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Shorter Contributions to Paleontology and Stratigraphy

U.S. GEOLOGICAL SURVEY BULLETIN 1690

U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849

Shorter Contributions to Paleontology and Stratigraphy

Edited by William J. Sando

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The Upper Cretaceous Ammonite *Eubostrychoceras* Matsumoto in the Western Interior of the United States

By William A. Cobban

Description and illustrations of an unusual ammonite
from Wyoming, South Dakota, and New Mexico

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Shorter Contributions to Paleontology and Stratigraphy

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FIGURES

The Upper Cretaceous Ammonite *Eubostrychoceras* Matsumoto in the Western Interior of the United States

By William A. Cobban

Abstract

The ammonite genus *Eubostrychoceras* is recorded for the first time in the western interior region, and the new species *E. matsumotoi* is described and illustrated. The new species has been found in the Wall Creek Member of the Frontier Formation in central Wyoming, in the Turner and Sage Breaks Members of the Carlile Shale in northeastern Wyoming and southwestern South Dakota, and in the D-Cross Tongue of the Mancos Shale in southern New Mexico. Outside the western interior region, the species occurs in the basal part of the Austin Chalk in southwestern Texas. The age is latest Turonian.

INTRODUCTION

The heteromorph ammonite *Eubostrychoceras* was named by Matsumoto (1967, p. 332) for helically coiled forms that usually have the whorls in contact. Ribs are conspicuous and generally simple. Constrictions are usually present, but tubercles are absent. Matsumoto (1967, p. 333) noted that the genus occurs in rocks of Albian to Santonian Age in Japan, India, Madagascar, North Africa, Western Europe, and the Pacific coast of North America.

Eubostrychoceras has not been reported previously from the western interior of the United States. Specimens referable to the genus, however, are present in some of the collections of fossils of the U.S. Geological Survey. A specimen was collected by V. H. Barnett as far back as 1913 in the course of mapping the Moorcroft oil field on the west flank of the Black Hills uplift in northeastern Wyoming. However, the fossil was not mentioned in his report on the area (Barnett, 1914). At a later date, a specimen collected farther southeastward near Newcastle, Wyo., was identified by J. B. Reeside, Jr., as *Helicoceras?* n. sp. (Mapel and Pillmore, 1963, p. N48; Robinson and others, 1964, p. 68). *Eubostrychoceras* was also found far to the south in southern New Mexico. Specimens were identified first as *Turrilitoides* by Alexander Stoyanow (Kottlowski and others, 1956, p. 68) and later by me as *Bostrychoceras* cf. *B. elongatum* (Whiteaves) (Bachman and Myers, 1969, p. C39). In recent years, excellent examples of *Eubostrychoceras* have been collected from the Frontier Formation near Casper, Wyo., and from the D-Cross Tongue of the Mancos Shale in southern New Mexico. All specimens seem referable to a single new species described herein as *E. matsumotoi.* Outside the western interior region, fragments of *E. matsumotoi* have been found in the basal part of the Austin Chalk in the Rio Grande area in Terrell and Val Verde Counties, Tex.

The fossils described in this report are kept in the National Museum of Natural History in Washington, D.C. All specimens have USNM catalog numbers. Plaster casts of a few of the specimens are in the reference collection of the U.S. Geological Survey at the Federal Center, Denver, Colo. R.E. Burkholder, of the U.S. Geological Survey, made the photographs.

LOCALITIES OF COLLECTIONS

Localities at which the new species *Eubostrychoceras matsumotoi* were collected in the western interior region are shown on figure 1. The U.S. Geological Survey Mesozoic locality number, names of collectors, year of collection, locality, and stratigraphic assignment are as follows (prefix D indicates Denver Mesozoic locality numbers; the others are Washington, D.C., Mesozoic locality numbers):

8864. V.H. Barnett, 1913. About 24 km (15 mi) north of Moorcroft in the SE 1/4 sec. 33, T. 52 N., R. 67 W., Crook County, Wyo. Carlile Shale [Turner Sandy Member].

11184. W.W. Rubey and C.R. Longwell, 1922. Beside highway about 3.2 km (2 mi) west of Newcastle, Weston County, Wyo. Carlile Shale [Turner Sandy Member].

21765. W.A. Cobban, 1948. North of Spring Creek in the NE 1/4 sec. 22, T. 1 S., R. 8 E., Pennington County, S. Dak. Carlile Shale, 13 m (42.6 ft) above base of Sage Breaks Member.

