Molluscan Record From a Mid-Cretaceous Borehole in Weston County, Wyoming

GEOLOGICAL SURVEY PROFESSIONAL PAPER 1271

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Molluscan Record From a Mid-Cretaceous Borehole in Weston County, Wyoming

By WILLIAM A. COBBAN

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Brief descriptions, illustrations, and stratigraphic ranges of the more common fossils

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MOLLUSCAN RECORD FROM A MID-CRETACEOUS BOREHOLE IN WESTON COUNTY, WYOMING

By WILLIAM A. COBBAN

ABSTRACT

A core borehole in the Osage oilfield on the west flank of the Black Hills uplift in eastern Wyoming penetrated, in decending order, most of the Carlile Shale, all of the Greenhorn Formation, and the upper part of the underlying Belle Fourche Shale. Molluscan fossils are abundant in parts of the core and indicate an age span of early Coniacian to the middle Cenomanian. Most of the fossils are bivalves and ammonites; gastropods are scarce.

Fossils in the cores indicate the following zones

Lower Coniacian
Cremnoceramus? *waltersdorfensis*
Upper Turonian
Scaphites corvensis
S. nigricollensis
S. whitfieldi
S. warreni
Middle Turonian
Collignoniceras woollgari
Lower Turonian
Mytiloides mytiloides
Mytiloides aff. *M. duplicostatus*
Upper Cenomanian
Sciponoceras gracile
Dunveganoceras albertense
D. pondi
Middle Cenomanian
Acanthoceras amphibolum

INTRODUCTION

A cored borehole was drilled by the U.S. Geological Survey in 1976 in the Osage oilfield on the west flank of the Black Hills uplift in eastern Wyoming (Merewether, 1980). This borehole, in the SW¼NW¼ sec. 30, T. 46 N., R. 63 W., Weston County, was drilled to a total depth of 270.8 meters. The purpose was to obtain fresh samples for sedimentologic and paleontologic analyses as well as to obtain geophysical logs for references to subsurface studies of mid-Cretaceous rocks in the Powder River Basin. The site of the borehole was selected because of its proximity to measured outcrop sections of mid-Cretaceous rocks. Cores from the borehole were split along bedding planes for molluscan fossils, and samples of the cores were taken at intervals for investigations of the foraminifera, dinoflagellates, and palynomorphs. Unfortunately, the diameter of the cores is small (47 mm), but, nevertheless, an impressive fossil record was obtained.

ACKNOWLEDGMENTS

E. A. Merewether of the U.S. Geological Survey proposed this project, selected the borehole site, and supervised the coring. He also split most of the cores and collected most of the megafossils as well as the samples for micropaleontological studies. R. E. Burkholder, also of the Geological Survey, photographed the megafossils and prepared some of the specimens.

All illustrated specimens are stored in the National Museum of Natural History in Washington, D. C., and have USNM catalog numbers.

STRATIGRAPHIC SUMMARY

A graphic log of the borehole showing formational assignments and lithologic contacts was presented by Merewether (1980, fig. 4). The top of the borehole is probably a little below the top of the Carlile Shale. Here the Carlile consists of three members. The upper member, Sage Breaks, consists of calcareous and noncalcareous shale with scattered limestone concretions. About 85 m were penetrated in the borehole. Merewether (1980, p. 13) noted thicknesses of 91–94 m in wells in the Osage oilfield. The Turner Sandy Member, the middle part of the Carlile, extends from depths of 85–140 m and consists of interbedded fine- to very fine grained sandstone, siltstone, and noncalcareous shale with sandy or silty limestone concretions. The underlying Pool Creek Member extends from 140–163 m and consists of calcareous shale. Calcareous shale and thin beds of limestone make up the Greenhorn Formation, which extends from 163 to 240 m. Noncalcareous shale with several beds of bentonite comprise the underlying Belle Fourche Shale of which the upper 31 m were penetrated in the borehole.

PRESERVATION OF FOSSILS

With few exceptions, the mollusks in the cores occur crushed in dark-gray shale. Some specimens are completely flattened. Other specimens, especially those in more silty matrices, are not as crushed. A few specimens in gray siltstone beds in the Turner Sandy Member of the Carlile Shale are almost undeformed. Some shell material is usually preserved on most specimens. Pyritic fossils are common in the lower part of the Greenhorn Formation at depths of 216–230 m and 244–247.5 m.

STRATIGRAPHIC DISTRIBUTION AND AGE

The ranges of most of the mollusks from the borehole are shown in figure 1. Gastropods are extremely scarce, and none is shown.

The mollusks reveal an age span of the cores of middle Cenomanian into early Coniacian. The middle Cenomanian age of the lowest cores is based mainly on the occurrence of the ammonite *Acanthoceras* at depths of 243.8–257.3 m. With the exception of *A. hippocastanum* (J. de C. Sowerby), most occurrences of the genus are in rocks regarded as middle Cenomanian age (for example Kennedy and Hancock, 1976, p. 5.15; 1977, p. 130–135). Cores from depths of 237.7–246 m contain *Inoceramus crippsi* Mantell, a species found mostly in lower and middle Cenomanian rocks of Europe. Cores from depths of 220.7–240 m contain *Inoceramus prefragilis* Stephenson, a species restricted to the ammonite zones of *Plesiacanthoceras wyomingense* (Reagan) and *Dunveganoceras pondi* Haas in the Western Interior. These ammonites, which developed out of *Acanthoceras*, seem best assigned a late Cenomanian age. The boundary between the middle and upper Cenomanian is probably near a depth of 240 m in the borehole.

The boundary between the Cenomanian and Turonian seems best placed at a depth of about 180 m, which lies about at the top of the range of *Inoceramus pictus* J. de C. Sowerby and base of the range of *Mytiloides*. Ammonites associated with *I. pictus* in cores from depths of 181.1–184.7 m include *Scaphites* (*Pteroscaphites*) *minutus* Moreman, *Worthoceras vermiculum* (Shumard), and *Allocrioceras annulatum* (Shumard), which are restricted to the zone of *Sciponoceras gracile* (Shumard). This zone is usually regarded as the top of the Cenomanian (for example Kennedy and Hancock, 1976, p. 5.16; 1977, p. 134–136).

The boundary between the lower and middle Turonian lies near the top of the Greenhorn Formation. *Collignoniceras woollgari regulare* (Haas), which occurs in the cores of the basal part of the Carlile Shale at depths of 155–160.9 m, is a middle Turonian ammonite (Cobban and Hook, 1979, p. 12). *Mytiloides mytiloides* (Mantell), found in cores from the upper part of the Greenhorn Formation at depths of 164–171.4 m, is usually regarded as a guide fossil to the lower Turonian although the species overlaps the lower range of *C. woollgari*. *Mytiloides subhercynicus* (Seitz) occurs in cores from depths of 167.1–168.4 m. Inasmuch as this fossil is found with both the early (*woollgari woollgari*) and late (*woollgari regulare*) forms of *C. woollgari*, the boundary between the lower and middle Turonian is probably best placed at a depth of about 168 m.

The boundary between the middle and upper Turonian lies somewhere between depths of 136–155 m. Megafossils were not found in the cores from those depths. A core from a depth of 155 m has *Collignoniceras woollgari regulare* (Haas) of middle Turonian age, and a core from a depth of 136 m has *Scaphites warreni* Meek and Hayden of early late Turonian age.

The boundary between the Turonian and Coniacian is placed at the lowest occurrence of *Cremnoceramus*? *waltersdorfensis* (Andert) and *C*? *rotundatus* (Fiege) following the proposals by Kauffman, Cobban, and Eicher (1976 p. 23.16). This is at a depth of about 70 m. The next lower control point is a core from a depth of 76 m that contains *Mytiloides fiegei fiegei* (Tröger) of late Turonian age.

MOLLUSCAN ZONES

Fossils from the lowest part of the core include *Acanthoceras amphibolum* Morrow and *Inoceramus rutherfordi* Warren, both restricted to the middle Cenomanian zone of *A. amphibolum*. That ammonite has long been accepted as a guide fossil to one of the Western Interior Cenomanian zones (Cobban, 1951a, p. 2197; Cobban and Reeside, 1952a, p. 1017). The top of the zone is placed at a depth of 248 m in the borehole.

Plesiacanthoceras wyomingense (Reagan) marks the next Cenomanian zone above that of *A. amphibolum* in the Western Interior. The zone of *P. wyomingense* was originally recorded as the zone of *Acanthoceras*? n. sp. (Cobban, 1951a, p. 2197), next as the zone of *Acanthoceras*? sp. A (Cobban and Reeside, 1952a, p. 1017), later as the zone of *Acanthoceras*? *wyomingense* (Cobban, 1958, p. 117–119), and finally as the zone of *Plesiacanthoceras wyomingense* (Merewether and Cobban, 1972, p. D59). On outcrops in the vicinity of the borehole, a disconformity separates the Belle Fourche

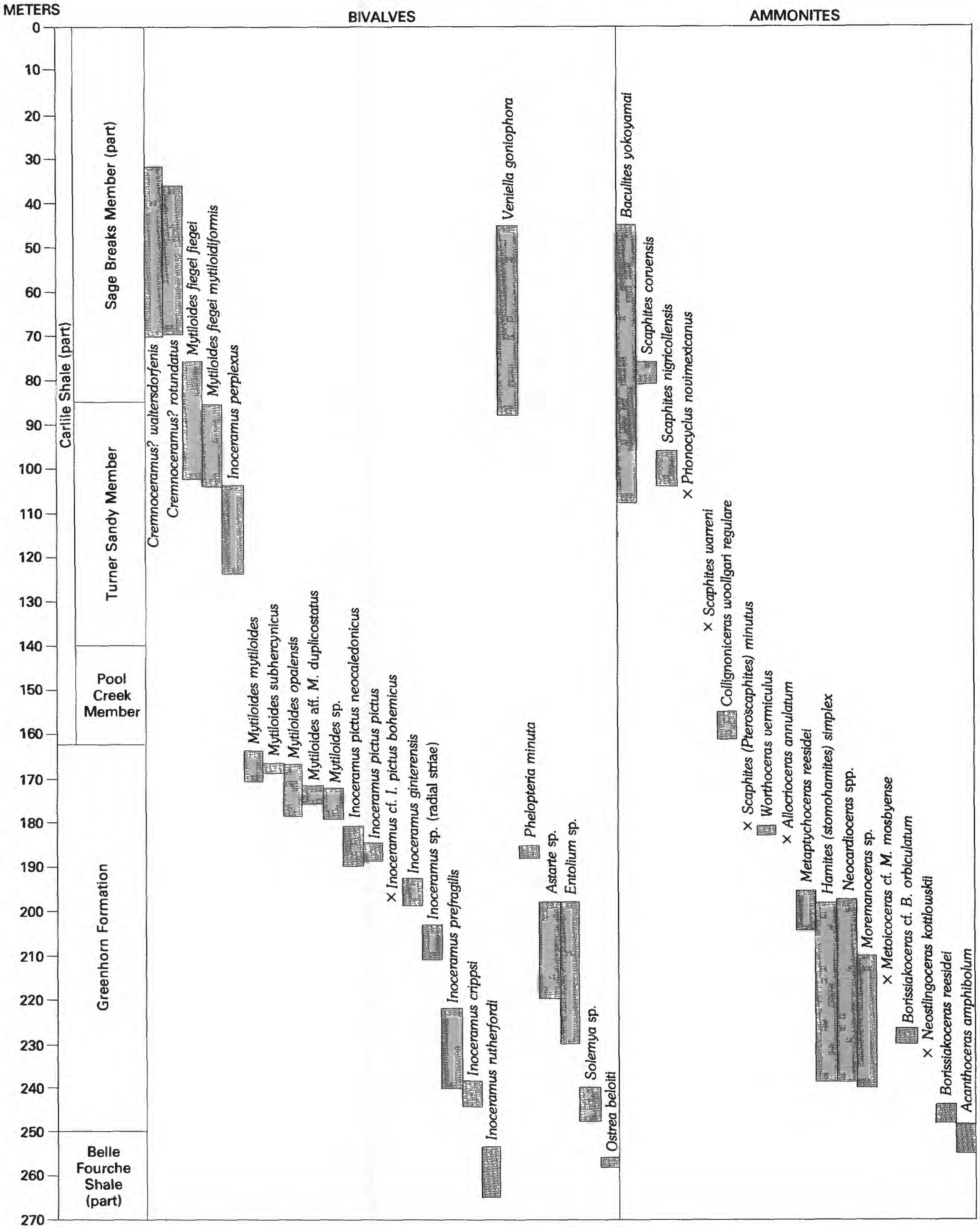

FIGURE 1.—Ranges of most of the bivalves and ammonites in the cores from the borehole in sec. 30, T. 46 N., R. 63 W., Weston County, Wyo.

Shale from the overlying Greenhorn Formation, and *P. wyomingense*, which normally should be in the uppermost Belle Fourche Shale, is missing.

In the Western Interior, the ammonite *Dunveganoceras pondi* Haas marks the next Cenomanian zone above that of *P. wyomingense*. The zone of *D. pondi* (Cobban, 1951a, p. 2197) is best documented in the lower part of the Greenhorn Formation in the central Great Plains and in the equivalent part of the Frontier Formation of Wyoming, where the upper part of the range of *Inoceramus prefragilis* Stephenson overlaps the range of *D. pondi*. *Dunveganoceras pondi* was not found in the cores from the borehole, but *I. prefragilis* occurs in the cores from the lower part of the Greenhorn Formation at depths of 221–240 m, and this interval is assumed to represent the zone of *D. pondi*.

The zone of *Dunveganoceras albertense* (Warren) (Cobban, 1951a, p. 2197) is the next Cenomanian zone above that of *D. pondi* in the Western Interior. Guide fossils to the zone of *D. albertense* include *Inoceramus ginterensis* Pergament and *Metoicoceras mosbyense* Cobban, which occur in the cores from depths of 192.5–199 m and 216 m, respectively. *Inoceramus pictus pictus*, which may be restricted to the overlying zone of *Sciponoceras gracile* (Shumard), occurs in a core at a depth of 189 m, and, accordingly, the zone of *D. albertense* probably extends from about 190–221 m.

