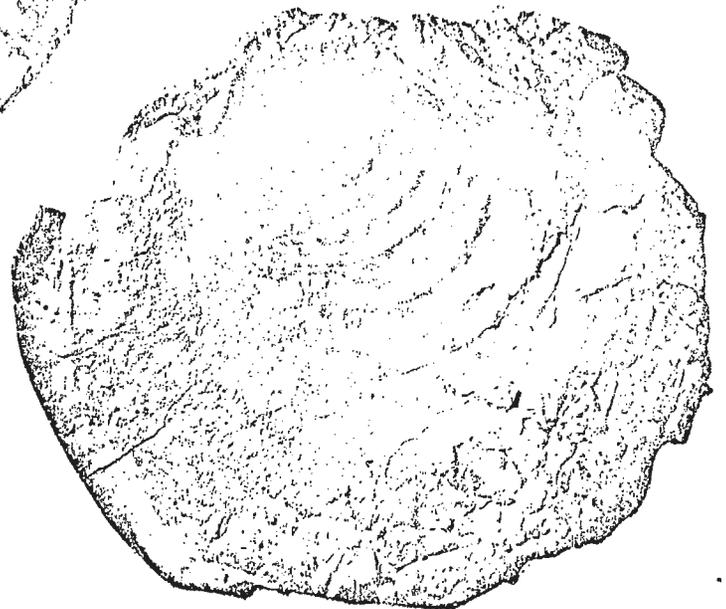
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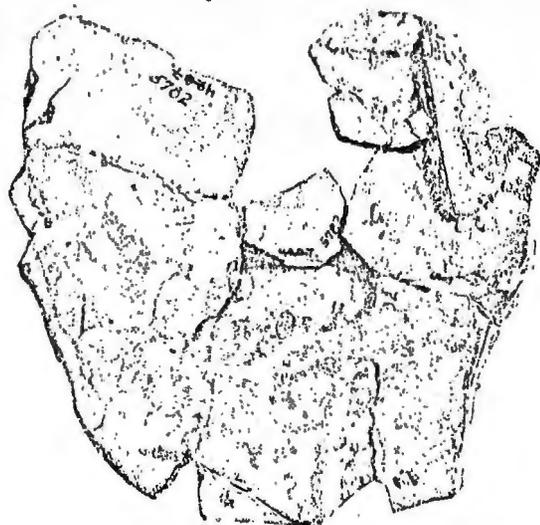
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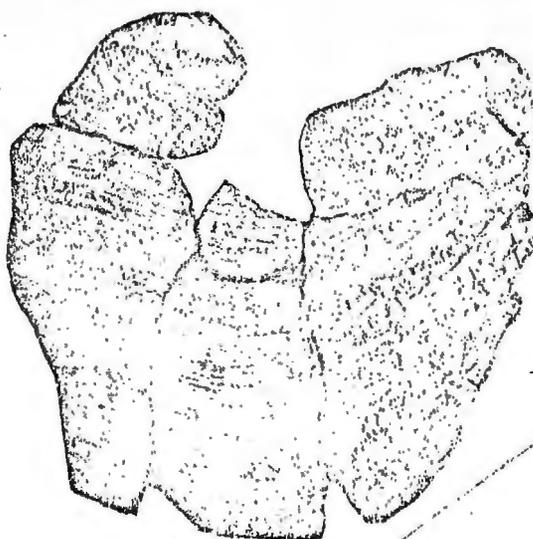
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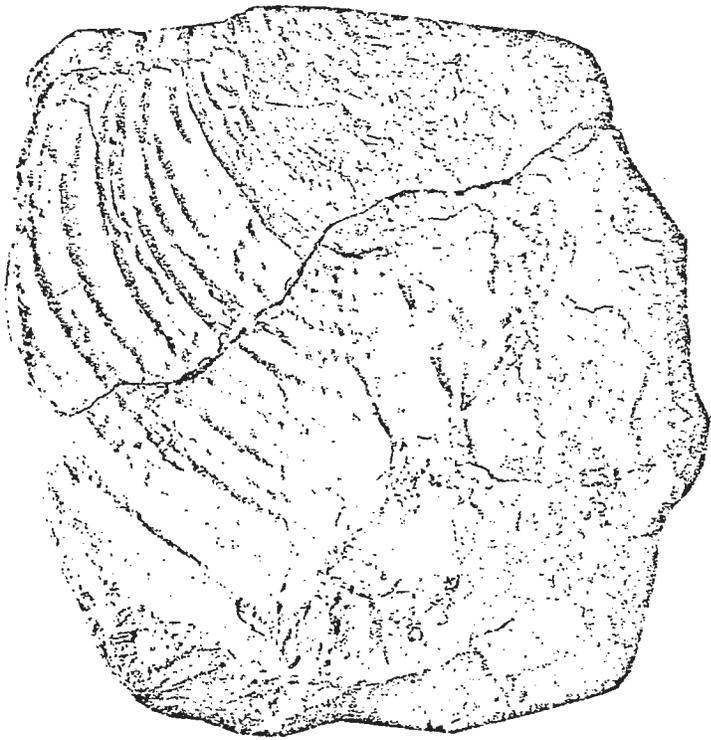