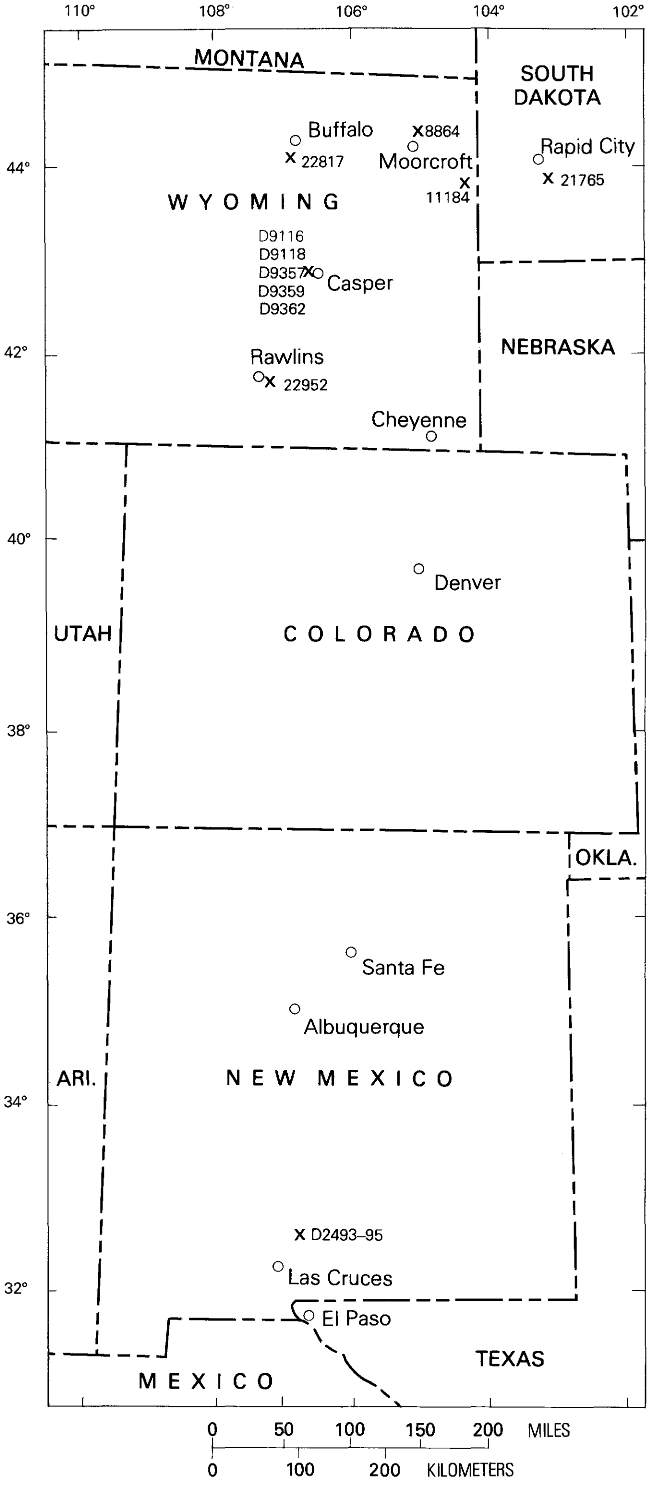

Figure 1. Map of part of the western interior of the United States showing localities where *Eubostrychoceras matsumotoi* Cobban, n. sp., has been collected. Numbers are U.S. Geological Survey Mesozoic localities.

22817. R.K. Hose, J.B. Reeside, Jr., and W.A. Cobban, 1950. Dry Muddy Creek in the NE 1/4 sec. 1, T. 48 N., R. 83 W., Johnson County, Wyo. Cody Shale, from septarian limestone concretions in lower part.

22952. J.B. Reeside, Jr., 1950. North flank of Grenville dome 1.6 km (1 mi) southeast of Sinclair in the SE 1/4 sec. 22, T. 21 N., R. 86 W., Carbon County, Wyo. Frontier Formation, from a sandstone concretion 16 m (52 ft) above base of Wall Creek Member.

D2493. G.O. Bachman and D.A. Myers, 1960; S.C. Hook and W.A. Cobban, 1980. West side of San Andres Mountains in the SW 1/4 sec. 19, T. 20 S., R. 4 E., Dona Ana County, N. Mex. Mancos Shale, from lower part of D-Cross Tongue.

D2494. G.O. Bachman and D.A. Myers, 1960; S.C. Hook and W.A. Cobban, 1980. Same locality as D2493. From concretion in D-Cross Tongue 2–3 m (6–10 ft) above D2493.

D2495. G.O. Bachman and D.A. Myers, 1960; S.C. Hook and W.A. Cobban, 1980. Same locality as D2493. From concretions in D-Cross Tongue 8 m (26 ft) above D2494.

D9116. E.A. Merewether and W.A. Cobban, 1974. Emigrant Gap Ridge 16 km (10 mi) west of Casper in the SE 1/4 sec. 3, T. 33 N., R. 81 W., Natrona County, Wyo. Frontier Formation, from sandstone concretions in upper part of Wall Creek Member.