The latest Cenomanian zone of *Sciponoceras gracile* (Shumard) (Cobban, 1951a, p. 2197) occupies the interval 181–190 m in the borehole. Characteristic ammonites of this zone in the cores include *Allocrioceras annulatum* (Shumard), *Worthoceras vermiculum* (Shumard), and *Scaphites* (*Pteroscaphites*) *minutus* Moreman found at depths of 181.1–184.7 m. The zone is extended to a depth of 189 m because of the presence of *Inoceramus pictus pictus* in cores from depths of 185–189 m.

Owing to the lack of ammonites and the fragmentary state of the inoceramids in the cores from the upper part of the Greenhorn Formation at depths of 164–180 m, well-defined early Turonian zones, like those at Pueblo, Colo. (Cobban and Scott, 1972, p. 31, 32), cannot be satisfactorily determined for the borehole. The inoceramids, however, reveal at least two early Turonian zones, a lower one of *Mytiloides* aff. *M. duplicostatus* (Anderson) and an upper one of *M. mytiloides* (Mantell). The first clearly defined zone above the Greenhorn Formation is that of *Collignoniceras woollgari regulare* (Haas) in the cores from depths of 155–160.9 m.

Lack of mollusks in the 19 m of Carlile Shale overlying the highest occurrence of *C. woollgari regulare* in the borehole prevents the recognition of other middle Turonian zones, such as that of *Scaphites carlilensis* Morrow–*Prionocyclus hyatti* (Stanton) (Cobban, 1951a, p. 2197). A single specimen of *Scaphites warreni* Meek and Hayden at a depth of 136 m reveals the presence of this late Turonian zone, but the thickness of the zone cannot be determined. Likewise, the occurrence of *Prionocyclus novimexicanus* (Marcou) in a core at a depth of 106.1 m indicates the zone of *Scaphites whitfieldi* Cobban (1951a, p. 2197), but the thickness is unknown. The next younger Turonian scaphite zone, that of *Scaphites nigricollensis* Cobban (1951a, p. 2197), is well represented in the cores from the depths of 96–104 m, and the youngest Turonian scaphite zone of *S. corvensis* Cobban is indicated by the presence of specimens in the cores of the lower part of the Sage Breaks Member of the Carlile Shale at depths of 76–81 m. The zone of *S. corvensis* should extend lower inasmuch as the scaphite also occurs in the upper part of the Turner Sandy Member at outcrops in the Black Hills area. Above this scaphite zonation, the only molluscan zone that can be recognized in the cores is the early Coniacian zone of *Cremnoceramus*? *waltersdorfensis* (Andert) at depths of 32–70 m.

MEGAFOSSIL CONTENT

Megafossils, chiefly mollusks, were collected from cores at the following depths. The first number is the USGS Mesozoic locality number, and the second is the depth.

CARLILE SHALE

SAGE BREAKS MEMBER

D9982. 32–33 m. Calcareous shale.
Phelopteria sp.
Cremnoceramus? *waltersdorfensis* (Andert)
Lucina sp.

D9983. 33.5–35 m. Calcareous shale.
Nucula (*Pectinucula*) sp.
Nuculana sp.
Striarca sp.
Cremnoceramus? *waltersdorfensis* (Andert).
Scaphites sp.

D9984. 35.5–36.5 m. Slightly calcareous to noncalcareous shale.
calcareous worm tubes
Nucula (*Pectinucula*) sp.
Striarca sp.
Cremnoceramus? *waltersdorfensis* (Andert).
Baculites sp.

D9985. 38.9–39.6 m. Slightly calcareous shale.
Cremnoceramus? *rotundatus* (Fiege).

D9986. 40.2–42.1 m. Slightly calcareous to noncalcareous shale.
Cremnoceramus? *waltersdorfensis* (Andert)
Pholadomya sp.

D9987. 45–45.2 m. Slightly calcareous shale.
Cremnoceramus? *walterdorfensis* (Andert)
Veniella goniophora Meek
Baculites yokoyamai Tokunaga and Shimizu

D9988. 47.9 m. Very slightly calcareous shale.
Pseudoperna sp.
Baculites yokoyamai Tokunaga and Shimizu
D9989. 52.7 m. Noncalcareous shale.
Compressed, indeterminate mesogastropod
D9990. 57.2 m. Noncalcareous shale.
Nuculana sp.
Baculites sp.
D9991. 69.9 m. Noncalcareous shale.
Cremnoceramus? *waltersdorfensis* (Andert)
C.? *rotundatus* (Fiege)
D9992. 76–76.7 m. Noncalcareous shale.
Mytiloides fiegei fiegei (Tröger)
Scaphites corvensis Cobban
D9993. 78.7–79.8 m. Noncalcareous shale.
Calcareous worm tube
Nucula (*Pectinucula*) sp.
Striarca sp.
Veniella goniophora Meek
Corbulid
Scaphites corvensis Cobban
D9994. 80.6–81.2 m. Slightly calcareous to noncalcareous shale.
Mytiloides fiegei fiegei (Tröger)
Compressed incomplete aporrhaid gastropod
Scaphites corvensis Cobban
D9995. 81.7–82 m. Slightly calcareous to noncalcareous shale.
Phelopteria sp.
Cremnoceramus? cf. *C.*? *rotundatus* (Fiege)
Baculites sp.
Prionocyclus sp.
D9996. 84.8–84.9 m. Noncalcareous shale.
Mytiloides cf. *M. dresdensis labiatoidiformis* (Tröger)
Scaphites sp.

TURNER SANDY MEMBER

D9997. 85.5–86.6 m. Bioturbated argillaceous siltstone.
Mytiloides fiegei mytiloidiformis (Tröger)
Amauropsis? sp.
Baculites yokoyamai Tokunaga and Shimizu
D9998. 87–88.9 m. Bioturbated argillaceous siltstone and very fine grained sandstone.
Mytiloides fiegei fiegei (Tröger)
M. fiegei mytiloidiformis (Tröger)
Veniella goniophora Meek
Barnacle plate
D9999. 90.1–91 m. Bioturbated siltstone and very fine grained sandstone.
Mytiloides fiegei fiegei (Tröger)
Baculites yokoyamai Tokunaga and Shimizu
D10000. 92.2–93.6 m. Bioturbated argillaceous siltstone.
Striarca? sp.
Mytiloides fiegei fiegei (Tröger)
Baculites yokoyamai Tokunaga and Shimizu
D10001. 95.8–97.4 m. Bioturbated siltstone.
Nuculana sp.
Amauropsis bulbiformis Stanton, non Sowerby
Baculites yokoyamai Tokunaga and Shimizu
Scaphites nigricollensis Cobban
Prionocyclus sp.
D10002. 97.8–100 m. Bioturbated siltstone.
Nuculana sp.
Mytiloides fiegei fiegei (Tröger)
Bellifusus? sp.
Baculites yokoyamai Tokunaga and Shimizu
Prionocyclus sp.
D10003. 100.9–102.4 m. Bioturbated siltstone.
Mytiloides fiegei fiegei (Tröger)
Bellifusus? sp.
Baculites yokoyamai Tokunaga and Shimizu
Scaphites sp.
D10004. 103.1–104 m. Bioturbated siltstone.
Mytiloides fiegei mytiloidiformis (Tröger)
Scaphites nigricollensis Cobban
D10005. 104.2–105.3 m. Silty shale.
Inoceramus perplexus Whitfield
Amauropsis bulbiformis Stanton, non Sowerby
Gyrodes sp.
Baculites yokoyamai Tokunaga and Shimizu
Hoploparia sp.
D10006. 106.1–106.4 m. Bioturbated very fine grained sandstone.
Nuculana sp.
Inoceramus perplexus Whitfield
Indeterminate neogastropod
Baculites yokoyamai Tokunaga and Shimizu
Prionocyclus novimexicanus (Marcou)
D10007. 106.7–107.9 m. Bioturbated very fine grained sandstone.
Inoceramus perplexus Whitfield
Baculites yokoyamai Tokunaga and Shimizu
D10008. 109–111.4 m. Bioturbated shaly siltstone.
Inoceramus perplexus Whitfield
Plicatula sp.
D10009. 111.6–112.8 m. Noncalcareous shale.
Nuculana sp.
Inoceramus perplexus Whitfield
Entolium sp.
Prionocyclus sp.
D10010. 114.6 m. Bioturbated sandy siltstone.
Inoceramus perplexus Whitfield
D10011. 123.9–124.2 m. Noncalcareous shale.
Inoceramus perplexus Whitfield
Scaphites sp.
D10012. 127.4 m. Very fine grained sandstone.
Prionocyclus sp.
D10013. 136 m. Noncalcareous shale.
Scaphites warreni Meek and Hayden

POOL CREEK MEMBER

D10014. 155 m. Calcareous shale.
Pseudoperna bentonensis (Logan)
Collignoniceras woollgari regulare (Haas)
D10015. 155.7–155.8 m. Noncalcareous to slightly calcareous shale.
Collignoniceras woollgari regulare (Haas)
D10016. 157–157.9 m. Noncalcareous shale.
Collignoniceras woollgari regulare (Haas)
D10017. 160.9 Calcareous shale.
Collignoniceras woollgari regulare (Haas)

GREENHORN FORMATION

D10018. 164–164.2 m. Calcareous shale and calcarenite.
Mytiloides mytiloides (Mantell)
D10019. 164.9 m. Calcareous shale and calcarenite.
Mytiloides mytiloides (Mantell)
D10020. 167.1–167.6 m. Argillaceous limestone.
Mytiloides mytiloides (Mantell)
M. subhercynicus (Seitz)
M. opalensis (Böse)
D10021. 168–168.4 m. Argillaceous limestone.
Mytiloides mytiloides (Mantell)
M. subhercynicus (Seitz)

D10022. 168.7–168.9 m. Argillaceous limestone.
Mytiloides mytiloides (Mantell)
D10023. 169.2 m. Argillaceous limestone.
Mytiloides mytiloides (Mantell)
D10024. 169.5–169.8 m. Argillaceous limestone.
Mytiloides mytiloides (Mantell)
D10025. 170.5–171.4 m. Calcareous shale and calcarenite.
Mytiloides mytiloides (Mantell)
M. opalensis (Böse).
D10026. 171.7–172 m. Calcareous shale.
Mytiloides aff. *M. duplicostatus* (Anderson)
D10027. 172.6–173.4 m. Calcareous shale.
Mytiloides aff. *M. duplicostatus* (Anderson)
M. sp. (fine growth lines)
D10028. 176.3 m. Speckled limestone.
Mytiloides aff. *M. duplicostatus* (Anderson)
D10029. 178.7–178.9 m. Calcareous shale.
Mytiloides sp. (fine growth lines)
M. opalensis (Böse)
D10030. 179.3–179.4 m. Calcareous shale.
Mytiloides sp. (fine growth lines)
Inoceramus cf. *I. pictus* J. de C. Sowerby
D10031. 181.1–181.7 m. Calcareous shale.
Solitary coral
Phelopteria sp.
Inoceramus pictus neocaledonicus Jeannet
Baculites? sp.
Scaphites (*Pteroscaphites*) *minutus* Moreman
Worthoceras sp.
D10032. 182.7–182.9 m. Calcareous shale.
Inoceramus pictus neocaledonicus Jeannet
Baculites? sp.
Worthoceras sp.
D10033. 183.2–184.7 m. Calcareous shale.
Inoceramus pictus neocaledonicus Jeannet
Sciponoceras? sp.
Allocrioceras annulatum (Shumard)
Worthoceras vermiculum (Shumard)
Metoicoceras sp.
D10034. 185.1 m. Noncalcareous shale.
Inoceramus pictus pictus J. de C. Sowerby
D10035. 185.9–186.2 m. Noncalcareous shale.
Phelopteria minuta Kauffman and Powell
Inoceramus pictus neocaledonicus Jeannet
D10036. 186.6–186.8 m. Noncalcareous shale.
Phelopteria minuta Kauffman and Powell
Inoceramus pictus pictus J. de C. Sowerby
D10037. 187.1–188.1 m. Noncalcareous shale.
Phelopteria minuta Kauffman and Powell
Inoceramus pictus pictus J. de C. Sowerby
D10038. 188.6–188.9 m. Noncalcareous shale.
Inoceramus pictus pictus J. de C. Sowerby
D10039. 189.6–189.7 m. Noncalcareous shale.
Inoceramus pictus pictus J. de C. Sowerby
D10040. 190.4–190.6 m. Calcareous to noncalcareous shale.
Inoceramus pictus neocaledonicus Jeannet
D10041. 192.5 m. Calcareous to noncalcareous shale.
Inoceramus ginterensis Pergament
D10042. 194.2 m. Calcareous to noncalcareous shale.
Inoceramus ginterensis Pergament
D10043. 194.6 m. Noncalcareous shale.
Phelopteria? sp.
Inoceramus sp.
Juvenile ammonites
D10044. 195.6–195.9 m. Noncalcareous shale.
Inoceramus flavus pictoides Sornay
Metaptychoceras reesidei (Cobban and Scott)
D10045. 197–197.1 m. Calcareous to noncalcareous shale.
Inoceramus ginterensis Pergament
I. cf. *I. pictus bohemicus* Leonhard
D10046. 197.7–198.1 m. Noncalcareous shale.
Inoceramus ginterensis Pergament
Hamites (*Stomohamites*) *simplex* d'Orbigny
D10047. 198.1–198.9 m. Slightly calcareous shale.
Inoceramus ginterensis Pergament.
Entolium sp.
Astarte sp.
Neocardioceras sp.
D10048. 199.1–199.3 m. Calcareous to noncalcareous shale.
Inoceramus sp.
Neocardioceras sp.
Metoicoceras sp.
D10049. 199.8–200 m. Calcareous to noncalcareous shale.
Inoceramus sp.
Entolium sp.
Metaptychoceras reesidei (Cobban and Scott)
Neocardioceras sp.
D10050. 200.6–201.5 m. Calcareous to noncalcareous shale.
Inoceramus ginterensis Pergament
Entolium sp.
Minute bivalve
Metaptychoceras sp.
Neocardioceras sp.
D10051. 201.5–202.7 m. Calcareous to noncalcareous shale.
Inoceramus ginterensis Pergament
Immature archeogastropod, possibly *Calliomphalus*
Euspira? sp.
Metaptychoceras reesidei (Cobban and Scott)
Hamites (*Stomohamites*) *simplex* d'Orbigny
Neocardioceras sp.
D10052. 203.1–204.1 m. Noncalcareous shale.
Inoceramus ginterensis Pergament
I. sp.
D10053. 204.5–204.9 m. Calcareous to noncalcareous shale.
Inoceramus ginterensis Pergament
Entolium sp.
Metaptychoceras reesidei (Cobban and Scott)
Neocardioceras sp.
D10054. 207.9 m. Slightly calcareous shale.
Inoceramus ginterensis Pergament
D10055. 209.9–210.2 m. Slightly calcareous to noncalcareous shale.
Inoceramus sp.
Metoicoceras sp.
D10056. 210.3–210.9 m. Slightly calcareous to noncalcareous shale.
Inoceramus sp.
Moremanoceras sp.
D10057. 211.2–211.5 m. Slightly calcareous to noncalcareous shale.
Inoceramus sp.
Entolium sp.
D10058. 211.8–211.9 m. Calcareous to noncalcareous shale.
Inoceramus sp.
Entolium sp.
Neocardioceras sp.
Moremanoceras sp.
D10059. 212.1–212.8 m. Slightly calcareous shale.
Entolium sp.
Hamites (*Stomohamites*) *simplex* d'Orbigny
Metoicoceras sp.