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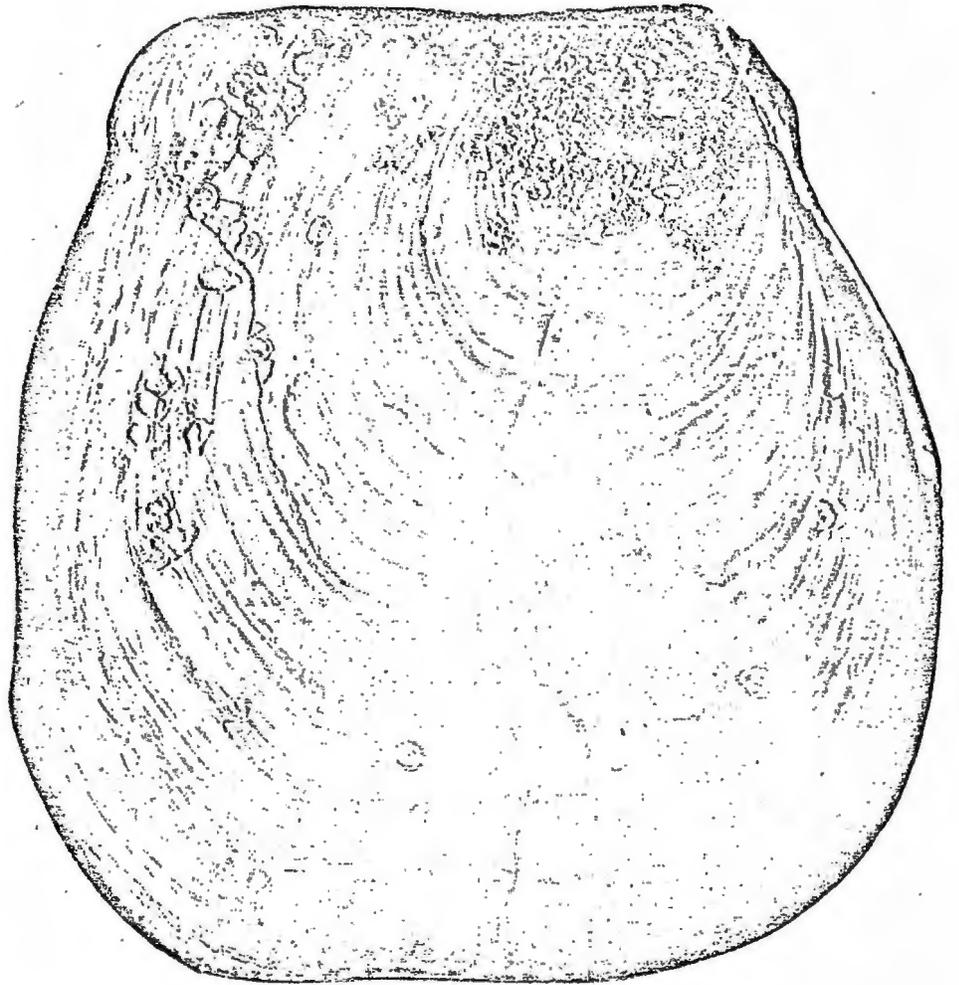
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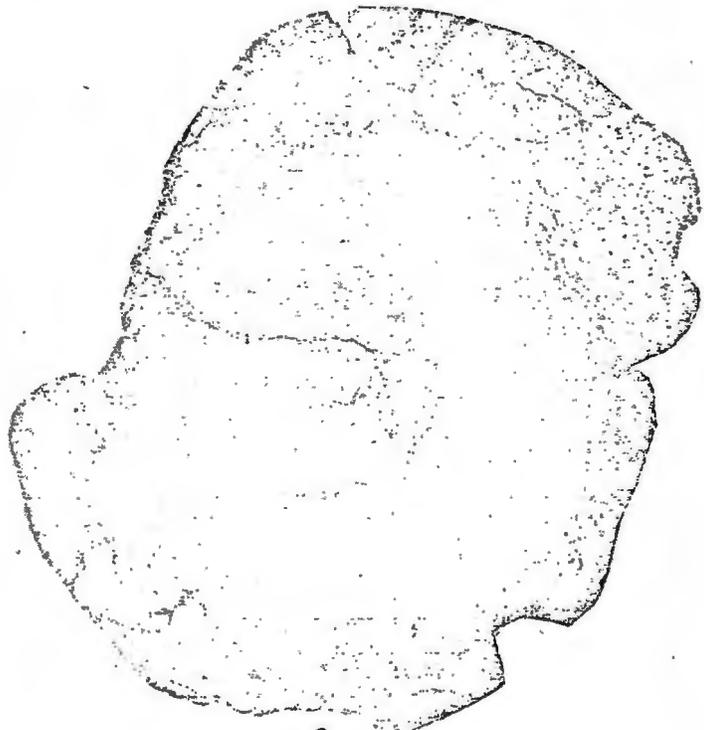
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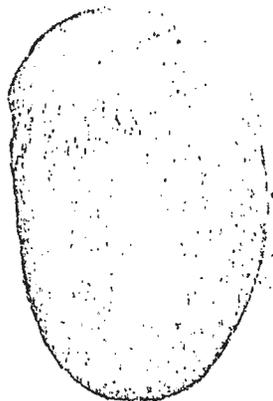