D9118. E.A. Merewether and W.A. Cobban, 1974. Emigrant Gap Ridge in the NE 1/4 sec. 4, T. 33 N., R. 81 W., Natrona County, Wyo. Frontier Formation, from same stratigraphic level as D9116.

D9357. E.T. Cavanaugh, 1975. Emigrant Gap Ridge in the NW 1/4 sec. 11., T. 33 N., R. 81 W., Natrona County, Wyo. Frontier Formation, from same stratigraphic level as D9116.

D9359. E.T. Cavanaugh, 1975. Emigrant Gap Ridge in the NE 1/4 sec. 32, T. 34 N., R. 81 W., Natrona County, Wyo. Frontier Formation, from top of Wall Creek Member.

D9362. E.T. Cavanaugh and E.A. Merewether, 1975. Casper Canal in the SE 1/4 sec. 5, T. 33 N., R. 81 W., Natrona County, Wyo. Frontier Formation, from upper part of Wall Creek Member.

SYSTEMATIC PALEONTOLOGY

Family NOSTOCERATIDAE Hyatt, 1894

Genus EUBOSTRYCHOCERAS Matsumoto, 1967

Type species—Eubostrychoceras indopacificum Matsumoto, 1967, by original designation.

Matsumoto (1977, p. 324) gave the following amended definition of *Eubostrychoceras:*

> Main part of the septate whorls are helically coiled and the adult body-chamber deviates slightly or remarkably from this helix, with its apertural end facing obliquely or nearly straight upward or "backward", i.e., in more

> or less reversed orientation against the orientation of the axis of helical coiling. The whorls may be tightly contiguous or slightly or considerably separated, depending on species or in some cases even on individuals. Periodic constrictions, with accompanied flared ribs, may be present or absent, again depending on species and also on growth-stages. Even in the species without periodic constrictions the adult body-chamber is generally provided with one or more constrictions at or near its peristome. The length of the body-chamber is apparently variable.
>
> The whorl is ornamented with numerous ribs which are mostly simple, occasionally branched or inserted, more or less oblique and gently sinuous on the external part (i.e., the convex side), with bending at the shoulders. No tubercles are developed at any stage.
>
> The siphuncle runs approximately at the middle of the external side of the helical whorl but may somewhat deviate from that position. The suture is of modified lytoceratid type, deeply and finely incised, with much narrowed stems and expanded branches of bifid L, U, and lateral saddles.

Wright (1979, p. 296) believed *Eubostrychoceras* was an unnecessary name or at best a subgenus of *Didymoceras* Hyatt (1894, p. 573). In a more recent work, Kennedy and Summesberger (1984, p. 165) regarded *Didymoceras* as a subgenus of *Nostoceras* (Hyatt, 1894, p. 569). *Didymoceras* and *Nostoceras* have tubercles at some growth stage. *Eubostrychoceras* seems distinct though in lacking tubercles at any growth stage, and in having a peculiar arrangement in the juvenile coiling. This odd juvenile coiling was noted by Matsumoto (1967, p. 335) in the description of his new species *E. muramotoi* from Coniacian strata of Japan. Matsumoto observed that:

> ***the earliest shell is nearly straight, ascending and then followed by a subcircularly curved, half whorl, which, in turn, is twisted obliquely down, passing to the main helical whorls, whose axis of coiling is along the earliest straight shaft. Thus the youngest whorl is apparently incurved into the axial part of the helix. The same mode of coiling does not seem to be constantly held in the present species, since in some other specimens the apical end of the earliest whorl shows an oblique orientation. Anyhow, the young whorl is more or less deviated from the main helical ones, showing some irregularity.

Eubostrychoceras matsumotoi Cobban, n. sp.

Plate 1, figures 1–26; text-figure 2

This species is characterized by its large apical angle and sparse ribbing. The earliest whorls are hamitid and enclosed by the earliest whorl of the spire.

The holotype (pl. 1, figs. 24–26), from the Frontier Formation of Wyoming, is an adult sinistral spire of four whorls in contact that have an apical angle of 65° and a height of 69 mm. A little more than one half of the last whorl is body chamber. An impressed area around the umbilicus (pl. 1, fig. 26) suggests that the complete body chamber may have included a whorl and a half. Whorl sections are higher than they are wide with very broadly rounded outer flanks. Ribs are single and narrow and number 29 on the smallest whorl, 25 on the next one, 20 on the next, and 30 on the largest. Each rib slants straight across the side and than bends forward a little on the opposite shoulder.

The earliest whorls are best seen on a specimen from the D-Cross Tongue of the Mancos Shale of southern New Mexico. This specimen consists of two parallel limbs incurved into a spire of one complete whorl (pl. 1, figs. 1–4). The smaller straight limb, 14 mm long, has a diameter of 0.5 mm at one end and 1 mm at the other. Its angle of growth is very low, and its whorl section is circular. Ornament is lacking. The second straight limb, which is connected to the first by a U-shaped elbow, is about 12 mm long. This limb has a section a little broader than it is high with very broadly rounded venter and narrowly rounded flanks. Closely spaced, transverse, rounded ribs are present on the younger (larger) half. Upon forming the second U-shaped elbow, the limb then curves obliquely downward and passes into a helical spire.