Neocardioceras sp.
Ammonite undet.

D10060. 214.1 m. Calcareous shale.
Entolium sp.

D10061. 215.9–216.8 m. Slightly calcareous to noncalcareous shale.
Inoceramus cf. *I. flavus* Sornay
Entolium sp.
Astarte sp.
Hamites (*Stomohamites*) *simplex* d'Orbigny
Metoicoceras cf. *M. mosbyense* Cobban
Neocardioceras sp.

D10062. 218.2–218.3 m. Noncalcareous shale.
Nuculana sp.
Astarte sp.
Hamites (*Stomohamites*) sp.
Metoicoceras sp.

D10063. 218.5–219 m. Noncalcareous shale; pyritic fossils.
Astarte sp.
Hamites (*Stomohamites*) *simplex* d'Orbigny
Neocardioceras sp.

D10064. 219.5–219.9 m. Noncalcareous to slightly calcareous shale; pyritic fossils.
Nuculana sp.
Astarte? sp.
Crenella? sp.
Hamites (*Stomohamites*) sp.
Dunveganoceras? sp.
Neocardioceras sp.

D10065. 220.1–220.5 m. Noncalcareous shale; pyritic fossils.
Astarte sp.
Hamites (*Stomohamites*) *simplex* d'Orbigny
Neocardiocras sp.

D10066. 220.7–221.8 m. Noncalcareous shale; pyritic fossils.
Inoceramus prefragilis Stephenson
Hamites (*Stomohamites*) *simplex* d'Orbigny
Metoicoceras sp.

D10067. 222.7–222.8 m. Noncalcareous shale; pyritic fossils.
Inoceramus prefragilis Stephenson
Hamites (*Stomohamites*) *simplex* d'Orbigny
Moremanoceras sp.

D10068. 223.1–223.3 m. Noncalcareous shale; pyritic fossils.
Hamites (*Stomohamites*) *simplex* d'Orbigny
Ammonite (new genus?)

D10069. 223.5–224 m. Noncalcareous shale; pyritic fossils.
Inoceramus prefragilis Stephenson
Hamites (*Stomohamites*) *simplex* d'Orbigny
Moremanoceras n. sp.
Borissiakoceras sp.

D10070. 224.2–224.6 m. Noncalcareous shale; pyritic fossils.
Hamites (*Stomohamites*) *simplex* d'Orbigny
Moremanoceras sp.
Neocardioceras sp.

D10071. 224.9–225.5 m. Slightly calcareous shale.
Entolium sp.
Hamites (*Stomohamites*) *simplex* d'Orbigny
Moremanoceras sp.
Neocardioceras sp.

D10072. 225.8–226.5 m. Noncalcareous shale; pyritic fossils.
Inoceramus cf. *I. prefragilis* Stephenson
Astarte? sp.
Hamites (*Stomohamites*) sp.
Neocardioceras sp.
Borissiakoceras sp.

D10073. 226.6–227.1 m. Noncalcareous to calcareous shale; pyritic fossils.
Hamites (*Stomohamites*) sp.
Neocardioceras sp.
Borissiakoceras cf. *B. orbiculatum* Stephenson

D10074. 227.7–228.2 m. Noncalcareous to slightly calcareous shale; pyritic fossils.
Inoceramus cf. *I. prefragilis* Stephenson
Hamites (*Stomohamites*) *simplex* d'Orbigny
Neocardioceras sp.
Borissiakoceras cf. *B. orbiculatum* Stephenson

D10075. 228.4–229.1 m. Slightly calcareous shale; pyritic fossils.
Inoceramus sp.
Entolium sp.
Hamites (*Stomohamites*) *simplex* d'Orbigny
Neocardioceras sp.
Borissiakoceras cf. *B. orbiculatum* Stephenson

D10076. 229.2–229.5 m. Calcareous shale; pyritic fossils.
Inoceramus sp.
Entolium sp.
Hamites (*Stomohamites*) *simplex* d'Orbigny
Neocardioceras sp.
Borissiakoceras cf. *B. orbiculatum* Stephenson

D10077. 229.8–230.4 m. Calcareous shale.
Inoceramus sp.
Entolium sp.
Hamites (*Stomohamites*) *simplex* d'Orbigny
Neocardioceras sp.
Borissiakoceras cf.*B. orbiculatum* Stephenson

D10078. 231–231.4 m. Calcareous to noncalcareous shale.
Lingula sp.
Minute bivalve
Arrhoges? sp.
Hamites (*Stomohamites*) *simplex* d'Orbigny
Neocardioceras sp.
Metoicoceras sp.
Borissiakoceras sp.

D10079. 231.6–232.4 m. Calcareous shale.
Inoceramus prefragilis Stephenson
Hamites (*Stomohamites*) *simplex* d'Orbigny
Neostlingoceras kottlowskii Cobban and Hook
Neocardioceras sp.
Borissiakoceras sp.
Metoicoceras sp.

D10080. 239.9–233.4 m. Calcareous shale.
Inoceramus prefragilis Stephenson
Hamites (*Stomohamites*) *simplex* d'Orbigny
Borissiakoceras sp.

D10081. 234.2–234.7 m. Calcareous shale.
Hamites (*Stomohamities*) *simplex* d'Orbigny
Neocardioceras sp.
Borissiakoceras sp.

D10082. 235.3–237.2 m. Calcareous shale.
Inoceramus sp.
Minute bivalve
Hamites (*Stomohamites*) *simplex* d'Orbigny
Moremanoceras sp.
Neocardioceras sp.
Borissiakoceras sp.

D10083. 237.7–239.1 m. Noncalcareous to calcareous shale.
Inoceramus crippsi Mantell
Minute bivalve
Hamites (*Stomohamites*) *simplex* d'Orbigny
Neocardioceras sp.
Borissiakoceras sp.

D10084. 239.3–240 m. Calcareous shale.
Inoceramus prefragilis Stephenson
Minute bivalve
Moremanoceras sp.
Borissiakoceras sp.
Shark tooth

D10085. 240.3–240.7 m. Noncalcareous shale.
Solemya sp.
Pleuriocardia sp.

D10086. 241.1–241.7 m. Noncalcareous shale.
Pleuriocardia sp.
Indeterminate neogastropod
Hamites sp.

D10087. 242.3–243.8 m. Noncalcareous shale.
Lingula sp.
Solemya sp.
Inoceramus sp.
Pleuriocardia sp.
Compressed indeterminate neogastropod
Hamites sp.

D10088. 243.8–246 m. Noncalcareous shale; pyritic fossils.
Solemya sp.
Inoceramus crippsi Mantell
Minute bivalve
Immediate post-larval stages of a probable aporrhaid gastropod
Hamites sp.
Borissiakoceras reesidei Morrow
Acanthoceras sp.

D10089. 246–247.5 m. Noncalcareous shale, pyritic fossils.
Lingula sp.
Solemya sp.
Minute bivalve
Immediate post-larval stages of probable aporrhaid gastropod

D10090. 247.5–248.2 m. Slightly calcareous shale.
Minute bivalve
Juvenile aporrhaid gastropod
Hamites (Stomohamites) simplex d'Orbigny
Acanthoceras amphibolum Morrow
Borissiakoceras reesidei Morrow

D10091. 248.6–249.1 m. Noncalcareous to slightly calcareous shale.
Lingula sp.
Inoceramus sp.
Hamites sp.
Acanthoceras amphibolum Morrow
Borissiakoceras sp.

BELLE FOURCHE SHALE

D10092. 252.8–253.3 m. Noncalcareous shale.
Inoceramus rutherfordi Warren

D10093. 254.5–254.8 m. Noncalcareous shale.
Inoceramus sp.
Acanthoceras amphibolum Morrow

D10094. 255.9 m. Noncalcareous shale.
Ostrea beloiti Logan

D10095. 256.4–257.3 m. Noncalcareous shale.
Inoceramus sp.
Ostrea beloiti Logan
Acanthoceras sp.

D10096. 257.6–257.7 m. Noncalcareous shale.
Inoceramus sp.
Ostrea beloiti Logan

D10098. 258.3–258.6 m. Noncalcareous shale.
Inoceramus sp.
Small thin-shelled bivalve

D10099. 261.8 m. Noncalcareous shale.
Parmicorbula sp.

D10100. 262.1 m. Noncalcareous shale.
Inoceramus sp.

D10101. 265 m. Noncalcareous shale.
Inoceramus rutherfordi Warren

CHARACTERISTIC FOSSILS

Common or important molluscan fossils are briefly described and illustrated. The paper is not intended as a detailed systematic work but rather as a general overview of the subsurface mid-Cretaceous fossil record at one locality in the Powder River Basin. New species are not described or formally named, and synonomies are limited to the original papers and one or two later papers that have good illustrations or important changes in names of taxa.

Inoceramids and ammonites are the most biostratigraphically important mollusks in the cores. Owing to the large size of the adults of these fossils and the small diameter of the cores, only parts of the specimens are available for study, and many of them can only be assigned to genera.

Cremnoceramus? waltersdorfensis (Andert)

Plate 1, figure 1

Inoceramus walterdorfensis Andert, 1911, p. 53, pl. 5, figs. 2–5.
Inoceramus walterdorfensis Andert. Tröger, 1967, p. 114, pl. 12, figs. 1–4; pl. 13, figs. 1–9; text figs. 30, 31.
Cremnoceramus? *waltersdorfensis* (Andert). Kauffman, 1979, p. 59.

The juveniles of this subquadrate medium-sized species have closely spaced, subequal, strongly raised growth lines that curve sharply along the umbo-ventral axis of the shell. At a later growth stage, a few irregular rugae may occur with the raised growth lines. The posterior part of the shell is flattened, and the ornamentation tends to trend in a straight line across it.

Tröger (1967, p. 114–120) recognized two forms of this species, *waltersdorfensis waltersdorfensis* Andert and *waltersdorfensis hannovrensis* Heinz. The latter was differentiated in having a higher and more erect form with a flatter cross section and more numerous rugae.

Several small inoceramids in the cores at depths of 32–70 m have closely spaced, subequal, raised juvenile growth lines that usually bend conspicuously along the umbo-ventral axis. These specimens seem to be *C*? *waltersdorfensis* although they are too few and fragmentary for positive assignment to either of Tröger's subspecies.

Cremnoceramus? *waltersdorfensis* is widely distributed in rocks near the Turonian-Coniacian boundary in Europe, Asia, and North America. Until the last few years, the species has been regarded of late Turonian age (for example Andert, 1934, p. 114; Tröger, 1967, p. 117), but with the recent move to consider the Turonian-Coniacian boundary at a lower level (summarized by Seibertz, 1979), *C.*? *walterdorfensis* falls in the basal Coniacian (Kauffman and others, 1976, p. 23.16). The species has been used as a guide fossil for the basal Coniacian faunal zone in the Western Interior (Merewether and others, 1976, p. 38; Merewether and others, 1979, p. 70).

Type.—Hypotype USNM 308017.

Cremnoceramus? rotundatus (Fiege)

Plate 1, figures 2, 3,

Inoceramus inconstans rotundatus Fiege, 1930, p. 42, pl. 7, fig. 32; pl. 8, fig. 31; text fig. 3.
Inoceramus rotundatus Fiege. Tröger, 1967, p. 110, pl. 12, figs. 5, 6; pl. 13, figs. 10–13; text fig. 29.
Cremnoceramus? *rotundatus* (Fiege). Kauffman, 1979, p. 68, pl. 9, figs. A, C.

Cremnoceramus? *rotundatus* is closely related to *C.*? *walterdorfensis* and, like that species, it has closely and regularly spaced raised growth lines on the umbo. *Cremnoceramus*? *rotundatus* differs, however, in having a more convex shell ornamented by closely spaced conspicuous rugae. The posterior side is flattened, and the rugae trend fairly straight across it.

Specimens that seem referable to *C.*? *rotundatus* occur in the cores at depths between 35.4 and 70 m. A fragment of a large specimen on which calcareous worm tubes are attached (pl. 1, fig.2), closely resembles one of the types (Fiege, 1930, pl. 7, fig. 32).

Cremnoceramus? *rotundatus* was originally described from Germany. The species is known from many localities in Europe and North America. Although the species was considered of late Turonian age at first, it is now assigned to the base of the Coniacian (Kauffman and others, 1976, p. 23.16; Seibertz, 1979, p. 116).

Types.—Hypotypes USNM 308018, 308019.

Mytiloides fiegei fiegei (Tröger)

Plate 1, fig. 10

Inoceramus inconstans inconstans Woods. Fiege, 1930, p. 38, pl. 5, figs. 16, 17; pl. 6, figs. 18, 19.
Inoceramus fiegei fiegei Tröger, 1967, p. 105, pl. 13, figs. 14, 15, 17, 20; pl. 11, fig. 3.
Mytiloides fiegei fiegei (Tröger). Kauffman, 1977, p. 180.