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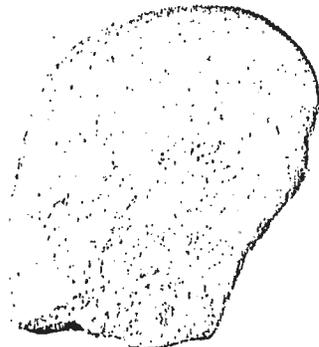


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Plate 4



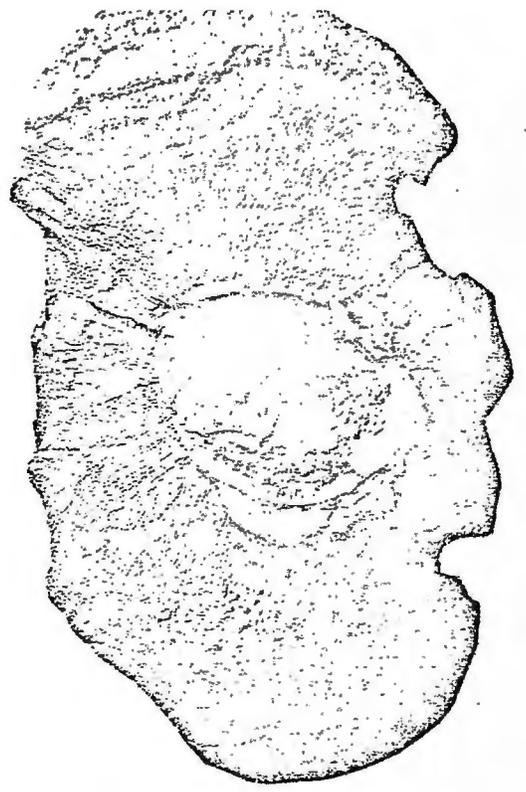
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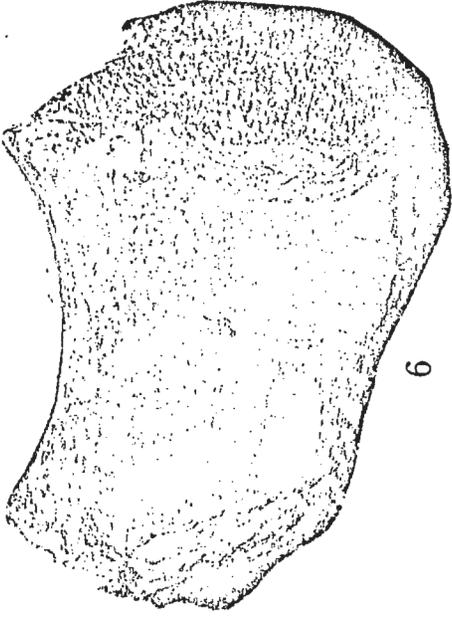