Constrictions are inconspicuous and parallel to the ribs. Most specimens, including the holotype, have one or two constrictions per whorl. A deeper constriction, bounded by high ribs, is present just before the aperture (pl. 1, fig. 16).

The apical angle ranges from 65°, for the holotype, to as much as 90° for specimens that have lower spires and wider umbilici (pl. 1, figs. 17–23). Specimens are about equally divided between dextral and sinistral coiling.

A complete individual is not present in the collections. Most specimens are fragments of whorls or no more than two or three whorls in the spire in addition to the hamitid early whorls. The last part of the adult body chamber may have pulled away slightly from the spire and then curved back to it in the manner described by Matsumoto (1967, p. 333, pl. 18, fig. 1a) for the type species of the genus, *Eubostrychoceras indopacificum.*

The suture, which is centered at midflank, is characterized by an extremely wide, deeply bifid lateral lobe (fig. 2). The rest of the lobes and saddles are deeply bifid except the small, narrow internal lobe, which is trifid.

The sparse ribbing of *Eubostrychoceras matsumotoi* easily distinguishes this form from the other species assigned to the genus by Matsumoto (1967, p. 332). However, *E. elongatum* (Whiteaves, 1903, p. 331, pl. 44, fig. 3), from Campanian rocks of British Columbia, is as coarsely ribbed, but it has a much more acute apical angle and, according to Usher (1952, p. 105, pl. 28, fig. 4), the body chamber becomes loosely coiled and freed from the septate spire.

The holotype is from a sandy concretion at the top of the Wall Creek Member of the Frontier Formation at USGS Mesozoic locality D9359 at Emigrant Gap Ridge west of Casper in the NE 1/4 sec. 32, T. 34 N., R. 81 W., Natrona County, Wyo. (fig. 1). The figured paratypes are from the Wall Creek Member west of Casper and from sandy concretions in the D-Cross Tongue of the Mancos Shale at a small outcrop on the west flank of the San Andres Mountains northeast of Las Cruces, Dona Ana County, N. Mex.

The species is named in honor of Prof. Tatsuro Matsumoto, Professor Emeritus, Kyushu University, Fukuoka, Japan, for his important contributions on Cretaceous ammonites and biostratigraphy.

Types.—Holotype USNM 395808, paratypes USNM 395809–395818.

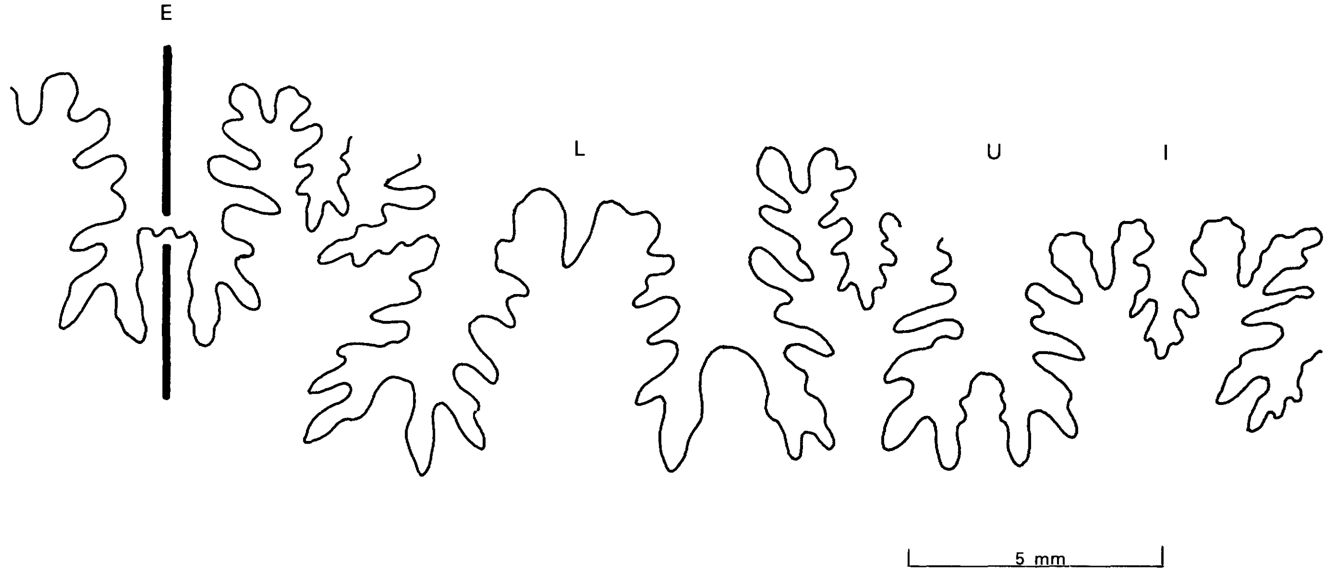

Figure 2. Suture of *Eubostrychoceras matsumotoi* Cobban, n. sp., at a whorl height of 13.3 mm. Paratype USNM 395818, from the Frontier Formation at USGS Mesozoic locality D9362 (fig. 1). E is the external lobe, L is the lateral lobe, U is the umbilical lobe, and I is the internal lobe.