This flattened inoceramid has a rounded outline and a distinctive ornamentation that consists of equally spaced concentric rugae separated by several equally spaced raised growth lines. The species is closely allied to, if not conspecific with, *Inoceramus incertus* Jimbo (1894, p. 43, pl. 8, fig. 7) as amended and illustrated by Nagao and Matsumoto (1940, p. 10, pl. 3, figs. 1–5; pl. 10, fig. 2). Jimbo's illustration (drawing) of the type specimen shows an elongate form, whereas Nagao and Matsumoto's illustrations are of rounded and prosocline forms. Although specimens from the Western Interior have been compared to *I. incertus* (Merewether and Cobban, 1972, p. D59; Merewether and others, 1975, p. 75; Merewether and others, 1976, p. 38), or reported as *I. incertus* (Merewether, 1980, p. 12), they are probably better assigned to the more clearly defined European species *M. fiegei fiegei*. Specimens referable to *M. fiegei fiegei* occur in cores of Carlile Shale from the borehole at depths of 76–102 m.

Mytiloides fiegei was described from the upper Turonian of Germany. The species occur at the top of the Turonian in the Western Interior (Kauffman and others, 1976, p. 23.16).

Types.—Hypotypes USNM 308024, 308025.

Mytiloides fiegei mytiloidiformis (Tröger)

Plate 1, figs. 8, 9, 11, 12; plate 2, fig. 12

Inoceramus inconstans inconstans Woods. Fiege, 1930, p. 38. pl. 6, fig. 19.
Inoceramus fiegei mytiloidiformis Tröger, 1967, p. 108, pl. 11, fig. 4; pl. 13, figs. 16, 18.

This subspecies differs from the typical form of the species in having a more elongate form. Specimens referable to it occur in the cores of the Turner Sandy Member of the Carlile Shale at depths from 85.5 to 104 m.

The holotype of *M. fiegei mytiloidiformis* is from the upper Turonian of Germany. An example from the uppermost part of the Carlile Shale of south-central Colorado was illustrated by Kauffman (in Kauffman and others, 1976, pl. 14, fig. 4).

Types.—Hypotypes USNM 308024, 308026–308028, 308044.

Mytiloides mytiloides (Mantell)

Plate 2, figures 14, 15

Inoceramus mytiloides Mantell, 1822, p. 215, pl. 28, fig. 2.
Mytiloides mytiloides (Mantell). Kauffman and Powell, 1977, p. 74, pl. 6, figs. 11–16.

An elongate form, low convexity, presence of a posterior auricle, and distinctive ornamentation or more or less evenly spaced rugae separated by numerous raised growth lines characterize this lower Turonian species. The axis of the shell forms an angle of about 40°–50° to the straight hinge line.

The species is abundant in the upper part of the Greenhorn Formation in the Great Plains region and in equivalent nearshore sandstone beds farther west. Near the site of the borehole, *M. mytiloides* was collected 11 m below the top of the Greenhorn Formation (Merewether, 1980, p. 7). Specimens are abundant in cores from the borehole in thin beds of limestone in the Greenhorn Formation at depths of 164–171 m.

Mytiloides mytiloides was originally described from the Middle Chalk of England. The species is most abundant in the upper part of the lower Turonian, but it ranges up into the lower part of the middle Turonian. In the literature, most records of *Inoceramus labiatus* (Schlotheim) are probably *M. mytiloides*. Specimens identified as *I. labiatus* have been recorded from Turonian rocks over most of the world. In the Western Interior, *M. mytiloides* has been recorded from northern Montana (Cobban and others, 1976, p. 41–44) south into New Mexico (Hook and Cobban, 1980, p. 43).

Types.—Hypotypes USNM 308046, 308047.

Mytiloides opalensis (Böse)

Plate 2, figures 10, 11

Inoceramus opalensis Böse, 1923, p. 184, pl. 13, figs. 1–3.
Mytiloides opalensis (Böse). Kauffman and Powell, 1977, p. 79, pl. 6, figs. 3, 6.

Böse illustrated two moderately prosocline specimens that have very low convexity, an inflated ovate outline, and broadly rounded concentric ornament. One specimen has prominent equally spaced growth lines on the earlier part of the shell and low rugae on the later part, whereas the other specimen has nearly equally spaced rugae over the entire shell and equally spaced growth lines on much of the shell. Böse's specimens came from Turonian rocks at Opal, Zacatecas, Mexico.

Specimens that resemble one or the other of Böse's types occur in the cores of the Greenhorn Formation from the borehole at depths of 167–179 m.

Types.—Hypotypes USNM 308042, 308043.

Mytiloides aff. M. duplicostatus (Anderson)

Plate 2, figure 13

Mytiloides sp. aff. *M. duplicostatus* (Anderson). Kauffman and Powell, 1977, p. 81, p. 6, fig. 5; pl. 7, figs. 2, 6.

This prosocline ovate species has a low covexity, long hingeline, convex anterior side, and narrowly rounded beaks projecting above the hingelines at its anterior end. Ornament consists of fairly regularly spaced rugae that usually have two prominent growth lines on their crests and as many as three raised growth lines in the rugae interspaces. The ornament resembles that of *Mytiloides duplicostatus* (Anderson, 1958, p. 100, pl. 17, figs. 3, 4) from Turonian rocks of California, but Anderson's species is more elongate.

Specimens that show affinities to *M. duplicostatus* occur in the cores of the Greenhorn Formation from the borehole at depths of 172–176 m.

Mytiloides aff. *M. duplicostatus* is abundant near the middle of the Bridge Creek Limestone Member of the Greenhorn Formation in the central Great Plains. The species is especially abundant and well preserved near Pueblo, Colo., in bed 97 of the published measured section, where the species is listed as *Inoceramus labiatus* (Cobban and Scott, 1972, p. 23). Ammonites from bed 97 include *Watinoceras coloradoense* (Henderson) and *Vascoceras (Greenhornoceras) birchbyi* Cobban and Scott of early Turonian age. *Mytiloides* aff. *M. duplicostatus* is present in Survey collections from as far southwest as the Silver City area in southwestern New Mexico and as far south as Trans-Pecos, Texas.

Type.—Figured specimen USNM 308045.

Mytiloides subhercynicus (Seitz)

Plate 2, figure 8

Inoceramus labiatus var. *subhercynica* Seitz, 1934, p. 465, pl. 40, figs. 1–5; text fig. 18.

This broadly ovate, nearly equivalve, prosocline species has a moderately low convexity, fairly long hinge line, and very convex anterior margin. Beaks are low, rounded, and barely extend over the hinge line. The valves have a subcircular outline at first, and later become elongated. Ornament on the early part consists of nearly equally spaced raised growth lines. Later, closely spaced rugae form, which may have raised growth lines on them and (or) in the interspaces.

In the Western Interior, *Mytiloides subhercynicus* occurs in the uppermost part of the Greenhorn Formation and in the basal part of the Carlile Shale in the central Great Plains and in the equivalent rocks farther west. In the borehole, specimens that may be *M. subhercynicus* occur in the cores from the Greenhorn Formation at depths of 167–168.4 m.

Mytiloides subhercynicus was first decribed from Turonian rocks of Germany. The species also occurs in other countries in Europe and North America. In the Western Interior, *M. subhercynicus* occurs in the late early Turonian zone of *Mammites nodosoides* and in the overlying early middle Turonian zone of *Collignoniceras woollgari* (Mantell).

Type.—Hypotype USNM 308040.

Mytiloides sp.

Plate 3, figure 1

A species of *Mytiloides* that has numerous closely spaced growth lines of irregular height on the early part of the valves occurs in the Greenhorn Formation in the cores from the borehole at depths of 172.6–179.4 m. At later growth stages, ornamentation consists of irregular rugae with or without well-defined growth lines. The species is characteristic of bed 86 of the Bridge Creek Limestone Member at Pueblo, Colo. (Cobban and Scott, 1972, p. 23), where it was listed as *Inoceramus labiatus* (Schlotheim). Bed 86 lies only 2.4 m above the top of the latest Cenomanian zone of *Sciponoceras gracile* (Shumard).

Type.—Figured specimen USNM 308049.

Inoceramus pictus neocaledonicus Jeannet

Plate 3, figures 3, 4, 14

Inoceramus pictus J. de C. Sowerby. Woods, 1911, p. 279 (part), pl. 49, figs. 5, 6, not text fig. 36.

Inoceramus neocaledonicus Jeannet, 1922, p. 251, text fig. 5.

Inoceramus pictus neocaledonicus Jeannet. Tröger, 1967, p. 50, pl. 4, fig. 4a, text fig. 13.

This subspecies is characterized by coarser and more widely spaced growth lines than those on *Inoceramus pictus pictus*, rugae are less conspicuous, and the early part of the shell has more evenly spaced growth lines. Specimens that seem referable to *I. pictus neocaledonicus* occur in the cores in the Greenhorn Formation at depths of 181–190 m.

Types.—Hypotypes USNM 308051–308053.

Inoceramus pictus pictus J. de C. Sowerby

Plate 3, figures 5–7

Inoceramus pictus J. de C. Sowerby, 1829, p. 215, pl. 604, fig. 1.

Inoceramus pictus J. de C. Sowerby. Woods, 1911, p. 279, text fig. 36 only.

Inoceramus pictus pictus J. de C. Sowerby. Tröger, 1967, p. 36., pl. 3, figs. 1–6; text figs. 6, 7.

This rather erect inequivalve species is moderately convex; it is higher than it is long, and the outline is subtriangular with a concave anterior side. Beaks are narrow, incurved, and project over the fairly short hinge line. Ornament consists of closely spaced raised growth lines and irregularly spaced rugae. The holotype, from the Chalk Marl of England, retains some of its original radial color bands; hence, the origin of its specific name.

Inoceramus pictus is widely distributed in the uppermost Cenomanian rocks of Europe, Africa, Australia, and North America. Several varietal and subspecific names have been proposed for this variable species. The neotype proposed by Moreman (1942, p. 197, pl. 32, figs. 1, 3) for *Inoceramus capulus* Shumard (1860, p. 606) may be a subspecies of *I. pictus*. Moreman's specimen came from the late Cenomanian zone of *Sciponoceras gracile* in the Eagle Ford Formation of Texas.

In the Western Interior, *Inoceramus pictus* may be restricted to the zone of *Sciponoceras gracile*, which has been considered the top of the Cenomanian. The basal part of the Bridge Creek Limestone Member of the Greenhorn Formation in the central Great Plains lies in this zone. Cores from the borehole at depths of 185–189 m in the Greenhorn Formation contain inoceramids that seem referable to *I. pictus pictus* as restricted by Tröger (1967).

Types.—Hypotypes USNM 308054–308056.

Inoceramus cf. I. pictus bohemicus Leonhard

Plate 3, Figure 8

Inoceramus bohemicus Leonhard, 1897, p. 26, pl. 5, figs. 1a – c.

Inoceramus pictus bohemicus Leonhard. Tröger, 1967, p. 52, pl. 3, figs. 9–11; text fig. 14.

Leonhard illustrated two small specimens from the Cenomanian of Czechoslovakia. Both are ornamentated by closely spaced growth lines. One of them, illustrated by two views (Leonhard, 1897, pl. 5, figs. 1b, c), shows a low convexity profile and growth lines numbering about 27 in a distance of about 21.5 mm from the beak. A small flattened inoceramid (pl. 3, fig. 8) from the Greenhorn Formation at a depth of 197 m in the borehole resembles Leonhard's specimen in having numerous growth lines—29 in a distance of 17 mm from the beak.

Type.—Figured specimen USMN 308057.

Inoceramus cf. I. pictus J. de C. Sowerby

Plate 2, figure 16

A flattened, suberect inoceramid that has conspicuous evenly and closely spaced raised growth lines on the early part of the valve and closely spaced rugae on the later part is represented by a single specimen from the Greenhorn Formation at a depth of 179.5 m. The growth lines and rugae curve more sharply than on figured specimens of *I. pictus*. The specimen may be transitional to *Mytiloides*.

Type.—Figured specimen USNM 308048.

Inoceramus perplexus Whitfield

Plate 2, figures 1–3

Inoceramus perplexus Whitfield, 1877, p. 31.

Inoceramus perplexus Whitfield. Whitfield, 1880, p. 392, pl. 8, fig. 3; pl. 10, figs. 4, 5.

This erect, nearly equivalve species is higher than long and has a subrectangular outline. The projecting beak is at the dorsoanterior corner. The anterior margin is steep and slightly concave. The hinge line is straight and fairly long. Ornament typically consists of rugae of irregular strength and spacing.

Inoceramus perplexus was originally described from the Carlile Shale on the west flank of the Black Hills at a locality about 58 km northwest of the borehole. The species is abundant in limestone and sandstone concretions in the Turner Sandy Member of the Carlile Shale along the flanks of the Black Hills (Cobban, 1951a, p. 2188; Mapel and Pillmore, 1964, p. J26). Near the site of the borehole, *I. perplexus* was collected from sandstone concretions 24 m below the top of the Turner Sandy Member (Merewether, 1980, p. 12). The bivalve occurs in cores of sandstone, siltstone, and silty shale, in the middle of the Turner Member at depths of 104–124 m in the borehole.

Inoceramus perplexus is present in many U.S. Geological Survey collections from rocks equivalent to the Turner Member from south-central Montana south to south-central New Mexico. The species is restricted to the upper Turonian.

Types.—Hypotypes USNM 308033–308035.

Inoceramus ginterensis Pergament

Plate 3, figures 10–12; plate 4, figure 1

Inoceramus ginterensis Pergament, 1966, p. 50, pl. 25, fig. 5; pl. 26, figs. 1, 2; pl. 27, figs. 1, 2; pl. 28, figs. 1, 2; pl. 29, fig. 1.

Inoceramus ginterensis is a suberect, inequivalve, slightly convex species that is higher than it is long. The outline is subrectangular to ovate with nearly straight to slightly concave anterior side. The beaks are at the anterior end and slightly project above the moderately long hinge line. A posterior auricle is present, although not well set off from the rest of the shell. Rugae of irregular height and spacing characterize the ornament. Fairly weak and irregular growth lines may be present, especially on the umbonal part.