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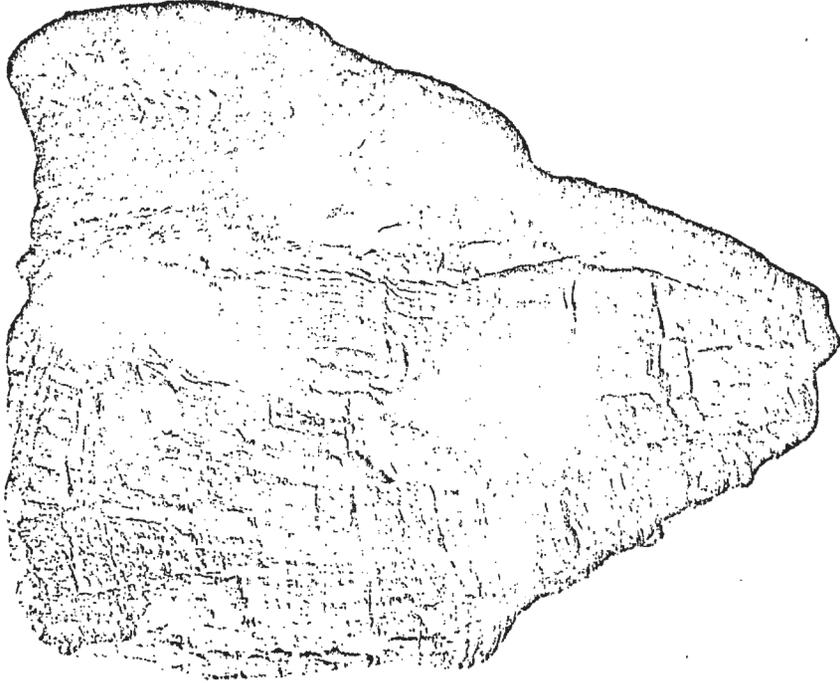
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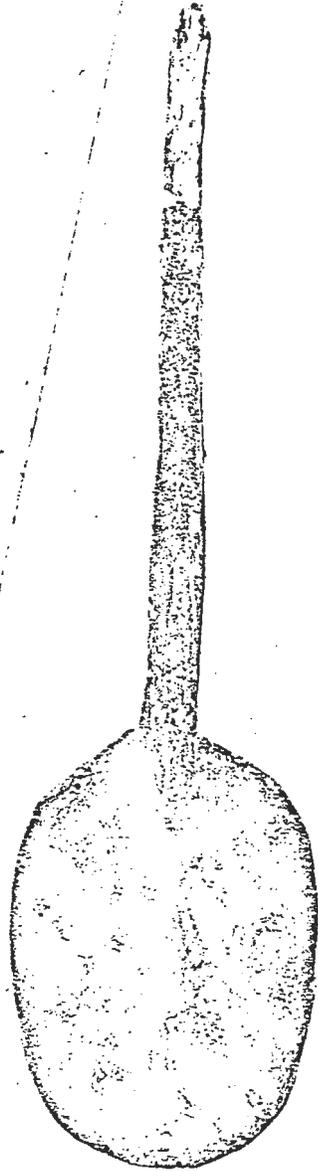
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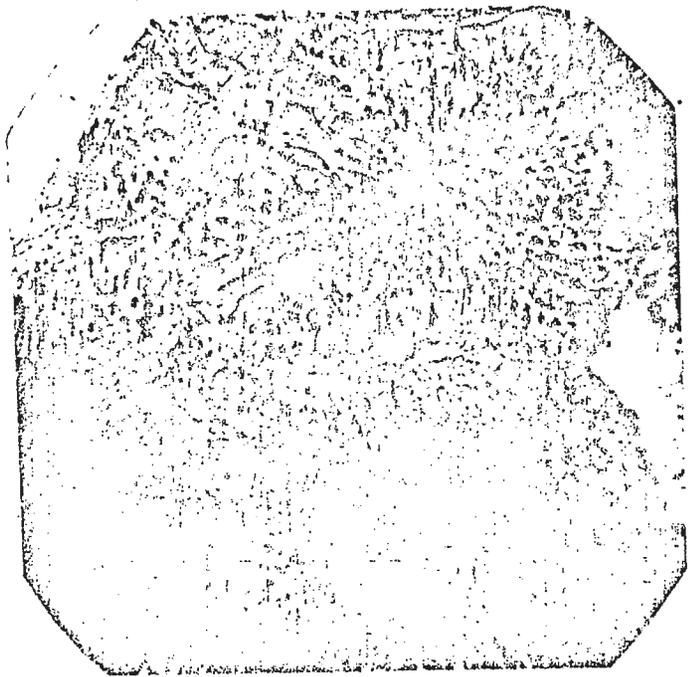
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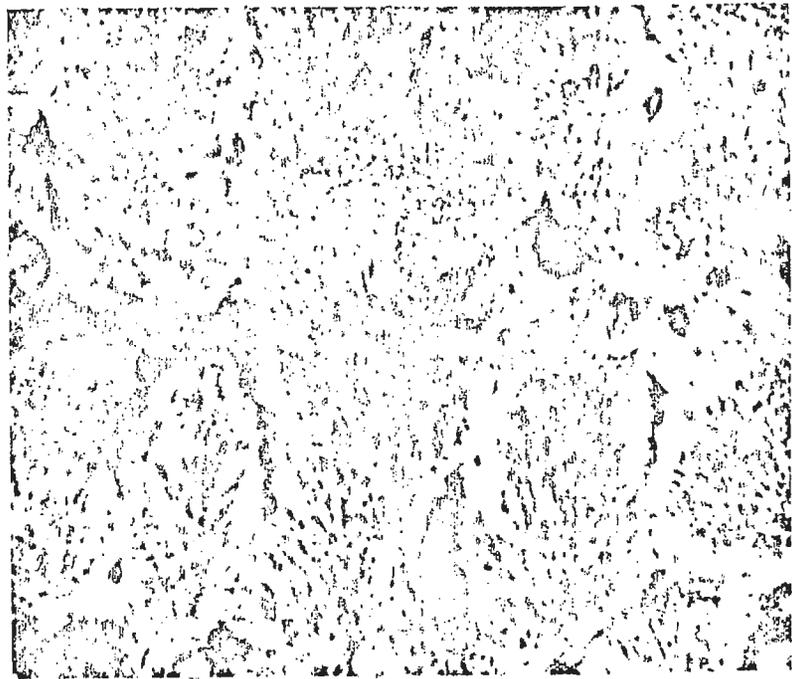