ASSOCIATED FOSSILS AND AGE

Important molluscan fossils found with the holotype and paratypes of *E. matsumotoi* in the Wall Creek Member of the Frontier Formation include *Inoceramus incertus* Jimbo, *Baculites yokoyamai* Tokunaga and Shimizu, and *Prionocyclus reesidei* Sidwell. *Inoceramus incertus* was described by Jimbo (1894, p. 43, pl. 8, fig. 7) from strata in Japan later assigned to the Turonian (Nagao and Matsumoto, 1939, p. 260). The species has been treated again recently by Matsumoto and Noda (1983), who regard it as late Turonian. These authors pointed out that *Inoceramus fiegei* Tröger (1967, p. 105, pl. 11, fig. 3; pl. 13, figs. 14, 15, 17, 20) from the very late Turonian of Europe is probably a synonym. *Baculites yokoyamai* was described from Coniacian rocks of Japan (Tokunaga and Shimizu,1926, p. 195, pl. 22, fig. 5a, b; pl. 26, fig. 11). This rather small species is a generalized form that has a stout elliptical to subelliptical section, very low degree of taper, finely ribbed venter, smooth to weakly ribbed flanks, and a fairly simple suture. Baculitids that are indistinguishable from the Japanese *B. yokoyamai* occur abundantly in rocks of early Turonian to early Coniacian age in the western interior of the United States. *Prionocyclus reesidei* was described by Sidwell (1932, p. 318, pl. 49, figs. 10–12) from the Frontier Formation near Rawlins, Wyo. Collections made later from this area reveal that *P. reesidei* occurs in the lower part of the Wall Creek Member (Cobban and Reeside, 1951, p. 60, 61; Merewether and Cobban, 1972, fig. 2). Associated fossils include *Inoceramus incertus* and *Baculities yokoyamai*. *Prionocylus quadratus* Cobban (1953), which also occurs at the stratigraphic level of *P. reesidei*, has been used as a guide fossil to rocks of latest Turonian age in the western interior region (Cobban, 1984, p. 76, 87). The known range of *Eubostrychoceras matsumotoi* is at the very top of the upper Turonian.

In the Rio Grande area of southwestern Texas, Freeman (1961, p. 105, 106) recorded *Inoceramus* cf. *I. incertus* and *Prionocyclus reesidei* from the basal part of the Austin Chalk. The inoceramid can be more definitely assigned to *I. incertus*. Associated with these fossils are fragments of *E. matsumotoi*.

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PLATE 1

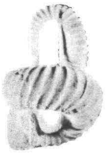
Contact photographs of the plates in this report are available at cost from U.S. Geological Survey Library, Federal Center, Denver, CO 80225

PLATE 1

[All figures natural size. Localities shown on figure 1 in text]

Figures 1–26. *Eubostrychoceras matsumotoi* Cobban, n. sp. (p. A3)