Inoceramus ginterensis was originally described from Cenomanian rocks on the Pacific side of the USSR: Pergament (1966) presented many good illustrations. The species is widely distributed in the Western Interior in the late Cenomanian zone of *Dunveganoceras albertense* (Warren). Specimens have been illustrated from the Hartland Shale Member of the Greenhorn Formation of western Oklahoma (Kauffman and Powell, 1977, pl. 1, fig. 2; pl. 3, fig. 1–4, 6; pl. 4, figs. 1,3–6; pl. 5, figs. 2, 3, 5) and from the Twowells Tongue of the Dakota Sandstone of central western New Mexico (Cobban, 1977, pl. 19, fig. 3).

Many inoceramids in the cores from the borehole at depths of 192.5–199 m are referred to *I. ginterensis*, although most of the specimens tend to have ornaments not quite as broadly curved as that on the majority of specimens illustrated by Pergament (1966). The specimens from the borehole are from the middle part of the Greenhorn Formation.

Types.—Hypotypes USNM 308058–308060, 308068.

Inoceramus sp.

Plate 3, figures 15, 16

Inoceramids that have a quadrate outline and ornament of very fine radial striae in addition to rugae and growth lines of irregular height, occur in cores from the borehole at depths of 203–211 m below the middle of the Greenhorn Formation. Beaks are located at the anterior end of a moderately long straight hinge line.

Types.—Figured specimens USNM 308061, 308062.

Inoceramus prefragilis Stephenson

Plate 4, figures 10, 11; plate 5, figure 6.

Inoceramus prefragilis Stephenson, 1952, [1953], p. 64, pl. 12, figs. 10–12; pl. 13, figs. 1, 2.

Inoceramus prefragilis is a fairly large suberect species that has an ovate to subrectangular outline and moderate convexity. The anterior side is steep and slightly concave. The hinge line is moderately long, and the narrow, sharp, incurved beaks project slightly above it at the anterior end. Large specimens may have a weak, shallow sulcus posterior to and paralleling the umbonal axis. Ornament consists of strong, flat raised growth lines that tend to be of even size and a few weak to moderately strong rugae.

Stephenson's types are from the Woodbine Formation of north Texas. The species is common in the lower part of the Greenhorn Formation in the Western Interior. Specimens occur in cores from the borehole at depths of 221–240m.

Types.—Hypotypes USNM 308076–308078, 308084.

Inoceramus crippsi Mantell

Plate 5, figures 1–3

Inoceramus crippsi Mantell, 1822, p. 133, pl. 27, fig. 11.
Inoceramus crippsi Mantell. Woods, 1911, p. 273, pl. 48, figs. 2,3; text figs., 33–35.

This erect inoceramid has a subrectangular outline that is higher than it is long. The hinge line is moderately long and is at a very high angle to the axis of the shell. The anterior border is slightly convex. Ornament consists of prominent closely spaced rugae which, on some specimens, are of nearly equal size.

Mantell's type came from the Chalk Marl of England. Specimens that seem referable to the species occur in a core in the basal part of the Greenhorn Formation at depths of 238 and 244 m. One specimen has fine growth lines on and between the rugae on the umbo, and in this manner, it resembles the ornament on a specimen of *I. crippsi* var. *reachensis* Etheridge from England illustrated by Woods (1911, pl. 49, fig. 1).

Types.—Hypotypes USNM 308085–308087.

Inoceramus rutherfordi Warren

Plate 5, figure 12

Inoceramus rutherfordi Warren, 1930, p. 59, pl. 7, figs. 1–3.

A squarish outline and posteroventral-trending folds and sulci feature this moderately inequivalve species. The shell is prosocline, and the beaks project over the fairly long hinge line. Ornament consists of irregular rugae.

Inoceramus rutherfordi was originally described from the Dunvegan Formation in the Peace River area of Alberta. The species has been found at many localities in the middle Cenomanian zone of *Acanthoceras amphibolum* Morrow in the Western Interior of the United States from Montana south to Trans-Pecos, Texas. In the borehole, fragments of inoceramids in the cores at depths of 253–265 m seem to represent this species. At nearby outcrops, *I. rutherfordi* occurs in dusky-red ferruginous concretions 7–13 m below the top of the Belle Fourche Shale (Merewether, 1980, p. 5).

Type.—Hypotype USNM 308092.

Veniella goniophora Meek

Plate 1, figure 4

Veniella goniophora Meek, 1876, p. 152, pl. 4, fig. 4, text fig. 12.

This very convex equivalve bivalve has a subquadrate outline, prominent umbo, sharp posterior ridge, and ornament of a few strong concentric lamellae. The species is small for the genus. Meek's type came from the Marias River Shale at Fort Benton, Mont.

Veniella goniophora is fairly common in the upper part of the Carlile Shale of the Black Hills, in the Kevin Member of the Marias River Shale of north-central Montana, and in the equivalent part of the Cody Shale of Wyoming. The age range is late Turonian-Santonian. Most records from the Black Hills are from the Sage Breaks Member of the Carlile Shale (Robinson and others, 1964, p. 69), but a specimen recorded as *Veniella* cf. *V. goniophora* was collected about 36 m above the base of the Turner Sandy Member 15 km northwest of the borehole site (Mapel and Pillmore, 1964, p. J26). In cores from the borehole, small specimens of *V. goniophora* occur in slightly calcareous to noncalcareous shale in the Sage Breaks Member at depths of 45–80 m (pl. 1, fig. 4) and in clayey siltstone in the upper part of the Turner Sandy Member at a depth of about 88 m.

Type.—Hypotype USNM 308020

Phelopteria minuta Kauffman and Powell

Plate 3, figure 2

Phelopteria minuta Kauffman and Powell, 1977, p. 50, pl. 8, figs. 4, 6.

Kauffman and Powell noted that this nearly smooth bivalve was small for the genus, and that the largest adult at hand attained a height of 21 mm. They noted that the species is moderately prosocline with an average angle of inclination of 42°, and that the outline is subrounded in juveniles and subrhombic in adults. The hinge line is long and straight, and triangular anterior and posterior auricles are present. The small beak projects slightly above the hinge line. Ornament consists of very fine raised growth lines. The holotype is from the middle part of the Hartland Shale Member of the Greenhorn Formation of the Oklahoma Panhandle.

Specimens that seem assignable to *P. minuta* occur in cores of noncalcareous shale of the Greenhorn Formation from depths of 186–188 m in the borehole.

Type.—Hypotype USNM 308050.

Entolium sp.

Plate 4, figure 7

Many of the cores of calcareous to noncalcareous shale from the lower half of the Greenhorn Formation from the borehole have very thin-shelled, small, fragile bivalves referable to *Entolium*. The specimens are crushed flat, have a subrounded outline, and do not exceed 12 mm in height. Beaks are small and subcentral, and anterior and posterior auricles are triangular and nearly equisized. Both valves have very fine irregular concentric growth lines. Left valves have, in addition, very fine radial riblets. Many of the specimens closely resemble *Entolium gregarium* Kauffman and Powell (1977, p. 87, pl. 4, fig. 2; pl. 5, fig. 4; pl. 6, figs. 8, 9; pl. 8, figs. 1, 2), and some may be that species. Radial ornamentation, however, is said to be absent on *E. gregarium*.

Type.—Figured specimen USNM 308074.

Ostrea beloiti Logan

Plate 5, figure 11

Ostrea beloiti Logan, 1899, p. 214, pl. 25, figs. 7, 8.

This small oyster usually has an elongated gently curved outline. The left valve is convex, and the right one is almost flat. Small ridglets and pits (chomata) are conspicuous on the periphery of the inner surfaces. The valves are fairly smooth except for a few weak radial ribs on the ventroanterior part of some left valves. Shells were loosely cemented together to form thin biostromes, or they were attached to other mollusks.

Ostrea beloiti was originally described from the basal part of the Greenhorn Formation of north-central Kansas. The species has a range of middle and late Cenomanian; it is most abundant in the middle Cenomanian zones of *Acanthoceras alvaradoense* Moreman and *A.*

amphibolum Morrow. The geographic range is great and extends from Manitoba to the Mexican border. A map showing the distribution of the species in the Western Interior was presented by Cobban and Hook (1980, fig. 3).

Ostrea beloiti was collected from a ferruginous concretion 27 m below the top of the Belle Fourche Shale near the borehole site (Merewether, 1980, p. 5). Cores of noncalcareous shale from the upper part of the Belle Fourche Shale from the borehole at depths of 256–258 m contain *O. beloiti.*

Type.—Hypotype USNM 308091.

Baculites yokoyamai Tokunaga and Shimizu

Plate 1, figures 5, 6

Baculites yokoyamai Tokunaga and Shimizu, 1926, p. 195, pl. 22, fig. 5a, b; pl. 26, fig. 11.

Baculites besairiei Collignon, 1931, p. 37, pl. 5, figs. 6–9.

Baculites cf. *B. yokoyamai* Tokunaga and Shimizu. Cobban and Scott, 1972 [1973], p. 48, pl. 20, figs. 15–21.

This small, straight ammonite has a nearly elliptical section, small degree of taper, finely ribbed venter, smooth to very weakly ribbed flanks, and suture simple for the genus. The holotype is from rocks of Coniacian Age of Japan.

Specimens identical to those from Japan are abundant and widely distributed in Turonian rocks in the Western Interior. The Western Interior specimens were at first reported as *Baculites* cf. *B. besairiei* Collignon (Cobban, 1951a, p. 2188, 2190–92; Cobban and Reeside, 1952a, p. 1018 and chart). Matsumoto and Obata (1963, p. 34) have shown that *B. besairiei* Collignon from Madagascar is quite likely a synonym of *B. yokoyamai.*

Near the site of the borehole, *B. yokoyamai* was collected from sandstone concretions about 17 m below that top of the Turner Sandy Member of Carlile Shale (Merewether, 1980, p. 12). Crushed fragments of smooth baculites are common in the borehole cores of the Sage Breaks Member (pl. 1, fig. 5) and Turner Sandy Member (pl. 1, fig. 6) at depths of 45–108 m.

Types.—Hypotypes USNM 308021, 308022.

Scaphites corvensis Cobban

Plate 1, figure 7

Scaphites corvensis Cobban, 1951b [1952], p. 26, pl. 7, figs. 6–17.

This is a moderately large species that has ribs equally spaced on the venter of the adult body chamber. The species occurs in two forms—a large stout one (holotype) herein interpreted as a female, and a small slender one believed to be a male. The latter was given the varietal name *bighornensis* (Cobban, 1951b, p. 26). The holotype, 63.5 mm long, has 15 primary ribs and 52 secondary ribs on the body chamber.

Scaphites corvensis is a guide fossil to one of the late Turonian ammonite zones in the Western Interior. The species is especially common in the upper part of the Carlile Shale of the Black Hills area (Mapel and Pillmore, 1963a, p. M36; 1963b, p. N48; Robinson and others, 1964, p. 68, 69) and in the upper part of the Frontier Formation farther west in Wyoming (Merewether and others, 1979, pl. 2, figs. 15, 16). In the vicinity of the borehole, *S. corvensis* was collected about 5 m below the top of the Turner Sandy Member of the Carlile Shale (Merewether, 1980, p. 12). The species also occurs in the lower part of the overlying Sage Breaks Member (Cobban, 1951b, p. 26; Robinson and others, 1964, p. 69).

In the borehole, crushed specimens of *S. corvensis* are present in the cores of the lower part of the Sage Breaks Member from depths of 76–81 m.

Type.—Hypotype USNM 308023.

Prionocyclus novimexicanus (Marcou)

Plate 1, figures 15, 16.

Ammonites novi-mexicani Marcou, 1858, p. 35, pl. 1, figs. 2, 2a.

Prionocyclus novimexicanus (Marcou). Hook and Cobban, 1979, p. 35, fig. 3E–L.

Characteristic features of this moderately large evolute ammonite are its closely spaced flexuous ribs on juveniles, its umbilical bullae or bullate umbilical tubercles, its single row of small ventrolateral tubercles, and its finely serrate keel.

The species is widely distributed in upper Turonian rocks in the Western Interior. The type specimen came from the Mancos Shale west of Albuquerque, N. Mex. Specimens are common in the Juana Lopez Member of the Mancos Shale of New Mexico, Utah and Colorado, in the basal part of the Niobrara Formation in southern Colorado, in the Turner Sandy Member of the Carlile Shale of the Black Hills area, in the Wall Creek Member of the Frontier Formation of central Wyoming, and in the Carlile Member of the Cody Shale of south-central Montana. In the Black Hills area, *P. novimexicanus* seems to be restricted to the lower part of the upper half of the Turner Sandy Member, where the species has usually been referred to as *P. wyomingensis* var. *elegans* Haas (Cobban, 1951a, p. 2188). Specimens were noted at a depth of 106 m in the cores of the Turner Sandy Member from the borehole.

Types.—Hypotypes USNM 308031, 308032.

Collignoniceras woollgari regulare (Haas)

Plate 2, figures 6, 7

Prionotropis woollgari var. *regularis* Haas, 1946, p. 154, pl. 16, figs. 1–17; text figs. 10–12, 59–74, 78, 80, 81, 83.

Prionotropis woollgari (Mantell) forma typica and varieties. Haas, 1946.
Collignoniceras woollgari (Mantell) (late form). Merewether, Cobban and Cavanaugh, 1979, pl. 3, figs. 4, 5.
Collignoniceras woollgari regulare (Haas). Cobban and Hook, 1979 [1980], p. 22, pl. 3; pl. 12, fig. 3.

This moderately evolute, ornate subspecies has been well illustrated by Meek (1876), Haas (1946), Matsumoto (1965), and Cobban and Hook (1979). The subspecies has conspicuous prorsiradiate ribs, umbilical and double ventrolateral tubercles, and a strongly serrate keel in which the siphonal clavi match the ventrolateral tubercles and ribs in number. Juveniles have numerous and closely spaced ribs that may be somewhat flexuous, whereas adults have widely spaced straight ribs of about equal size. Ventrolateral tubercles of adults merge into prominent horns.