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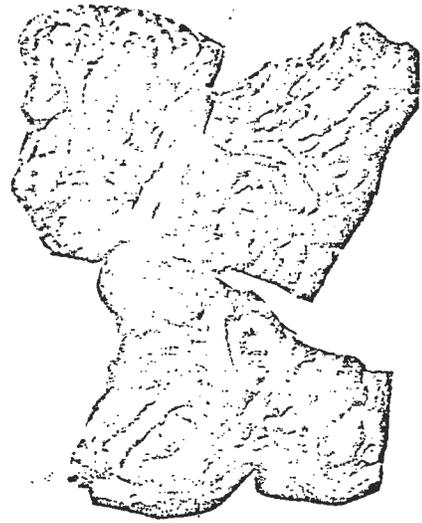
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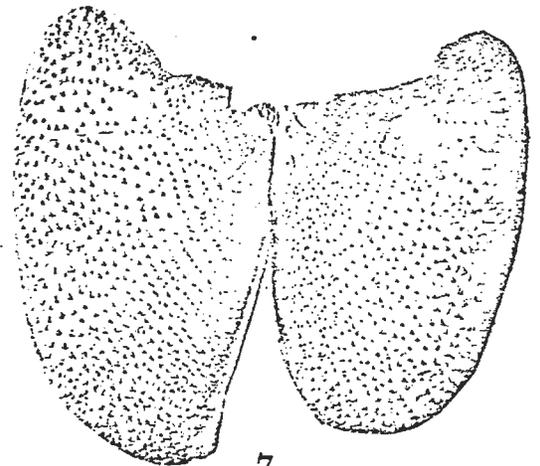
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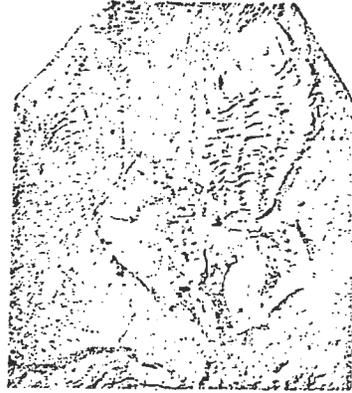