1–4. Paratype USNM 395809, from the D-Cross Tongue of the Mancos Shale at USGS Mesozoic locality D2493.
5–8. Paratype USNM 395810, from the Frontier Formation at USGS Mesozoic locality D9118.
9. Paratype USNM 395811, from the Frontier Formation at USGS Mesozoic locality D9116.
10. Paratype USNM 395812, from the same locality as figures 1–4.
11. Paratype USNM 395813, from the Frontier Formation at USGS Mesozoic locality D9357.
12–15. Paratype USNM 395814, from the same locality as figures 1–4.
16. Paratype USNM 395815, from the same locality as figure 9.
17–19. Paratype USNM 395816, from the same locality as D9118.
20–23. Paratype USNM 395817, from the Frontier Formation at USGS Mesozoic locality D9362.
24–26. Holotype USNM 395808, from the same locality as figures 20–23.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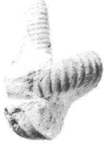
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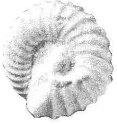
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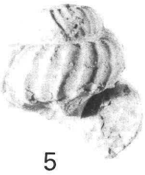
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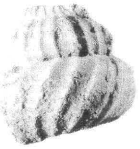
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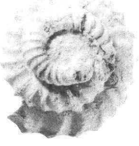
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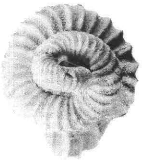
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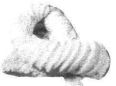
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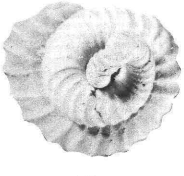
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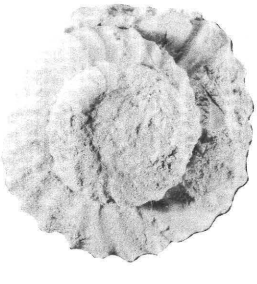
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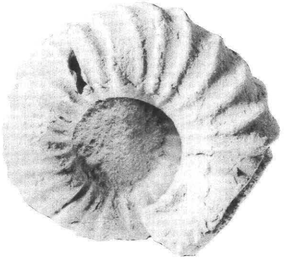
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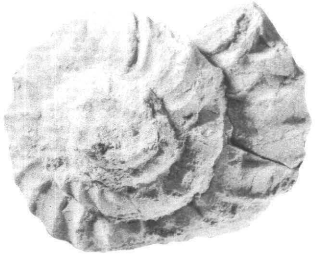
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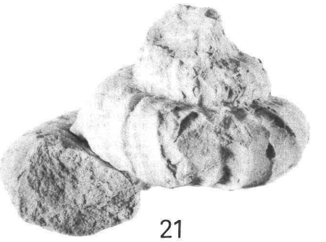
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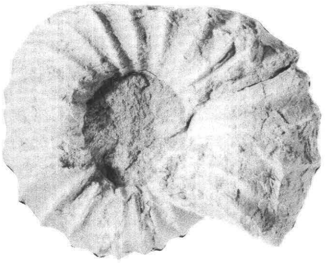
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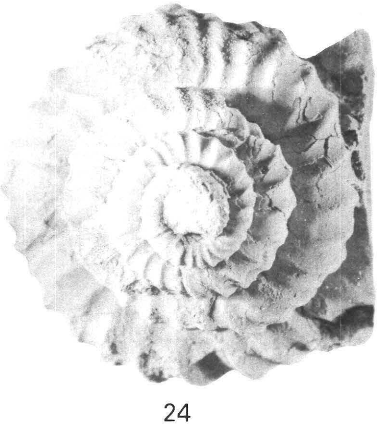
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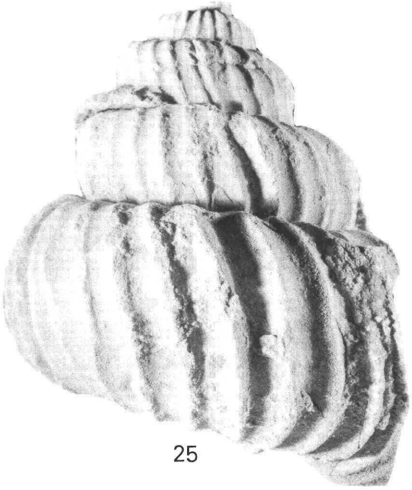
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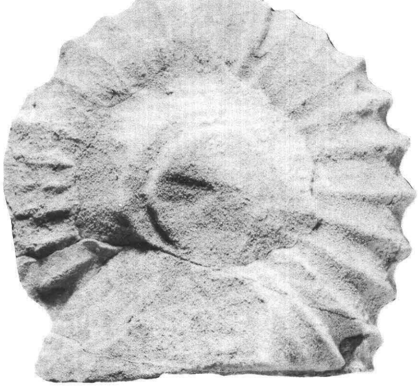
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EUBOSTRYCHOCERAS

CHAPTER B

A New Ammonite from the Upper Cretaceous of Kansas

By William A. Cobban

Description and illustrations of a new genus
and species from the Greenhorn Limestone

U.S. GEOLOGICAL SURVEY BULLETIN 1690
Shorter Contributions to Paleontology and Stratigraphy

CONTENTS

PLATE

[Plate follows References Cited]

FIGURE

A New Ammonite from the Upper Cretaceous of Kansas

By William A. Cobban

Abstract

The new ammonite genus *Bassites* is defined, and the new species *B. reesidei* is described and illustrated. *Bassites,* of early Turonian age, seems to have been derived from *Moremanoceras* of late Cenomanian age. The new genus is known only from a bed of limestone in the Bridge Creek Member of the Greenhorn Limestone of Kansas.

INTRODUCTION

Among the rarer forms of ammonites in the collections of molluscan fossils of the U.S. Geological Survey are two fairly large, robust specimens that cannot be assigned to any named genus. Both specimens represent the same genus and species, which is herein named *Bassites reesidei.* One specimen (the holotype) was collected in 1926, and the other was found in 1981.