Collignoniceras woollgari regulare is widely distributed, generally in calcareous beds, in the Western Interior. The subspecies is found in the Fairport Chalky Member and Pool Creek Member of the Carlile Shale in the central Great Plains, where it has been designated a guide fossil to one of the Turonian zones (Cobban and Reeside, 1952a, p. 1018). Farther northwest on the Sweetgrass arch of north-central Montana, the subspecies has been found at the top of the Cone Member of the Marias River Shale (Cobban and others, 1956; Cobban and others, 1976, p. 42). In southwestern Wyoming, *C. woollgari regulare* occurs in the Oyster Ridge Sandstone Member of the Frontier Formation (Cobban and Reeside, 1952b, p. 1925), and in the shale just below the Oyster Ridge Sandstone Member farther southwest in northeastern Utah (Trexler, 1966, p. 23). In east-central Utah, the subspecies has been recorded from the lower part of the Mancos Shale on the east flank of the San Rafael Swell (Fisher and others, 1960, p. 27) as well as on the west flank (Katich, 1954, p. 46). In southern Utah, the subspecies occurs in the upper part of the Tropic Shale (Peterson and Waldrop, 1965, p. 61, 62), and in northeastern Arizona, the subspecies occurs in the Mancos Shale (Repenning and Page, 1956, p. 263, 265, 268). Cobban and Hook (1979, fig. 2) noted several occurrences of *C. woollgari regulare* in the Mancos Shale in northwestern New Mexico.

Limestone concretions about 14 m below the top of the Pool Creek Member of the Carlile Shale near the borehole contain well-preserved specimens of *C. woollgari regulare* (Merewether, 1980, p. 10). In the borehole, flattened specimens are abundant in cores of calcareous and noncalcareous shale at depths of 155–161 m. These specimens are important in that they date this part of the borehole as of about the middle part of the middle Turonian (Cobban and Hook, 1979, fig. 1).

Types.—Hypotypes USNM 308038, 308039.

Scaphites nigricollensis Cobban

Plate 1, figure 13

Scaphites nigricollensis Cobban, 1951b [1952], p. 25, pl. 5, figs. 9–26; pl. 6, fig. 1–17; pl. 7, figs. 1–5.

This species is similar to *S. corvensis* in size and general form, but differs in that it has more numerous ribs, as well as a tendency to lose ribbing on the older half of the body chamber of internal molds. The species is restricted to the upper part of the Turner Sandy Member of Carlile Shale of the Black Hills area (Cobban 1951a, p. 2188) and the equivalent part of the Carlile Shale of south-central Montana (Richards, 1955, p. 54) and Ferdig Member of the Marias River Shale of north-central Montana (Cobban and others, 1976, p. 47–49).

Scaphites nigricollensis occurs in two forms—a large stout one (holotype) assumed to be a female and a small slender one assumed to be a male. The male was given the varietal name *meeki* (Cobban, 1951b, p. 26).

The species was collected from the upper part of the Turner Sandy Member on outcrops near the borehole (Robinson and others, 1964, p. 72). Small slender specimens (males) occur in cores of the Turner Sandy Member from the borehole at depths of 96–104 m.

Type.—Hypotype USNM 308029.

Scaphites warreni Meek and Hayden

Plate 1, figure 14

Scaphites warreni Meek and Hayden, 1860, p. 177.
Scaphites warreni Meek and Hayden. Meek, 1876, p. 420, pl. 6, fig. 5.

Scaphites warreni is a small and more sparsely ribbed species than *S. nigricollensis*, but like it, *S. warreni* occurs in a large, stout form (female) and a small, slender form (male). The holotype is a female, and the male form was given the varietal name *ubiquitosus* (Cobban, 1951b, p. 23). Both forms have the ribbing on the venter more widely spaced on the older part of the adult body chamber than on the young part.

Scaphites warreni is abundant in the lower part of the Turner Sandy Member of the Carlile Shale of the Black Hills area (Cobban, 1951a, p. 2189; Mapel and Pillmore, 1963b, p. N48; Robinson and others, 1964, p. 67–69); in the upper part of the Frontier Formation farther west in Wyoming (Merewether and others, 1979, p. 85, pl. 2, figs. 6–9); and in the Juana Lopez Member of the Mancos Shale farther south in Colorado, Utah, and New Mexico (Cobban, 1951b, p. 22, 23, table opposite p. 12).

Near the borehole, *S. warreni* was found in sandstone concretions about 40 m below the top of the Turner Sandy Member of the Carlile Shale and in sandstone 1 m above the base of the member (Merewether, 1980,

p. 12). In the borehole, a fairly slender sparsely ribbed phragmocone with part of the body chamber attached is referred to this species. The specimen is from the lower part of the Turner Sandy Member of the Carlile Shale at a depth of 136 m.

Type.—Hypotype USNM 308030.

Scaphites (Pteroscaphites) minutus Moreman

Plate 2, figure 9

Scaphites minutus Moreman, 1942, p. 216, pl. 34, figs. 9, 10; text fig. 2s.
Otoscaphites minutus (Moreman). Wright, 1953, p. 475.
Scaphites (Pteroscaphites) minutus (Moreman). Wiedmann, 1965, p. 435, pl. 58, figs. 5a–c; text fig. 6b.

This very small species has a moderately evolute septal coil and a large, very uncoiled U-shaped body chamber that is well separated from the coil. The aperture is collared, and lateral lappets are present. Ornament consists of closely spaced primary and secondary ribs.

This species is known only from the late Cenomanian zone of *Sciponoceras gracile* (Shumard). The holotype, an adult 11.5 mm long, is from the Eagle Ford Formation of north-central Texas. The species is scarce in the Western Interior, but a few examples may be present in the USGS collections from the Greenhorn Formation (Cobban, 1951a, p. 2185).

A flattened specimen of *S.* (*P.*) *minutus* is present in a core of calcareous shale from the borehole at a depth of 181.5 m. The specimen is from the top of the zone of *Sciponoceras gracile*.

Type.—Hypotype USNM 308041.

Worthoceras vermiculus (Shumard)

Plate 2, figure 5

Scaphites vermiculus Shumard, 1860, Academy of Science of St. Louis Transactions, v. 1, p. 594.
Macroscaphites vermiculus (Shumard). Meek, 1876, p. 419.
Scaphites vermiculus Shumard. White, 1883, p. 39, pl. 18, fig. 8a.
Worthoceras vermiculum (Shumard). Adkins, 1928, p. 220.
Worthoceras vermiculum (Shumard). Moreman, 1942, p. 214, pl. 34 figs. 12, 13; text fig. 2 p.

This small smooth ammonite has a large evolute septate coil and a long, straight shaft and hook. The lower part of the shaft is septate, and the mouth border is lappeted. The suture is very simple and has a broad little-divided lateral saddle and a narrow bifid lateral lobe (Moreman, 1942, fig. 2p; Wiedmann, 1965, fig. 10 e–g). Moreman (1942, p. 214) noted that the type was lost, and figured a neotype from the Eagle Ford Formation of north-central Texas.

Worthoceras vermiculus has been found in the late Cenomanian zone of *Sciponoceras gracile* in the Greenhorn Formation at many localities in the central Great Plains (Cobban, 1951a, p. 2185; Cobban and Scott, 1972, p. 22; Hattin, 1975, p. 33, pl. 5, figs. A, F, K). It is also present in USGS collections from the Frontier Formation in Johnson County in north-central Wyoming (Merewether, 1980, p. 17), as well as in collections from the Mancos Shale in Socorro County in south-central New Mexico. In southwestern New Mexico, *W. vermiculus* occurs not only in the zone of *Sciponoceras gracile* but also ranges up into the overlying zone of *Neocardioceras juddii* (Barrois and de Guerne).

A crushed hook and shaft of a small scaphite in a core of calcareous shale in the Greenhorn Formation at a depth of 184 m from the borehole seems assignable to *W. vermiculus*. Crushed evolute coils in cores at depths of 181–183 m are probably this species.

Type.—Hypotype USNM 308037.

Allocrioceras annulatum (Shumard)

Plate 2, figure 4

Ancyloceras annulatus Shumard, 1860, p. 595.
Helicoceras pariense White, 1877, p. 203, pl. 19, figs. 2a–d.
Exiteloceras pariense (White). Hyatt, 1894, p. 577.
Allocrioceras pariense (White). Adkins, 1932, p. 434, 437.
Allocrioceras annulatum (Shumard). Moreman, 1942, p. 208.
For full synonymy, see Cobban and Scott, 1972 [1973], p. 51.

This loosely coiled ammonite has some whorls helical and others coiled in one plane. Ornament consists of conspicuous annular ribs and small, pointed ventrolateral tubercles. Ribs, which number three for the shell diameter, are narrowly rounded except on the venter, where they are flattened a little.

Allocrioceras annulatum was originally described from the Eagle Ford Formation of north-central Texas. The species is common in the late Cenomanian zone of *Sciponoceras gracile* at many localities in the Western Interior. (See Cobban and Scott, 1972, p. 52 for general localities and references.)

Crushed fragments of *A. annulatum* occur in a core of calcareous shale in the Greenhorn Formation from the borehole at a depth of about 184 m.

Type.—Hypotype USNM 308036.

Hamites (Stomohamites) simplex d'Orbigny

Plate 3, figures 9, 13; plate 4, figures 8, 13; plate 5, figures 4, 5.

Hamites simplex d'Orbigny, 1842, p. 550, pl. 134, figs. 12–15.

Wright (1963, p. 597, pl. 81, fig. 1a–c) summarized this species as consisting of an initial open spire, followed by two fairly straight shafts, with the final aperture having three prominent oblique ribs. Whorl sections are oval to nearly circular. Ribs are annular, high and narrow, and, on internal molds, about as wide as the interspaces. The ribs number about 4½ in a distance equal to the whorl height. Kennedy (1971, p. 6, pl. 1, figs. 1–8) figured many specimens from southern England that have 5–10 ribs in a distance equal to the whorl height.

Hamites simplex was originally described from France, but the species is now known from many localities in Europe, Africa, Australia, and North America. In England, where mid-Cretaceous ammonite faunas have been extensively investigated, *H. simplex* seems to be restricted to the middle Cenomanian (Kennedy and Hancock, 1976, p. 5.15, 5.16).

Fragments of both the straight and curved whorls of hamitids that seem assignable to *H. simplex* are present in the USGS collections from many localities in the Western Interior. Most specimens are small and occur as flattened impressions in dark-gray shale. A large specimen that has the collared adult aperture has not been found. In faunal lists, the species has been reported as *Helicoceras* n. sp. (Mapel and Pillmore, 1964, p. J21; Robinson and others, 1964, p. 59), *Stomohamites* aff. *S. corrugatus* (Stanton) (Robinson and others, 1964, p. 63), and *Stomohamites* cf. *S. simplex* (d'Orbigny) (Cobban and Scott, 1972, p. 44, pl. 13, figs. 5–10; pl. 17, figs. 3, 4).

In the cores from the borehole, flattened fragments of small hamitids are abundant in dark-green calcareous to noncalcareous shale in the lower one-half of the Greenhorn Formation. These specimens closely match those illustrated from England by Kennedy (1971, pl. 6, figs. 1–8) and are assigned to *H. simplex*. Most specimens have more than 4½ ribs per whorl height mentioned by Wright (1963). Some of the cores reveal the very early growth stages of the species. A very small initial coil is followed by a smooth shaft 10–11 mm long, which is either straight or slightly curved.

Types.—Hypotypes USNM 308063–308067, 308073.

Metoicoceras cf. M. mosbyense Cobban

Plate 4, figures 14, 15

Metoicoceras mosbyense Cobban (1953, p. 48, pl. 6, figs. 1–14; pl. 7, figures 1–3) is a moderately large compressed involute ammonite that has early whorls with umbilical and double ventrolateral tubercles only, and adult body chamber without tubercles. Ribs consist of conspicuous, prorsiradiate, fairly straight primaries and secondaries, which become broad and flat on the venter of the adult body chamber. Near the aperture, ribs become narrow and closely spaced.

Metoicoceras mosbyense is confined to the late Cenomanian zone of *Dunveganoceras albertense* (Warren). Specimens are especially abundant in the upper part of the Frontier Formation of central Wyoming (Merewether and others, 1979, pl. 2, figs. 17, 20–22), where the species has been identified as *M. defordi* Young (1957, p. 1169, pl. 149, figs. 1–8; text fig. 1a, e, g, i). Near the borehole, *M. mosbyense* was collected 27–34 m below the top of the Greenhorn Formation (Merewether, 1980, p. 7, listed as *M. defordi*). Part of a juvenile, as well as part of the ventrolateral surface of an adult body chamber, is in the core of the Greenhorn Formation at a depth of 216 m in the borehole (pl. 4, figs. 14, 15).

Types—Hypotypes USNM 308082, 308083.

Neostlingoceras kottlowskii Cobban and Hook

Plate 4, figure 9

Neostlingoceras kottlowskii Cobban and Hook, 1981, p. 26, pl. 4, figs. 1–28.

Neostlingoceras kottlowskii is a small helically coiled (sinistral) ammonite that has an acute apical angle and three rows of tubercles of which two are visible in side views. Tubercles in the upper row are large and less numerous than those in the lower rows.

This ammonite may be confined to the late Cenomanian zone of *Dunveganoceras pondi*. The species is abundant only in the Mancos Shale and Colorado Formation of southwestern New Mexico. A few specimens have been found in the Mancos Shale of west-central New Mexico and the Benton Shale of north-central Colorado.

On the west flank of the Black Hills, a fragment of *N. kottlowskii* was found in a limestone concretion assigned to the Belle Fourche Shale (Robinson and others, 1964, p. 59, identified as *Turrilites* n. sp.; also Mapel and Pillmore, 1964, p. J21). In the borehole, *N. kottlowskii* occurs in a core of calcareous shale from the Greenhorn Formation at a depth of 232 m.

Type.—Hypotype USNM 308075.

Borissiakoceras reesidei Morrow

Plate 5, figure 8

Borissiakoceras reesidei Morrow, 1935, p. 463, pl. 49, fig. 7a, b; pl. 50, fig. 5; text fig. 8.