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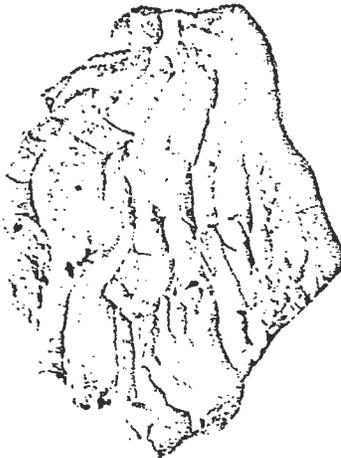
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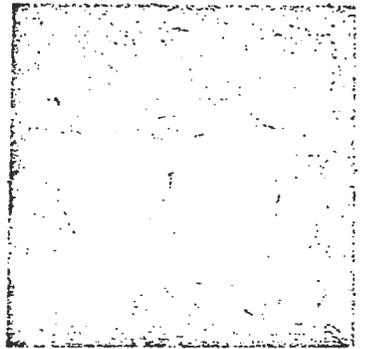
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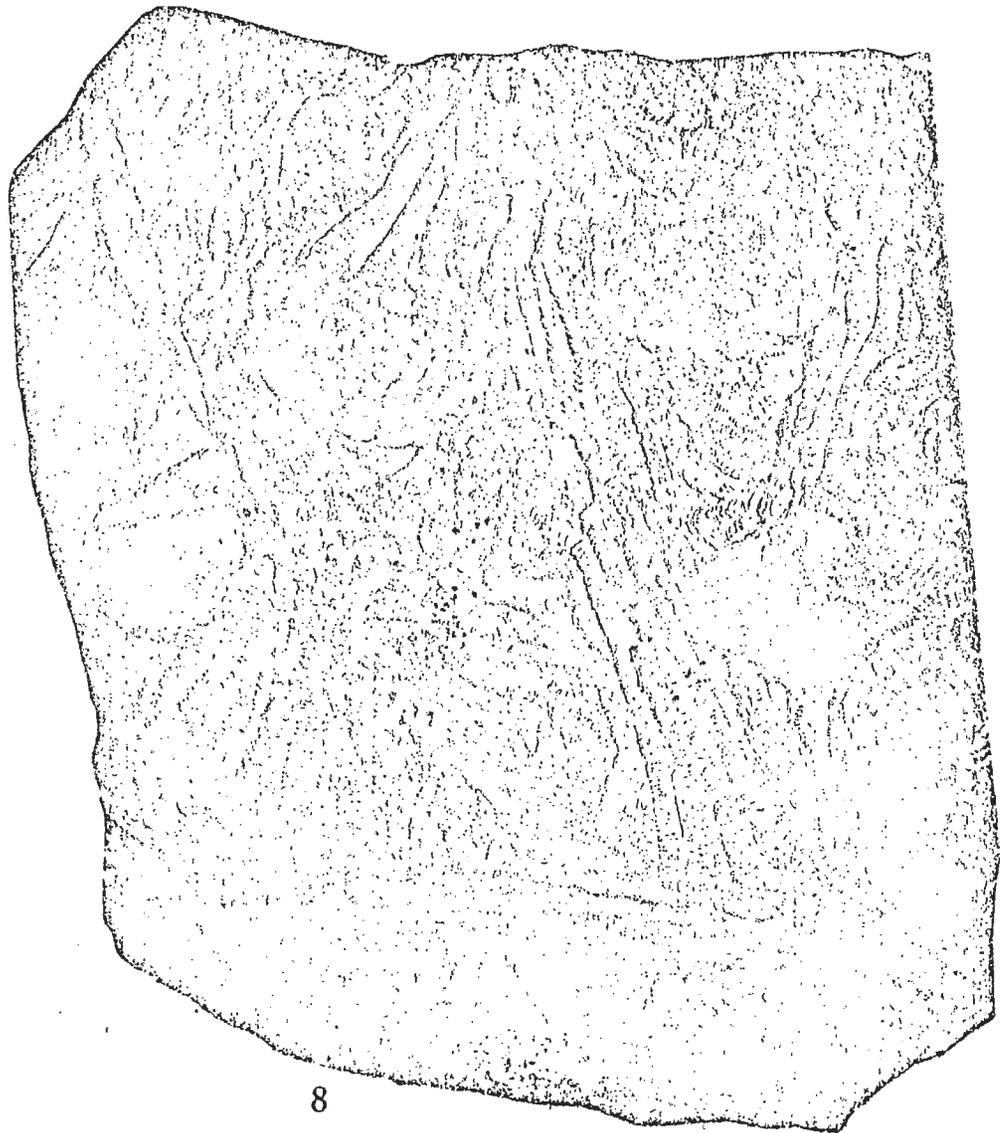
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