The specimens are kept in the National Museum of Natural History, Washington, D.C., and have USNM catalog numbers. Plaster casts of the specimens are in the reference collections of the U.S. Geological Survey at the Federal Center, Denver, Colo. R.E. Burkholder, of the U.S. Geological Survey, made the photographs.

SYSTEMATIC PALEONTOLOGY

Family DESMOCERATIDAE Zittel, 1895

Genus BASSITES Cobban, n. gen.

Type species.—Bassites reesidei Cobban, n. sp.

Bassites is characterized by its moderately large size; by its stout involute shell; by its ornament of weak closely spaced, flat, ribs; and by its simplified suture. The genus appears to have developed directly out of *Moremanoceras* (Cobban, 1971, p. 5) through an increase in size, loss of constrictions and raised ribs, and further simplification of the suture. *Bassites* is known only from lower Turonian rocks of Kansas.

The genus is named for the late Nathan W. Bass, of the U.S. Geological Survey, who collected the type specimen 1 during the course of his investigations of the Cretaceous stratigraphy of southwestern Kansas (Bass, 1926). Bass made many important collections of invertebrate fossils and contributed much to our knowledge of the mid-Cretaceous rocks of Kansas and southeastern Colorado (Lohman, 1984). The late John B. Reeside, Jr., of the U.S. Geological Survey, had set the type specimen aside with plans to eventually describe it and name it for Bass under the name of *Thomasites bassi.* The specimen has been listed as *Thomasites* n. sp. (Bass, 1926, p. 71). This is not a *Thomasites,* but rather a new genus. Inasmuch as there is already a *Reesidites* (Wright and Matsumoto, 1954, p. 130) and a *Reesideoceras* (Basse, 1947, p. 132), the taxon proposed in the present report seems the best way to honor both men.

Bassites reesidei Cobban, n. sp.

Plate 1

1926. *Thomasites* n. sp. Bass, Kansas Geological Survey Bulletin 11, p. 71.

This moderately large, robust, involute species has a rounded whorl section higher than wide. The species is known from only two incomplete adults.

The holotype (pl. 1) is a slightly crushed internal mold 147 mm in diameter with an umbilical width of 23 mm (ratio of 0.16). The specimen consists of a septate coil attached to a little less than a quarter of a whorl of the body chamber. Diameter at the base of the body chamber is 127.5 mm. Inner whorls are not preserved. The umbilicus has steep walls that merge evenly into a well-rounded umbilical shoulder. The last septate whorl has a well-rounded venter that grades evenly into broadly rounded flanks. Flanks on the preserved part of the body chamber are more rounded like the venter. Ornament consists of numerous weak rectiradiate ribs that begin at the umbilicus or on the lower part of the flank. All bend slightly forward at the ventrolateral shoulder and cross the venter with a little forward arching. There are about 56 ribs on the last half whorl of the phragmocone. The external suture (fig. 1) is rather simple with similar sized external (E) and lateral lobes (L) and first and second lateral saddles. The lateral lobe is deeply bifid. The next lobe is trifid and about half as large.