Diagnostic features of this small, compressed, involute ammonite are its nearly flat flanks, rounded venter, and either no ornament or the presence of 5 or 6 ventrolateral tubercles per half whorl. The types are from near the top of the Graneros Shale of central Kansas, where they were associated with *Acanthoceras amphibolum* Morrow of middle Cenomanian age.

Borissiakoceras reesidei is abundant in limestone concretions in the upper part of the Frontier Formation along the east side of the Bighorn Mountains in central northern Wyoming (Hose, 1955, p. 100) and in limestone concretions in the Soap Creek Bentonite Bed at the top of the Frontier Formation farther north at the

Wyoming–Montana State line (Cobban, 1961, p. 750, pl. 88, figs. 4–14).

In the cores from the borehole, *B. reesidei* occurs as flattened specimens in noncalcareous shale from depths of 244–248 m.

Type.—Hypotype USNM 308088.

Borissiakoceras cf. B. orbiculatum Stephenson

Plate 4, figure 4

Small, smooth specimens that are crushed flat but that appear to have a slight angularity of the ventrolateral shoulder occur in cores of calcareous to noncalcareous shale of the lower part of the Greenhorn Formation from the borehole at depths of 227–230 m. *Borissiakoceras orbiculatum* Stephenson (1955, p. 64, pl. 6, figs. 1–4) is a small compressed ammonite that has flattened flanks and a subangular ventrolateral shoulder with or without low clavate tubercles. Stephenson's specimens came from the basal part of the Eagle Ford Formation of north-central Texas, where they were associated with *Acanthoceras alvaradoense* Moreman of middle Cenomanian age. The specimens from the borehole occur in slightly younger rocks (early late Cenomanian) and may be the same as the form referred to as *Borissiakoceras* cf. *B. orbiculatum* from the later Cenomanian zone of *Sciponoceras gracile* (Shumard) (Cobban 1961, p. 753, pl. 89, figs. 10–14; text fig. 5g, i).

Type.—Figured specimen USNM 308084.

Acanthoceras amphibolum Morrow

Plate 5, figures 9, 10

Acanthoceras? amphibolum Morrow, 1935, p. 470, pl. 49, figs. 1–4, 6; pl. 51, figs. 3, 4; text fig. 4.

This moderate size involute ammonite has subrectangular to quadrate whorls on which the ornament differs greatly from juveniles to adults. Juveniles have umbilical, double ventrolateral, and clavate siphonal tubercles, whereas adults have a low siphonal ridge and ventrolateral horns. The species was designated a zonal index in the early 1950's (Cobban 1951a, p. 2197; Cobban and Reeside, 1952a, p. 1017).

Morrow's types are from near the top of the Graneros Shale of central Kansas. The species is widely distributed in the Western Interior from south-central Montana (Knechtel and Patterson, 1956, p. 20) to west-central New Mexico (Cobban, 1977, p. 23, pl. 8, figs. 8, 9; pl. 12, figs. 10–12, 15–23; text fig. 5).

Near the borehole site, *A. amphibolum* was collected from dusky-red ferruginous concretions 7–13 m below the top of the Belle Fourche Shale, where they were associated with *Inoceramus rutherfordi* Warren (Merewether, 1980, p. 5). Cores of noncalcareous to slightly calcareous shale from the upper part of the Belle Fourche Shale at depths of 248–255 m in the borehole contain crushed fragments of ammonites referred to *A. amphibolum*.

Type.—Hypotypes USNM 308089, 308090.

Metaptychoceras reesidei (Cobban and Scott)

Plate 4, figure 7

Hemiptychoceras reesidei Cobban and Scott, 1972 [1973], p. 45, pl. 17, figs. 7, 8.

This aberrant ammonite, originally assigned to *Hemiptychoceras* Spath, seems better assigned to *Metaptychoceras* Spath (1926, p. 81) because of similarities in size and simple suture and in lack of constrictions. Wright (1979, p. 284) has recently summarized the characteristics of *Hemiptychoceras* and *Metaptychoceras* and noted that the differences are small but real. The holotype of *M. reesidei* is from the late Cenomanian zone of *Sciponoceras gracile* (Shumard) in the basal part of the Bridge Creek Limestone Member of the Greenhorn Formation at Pueblo, Colo.

Cores of calcareous and noncalcareous shale from the Greenhorn Formation from the borehole contain crushed specimens referred to *M. reesidei* at depths of 195.6–204.5 m.

Type.—Hypotype USNM 308074.

Moremanoceras sp.

Plate 4, figures 12, 16; plate 5, figure 7

Moremanoceras is a very involute ammonite that has flat sides, broadly rounded venter with a low rounded keel, sinous growth lines or very fine ribs, and occasional thicker raised ribs that border the adapical side of constrictions. The genus closely resembles *Damesites* Matsumoto in its general appearance, but *Damesites* has a more complex suture with more lobes. According to Matsumoto and Obata (1955, p. 126), *Damesites* has a long range of late Cenomanian into Maestrichtian, whereas *Moremanoceras* is restricted to the Cenomanian.

Moremanoceras has been found in Montana, Wyoming, Colorado, Kansas, Oklahoma, New Mexico, and Arizona. Specimens from Montana and Wyoming were recorded as *Puzosia (Latidorsella)* n. sp. (Robinson and others, 1964, p. 56, 57, 63) or "*Puzosia*" n. sp. (Robinson and others, 1964, p. 59; Mapel and Pillmore, 1964, p. J21). Kansas and Oklahoma specimens were illustrated and recorded as *Desmoceras* sp. (Hattin, 1975, p. 24, pl. 2, figs. P, V; Kauffman and Powell, 1977, p. 101, pl. 9, figs. 2, 6).

In the cores from the borehole, fragments of

Moremanoceras occur in the lower half of the Greenhorn Formation at depths of 210–240 m.

Types.—Figured specimens USNM 308079–308081.

Neocardioceras spp.

Plate 4, figures 1–3, 5, 6

Many small ammonites that are crushed flat in cores from the borehole are probably undescribed species of *Neocardioceras* Spath (1926 p. 81). All specimens are moderately evolute and are ornamented by narrow, prorsiradiate ribs and umbilical bullae, small inner and outer venrolateral tubercles, and clavate siphonal tubercles. At the position of the inner ventrolateral tubercles, the ribs bend forward and cross the venter as chevrons. None of the specimens exceeds 17 mm in diameter. The specimens occur in the lower half of the Greenhorn Formation at depths of 198–239 m.

Neocardioceras occurs at many places in the Western Interior in rocks of late Cenomanian age. Specimens from the west flank of the Black Hills in eastern Wyoming have been reported as "Ammonite n. gen. spp. A and B" and *Mammites* n. sp. (Robinson and others, 1964, p. 59, 63; Mapel and Pillmore, 1964, p. J21). Specimens from the Lincoln Limestone Member of the Greenhorn Formation of Kansas have been reported as *Eucalyoceras* sp. B (Hattin, 1975, p. 24, 62, 64, pl. 2, figs. K–M, Q), and those from the Hartland Shale Member of the Greenhorn in the Oklahoma Panhandle were recorded as "Acanthoceras group A and group B" (Kauffman and Powell, 1977, p. 103, pl. 10, figs. 2, 3, 6, 7). Impressions of small *Neocardioceras* near the top of the Hartland Shale Member near Pueblo, Colo. were recorded as *Tarrantoceras*? sp. (Cobban and Scott, 1972, p. 17). Small crushed specimens of *Neocardioceras* are present in the U.S. Geological Survey collections from the Hartland Member along the Front Range in Colorado and from farther west in north-central Colorado in the equivalent part of the Benton Shale. A younger species of *Neocardioceras*, *N. juddii* (Barrois and de Guerne), has been found in beds just above the late Cenomanian zone of *Sciponceras gracile* (Shumard) in south-central Montana, northeastern Arizona, southwestern New Mexico, and Trans-Pecos, Texas.

Types.—Figured specimens USNM 308068–308072.

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[Italic numbers indicate major references]

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PLATES 1–5

PLATE 1

[All figures natural size]

FIGURE 1. *Cremnoceramus? waltersdorfensis* (Andert) (p. 8).
Hypotype USNM 308017 from depth of 34 m.

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8, 9, 11, 12. *Mytiloides fiegei mytiloidiformis* (Troger) (p. 9).
Hypotypes USNM 308024, 308026–308028 from depths of 86 and 103.1–104 m.

10. *Mytiloides fiegei fiegei* (Troger) (p. 9).
Hypotype USNM 308025 from depth of 76 m.

13. *Scaphites nigricollensis* Cobban (p. 15).
Hypotype USNM 308029 from depth of 96 m.

14. *Scaphites warreni* Meek and Hayden (p. 15).
Hypotype USNM 308030 from depth of 136 m.

15, 16. *Prionocyclus novimexicanus* (Marcou) (p. 14).
Hypotype USNM 308031 and 308032 from depth of 106.2 m.


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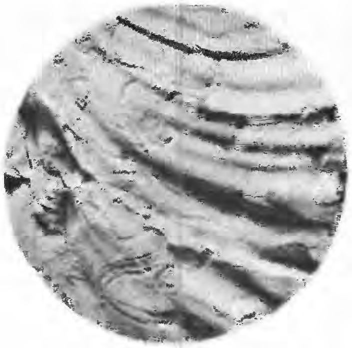
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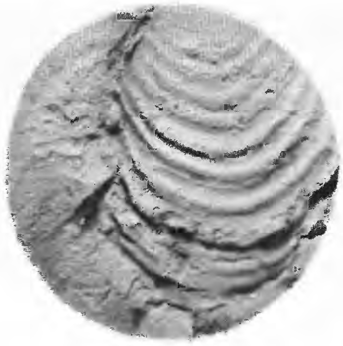
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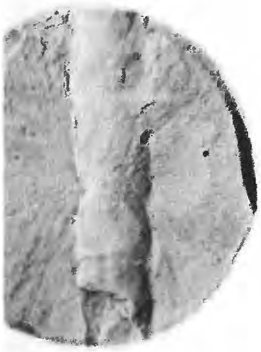
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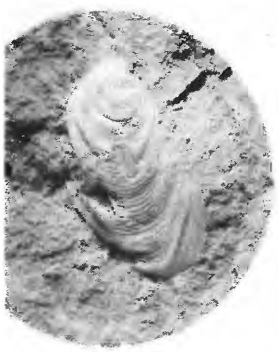
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CREMNOCERAMUS?, VENIELLA, BACULITES, SCAPHITES,
MYTILOIDES, AND *PRIONOCYCLUS*

PLATE 2

[All figures natural size]

FIGURES 1–3. *Inoceramus perplexus* Whitfield (p. 11).
Hypotypes USNM 308033–308035 from depths of 106.7–111.4 m.

4. *Allocrioceras annulatum* (Shumard) (p. 16).
Hypotype USNM 308036 from depth of 184 m.

5. *Worthoceras vermiculum* (Shumard) (p. 16).
Hypotype USNM 308037 from depth of 184 m.

6, 7. *Collignoniceras woollgari regulare* (Haas) (p. 14).
Hypotypes USNM 308038 and 308039 from depths of 155.7–157.9 m.

8. *Mytiloides subhercynicus* (Seitz) (p. 10).
Hypotype USNM 308040 from depth of 167.1 m.

9. *Scaphites (Pteroscaphites) minutus* Moreman (p. 16).
Hypotype USNM 308041 from depth of 181.5 m.

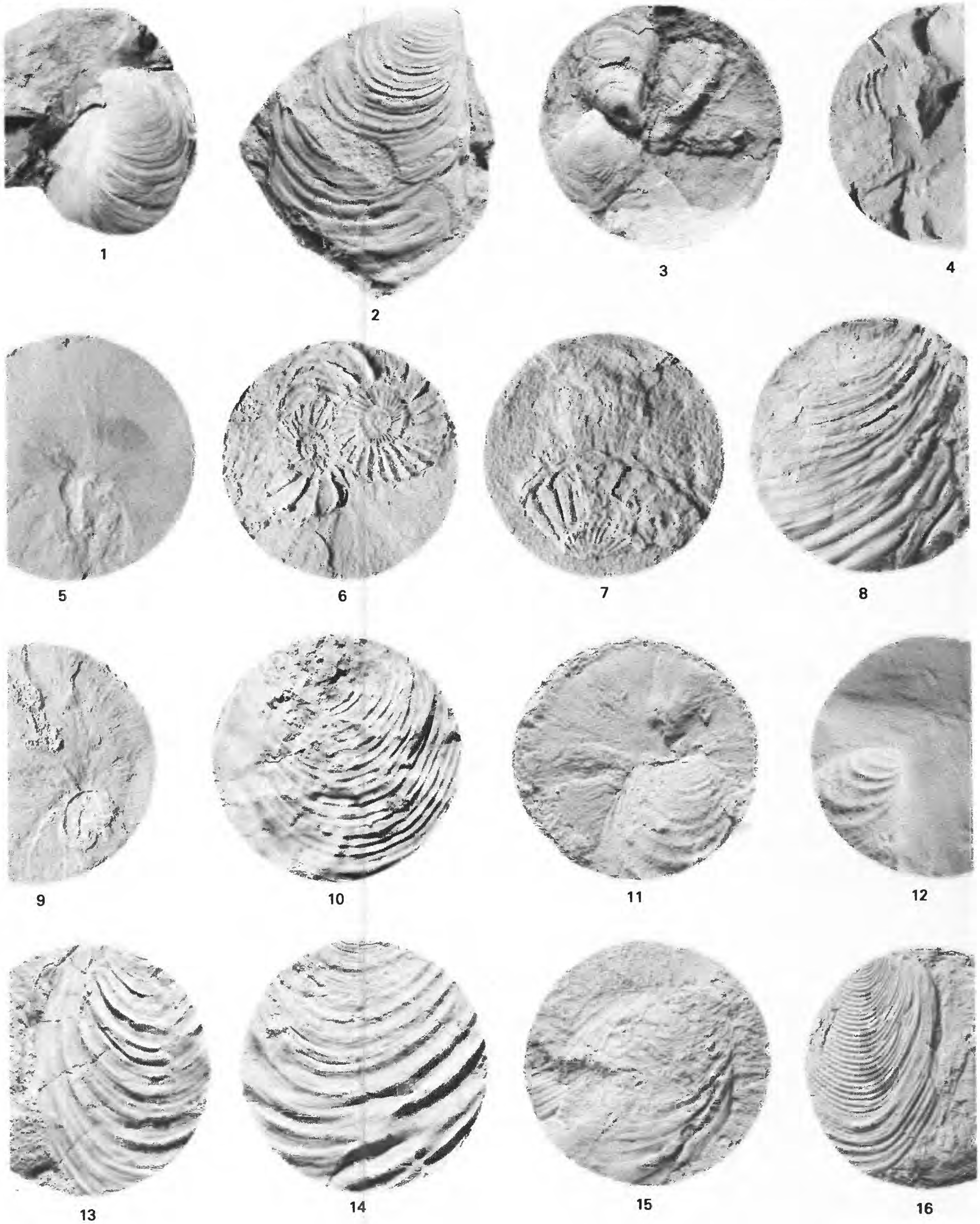
11. *Mytiloides opalensis* (Bose) (p. 10).
Two different forms like those illustrated by (Bose 1923). Hypotype USNM 308042 and 308043 from depths of 167.5 and 178.7 m.

12. *Mytiloides fiegei mytiloidiformis* (Troger) (p. 9).
Hypotype USNM 308044 from depth of 88 m.

13. *Mytiloides* aff. *M. duplicostatus* (Anderson) (p. 10).
Figured specimen USNM 308045 from depth of 173 m.

14, 15. *Mytiloides mytiloides* (Mantell) (p. 9).
Hypotypes USNM 308046 and 308047 from depths of 169.2 and 171 m.

16. *Inoceramus* cf. *I. pictus* J. de C. Sowerby (p. 11).
Figured specimen USNM 308048 from depth of 179.5 m.



INOCERAMUS, *ALLOCRIOCERAS*, *WORTHOCERAS*, *COLLIGNONICERAS*, *MYTILOIDES*, AND *SCAPHITES*

PLATE 3

[All figures natural size]

FIGURE 1. *Mytiloides* sp. (p. 10).
Figured specimen USNM 308049 from depth of 178.8 m.

2. *Phelopteria minuta* Kauffman and Powell (p. 13).
Hypotype USNM 308050 from depth of 186.7 m.

3, 4, 14. *Inoceramus pictus neocaledonicus* Jeannet (p. 11).
Hypotypes USNM 308051–308053 from depths of 181.5, 186, and 190.5 m.

5–7. *Inoceramus pictus pictus* J. de C. Sowerby (p. 11).
Hypotypes USNM 308054–308056 from depths of 185.1–186.8 m.

8. *Inoceramsu* cf. *I. pictus bohemicus* Leonhard (p. 11).
Figured specimen USNM 308057 from depth of 197 m.

9, 13. *Hamites* (*Stomohamites*) *simplex* d'Orbigny (p. 16).
Hypotypes USNM 308063 and 308064 from depth of 202 m.

10–12. *Inoceramus ginterensis* Pergament (p. 12).
Hypotypes USNM 308058–308060 from depths of 197–201 m.

15, 16. *Inoceramus* sp. (p. 12).
Figured specimens USNM 308061 and 308062 from depths of 203.1 and 210.3 m.

MYTILOIDES, *PHELOPTERIA*, *INOCERAMUS*, AND *HAMITES*

PLATE 4

[All figures natural size]

FIGURES 1–3, 5, 6. *Neocardioceras* spp. (p. 19).
Figured specimens USNM 308068–308072 from depths of 198.4, 198.5, 211.8, 212.1, and 231.6 m. Figure 1 also has a juvenile *Inoceramus ginteresis* Pergament, and figure 6 also has *Hamites (Stomohamites) simplex* d'Orbigny.

4. *Borissiakoceras* cf. *B. orbiculatum* Stephenson (p. 18).
Figured specimen USNM 308084 from depth of 228 m.

7. *Metaptychoceras reesidei* (Cobban and Scott) (p. 18) and *Entolium* sp. (p. 13).
Hypotype USNM 308074 from depth of 200 m.

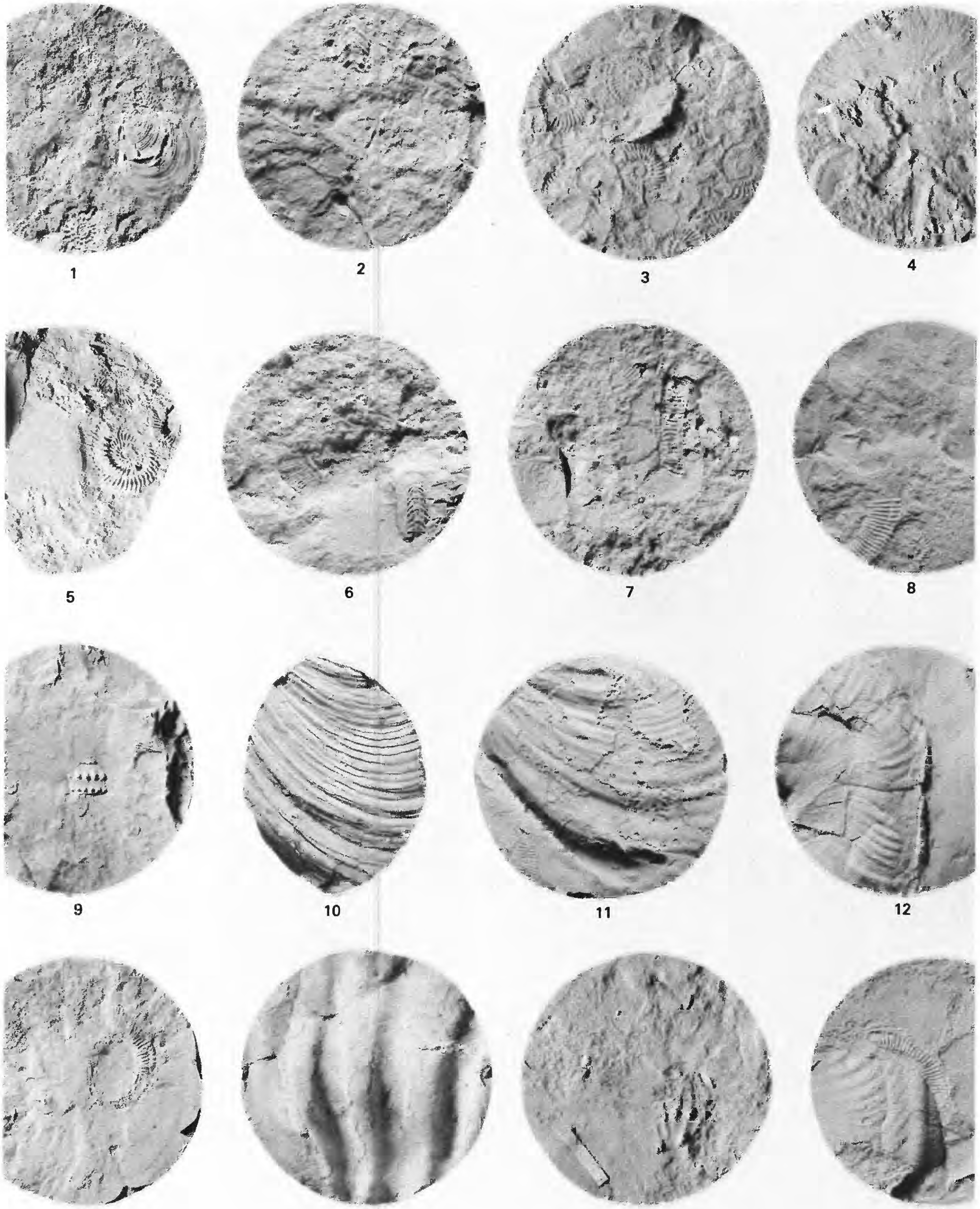
8, 13. *Hamites (Stomohamites) simplex* d'Orbigny (p. 16).
Hypotypes 308073 and 308065 from depths of 225 and 220.5 m. Figure 8 also has a juvenile *Neocardioceras* sp.

9. *Neostlingoceras kottlowskii* Cobban and Hook (p. 17).
Hypotype USNM 308075 from depth of 232 m.

10, 11. *Inoceramus prefragilis* Stephenson (p. 12).
Hypotypes USNM 308076 and 308077 from depth of 222.7 m. Figure 11 also has a small *Hamites (Stomohamites) simplex* d'Orbigny.

12, 16. *Moremanoceras* sp. (p. 18).
Figured specimens USNM 308079 and 308080 from depths of 210.5 and 224 m. Figure 16 also has a specimen of *Hamites (Stomohamites) simplex d'Orbigny*.

14, 15. *Metoicoceras* cf. *M. mosbyense* Cobban (p. 17).
Hypotypes USNM 308082 and 308083 from depth of 216 m.



NEOCARDIOCERAS, BORISSIAKOCERAS, METAPTYCHOCERAS, HAMITES, NEOSTLINGOCERAS, AND *INOCERAMUS*

PLATE 5

[All figures natural size]

FIGURES 1–3. *Inoceramus crippsi* Mantell (p. 12).
Hypotypes USNM 308085 and 308086 from depth of 238 m and hypotype USNM 308087 from depth of 244 m.

4, 5. *Hamites* (*Stomohamites*) *simplex* d'Orbigny (p. 16).
Hypotypes USNM 308066 and 308067 from depths of 236 and 233 m.

6. *Inoceramus prefragilis* Stephenson (p. 12).
Hypotype USNM 308078 associated with a shark tooth from depth of 240 m.

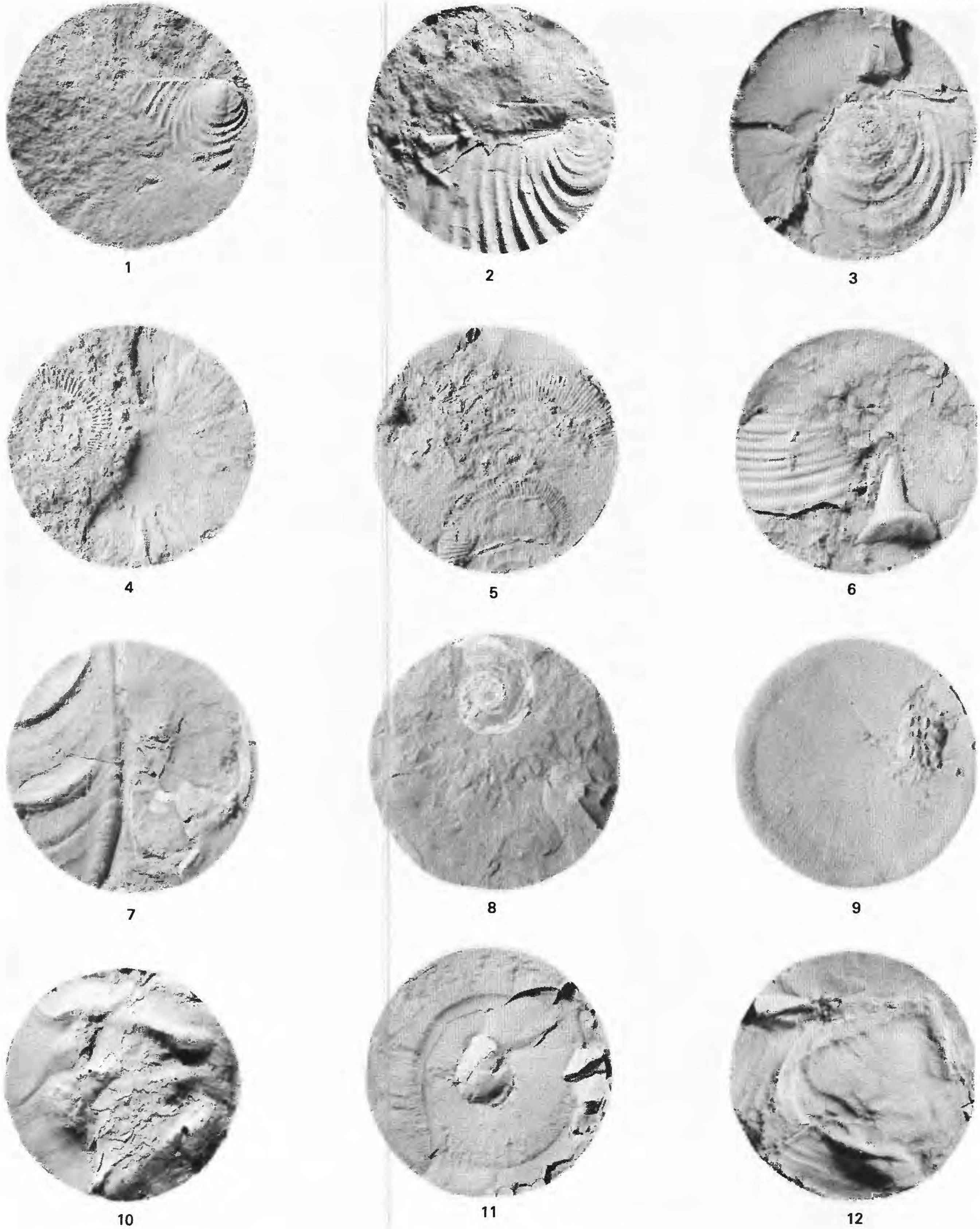
7. *Moremanoceras* sp. (p. 18).
Figured specimen USNM 308081 from depth of 222.7 m.

8. *Borissiakoceras reesidei* Morrow (p. 17).
Hypotype USNM 308088 from depth of 248 m.

9, 10. *Acanthoceras amphibolum* Morrow (p. 18).
Hypotype USNM 308089 and 308090 from depths of 254.5 and 249 m.

11. *Ostrea beloiti* Logan (p. 13).
Hypotype USNM 308091 from depth of 257.7 m.

12. *Inoceramus rutherfordi* Warren (p. 13).
Hypotype USNM 308092 from depth of 265 m.



INOCERAMUS, HAMITES, MOREMANOCERAS, BORISSIAKOCERAS, ACANTHOCERAS, AND *OSTREA*