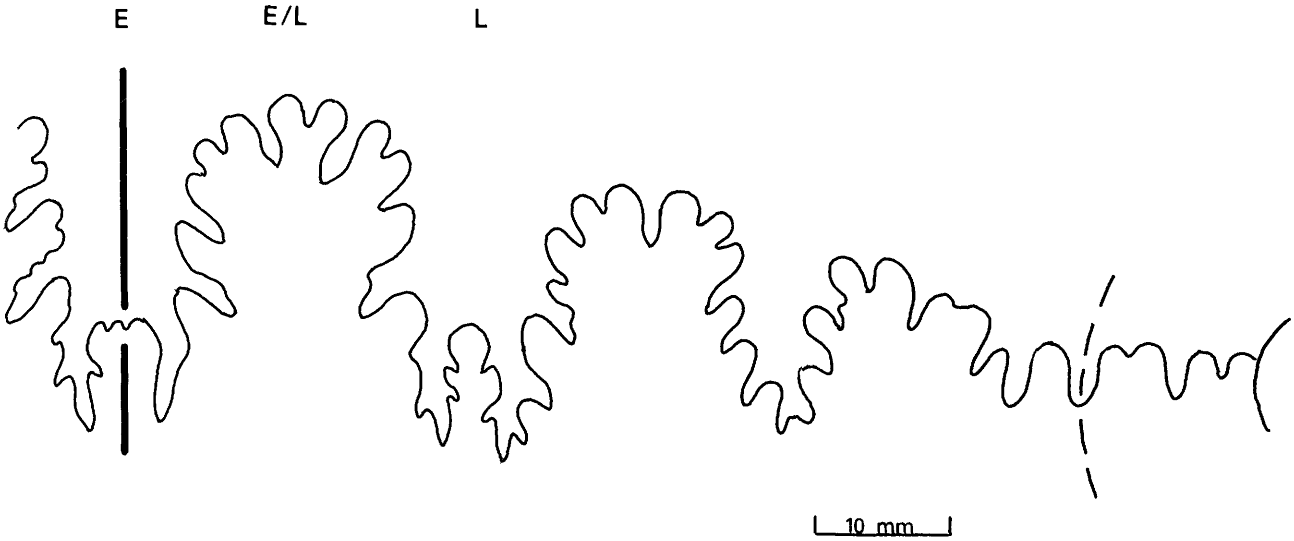

Figure 1. External suture of *Bassites reesidei* Cobban, n. sp., at a diameter of 106 mm. Holotype USNM 395819, from the Greenhorn Limestone at USGS Mesozoic locality 12773 in the SW 1/4 sec. 14, T. 23 S., R. 42 W., Hamilton County, Kans.

The paratype (USNM 395820) closely resembles the holotype in size and appearance. Diameter is 150 mm, and the umbilical width is 25.3 mm (0.17). The paratype, a slightly crushed internal mold, is nearly complete and includes more than half a whorl of body chamber, which has a diameter of 114 mm at its base.

Bassites reesidei does not closely resemble any known Cretaceous ammonite from North America. Occasional specimens of *Moremanoceras scotti* (Moreman), of late Cenomanian age, resemble *B. reesidei* in having stout, involute shells ornamented by numerous weak ribs (Cobban, 1971, pl. 2, figs. 12–14). The Cenomanian species, however, has periodic constrictions and raised ribs as well as a more complex suture with a large trifid lateral lobe.

Outside North America, the only species that shows some resemblance to *B. reesidei* is the ammonite from Portugal described originally as *Ammonites (Vascoceras?) barcoicensis* Choffat (1898, p. 67, pl. 16, fig. 11; pl. 17, fig. 1a–c; pl. 22, figs. 35, 36). This is a stout form with nearly smooth flanks except for weak closely spaced ribs much like those of *B. reesidei*. The Portuguese species, which may be about the same age, has been consistently considered a *Vascoceras* by many authors (for example, Wiedmann, 1959, p. 723; Lauverjat and Berthou, 1974, p. 269 and unnumbered table; Berthou and Lauverjat, 1975, p. 98, 103, 112; Berthou and others, 1975, p. 75, 81, 82). The Portuguese species is more evolute than the American form and has a suture more like *Vascoceras*.

The holotype came from a bed of limestone at about the base of the middle third of the Bridge Creek Member of the Greenhorn Limestone at USGS Mesozoic locality 12773 in the SW 1/4 sec. 14, T. 23 S., R. 42 W., Hamilton County, Kans. Additional fossils collected by G.R. Scott and the author (Cobban and Scott, 1972, p. 21, bed 40) from this bed at or about the same locality include *Mytiloides columbianus* (Heinz), *Watinoceras coloradoense* (Henderson), *Vascoceras (Greenhornoceras) birchbyi* Cobban and Scott, and *Neoptychites* cf. *N. cephalotus* (Courtiller).

The paratype, collected by E.A. Merewether of the U.S. Geological Survey, came from the same bed of limestone as that of the holotype, but at a locality 178 km (111 mi) farther east (USGS Mesozoic loc. D11631 in the NW 1/4 sec. 7, T. 23 S., R. 23 W., Hodgeman County, Kans.). *Mytiloides columbianus* (Heinz) was associated with it. At this locality, the bed of limestone forms the base of the Jetmore Chalk Member of the Greenhorn Limestone.

The bed of limestone that produced the holotype and paratype persists westward into Colorado at least as far as the Front Range. Near Pueblo, the bed (Cobban and Scott, 1972, p. 23, bed 97) contains many fossils including *Mytiloides columbianus* (Heinz), *M.* aff. *M. opalensis* (Böse), *Watinoceras coloradoense* (Henderson), *W.* aff. *W. devonense* Wright and Kennedy, *Ampakabites collignoni* Cobban and Scott, *Vascoceras (Greenhornoceras) birchbyi* Cobban and Scott, *Fagesia* sp., *Neoptychites cephalotus* (Courtiller), and *Puebloites spiralis* Cobban and Scott. Among the fossils collected from this bed along the Arkansas River valley in southeastern Colorado, is a form identified by J. B. Reeside, Jr., as *Thomasites* n. sp. (Dane and others, 1937, p. 214). This species, not to be confused with Reeside's *Thomasites* n. sp. from Kansas, was later described as *Vascoceras (Greenhornoceras) birchbyi* (Cobban and Scott, 1972, p. 84–87).

The presence of *Watinoceras coloradoense* and *Vascoceras birchbyi* in the same bed of limestone that produced the types of *Bassites reesidei* clearly indicates an early *Turonian* age. *Watinoceras coloradoense* was proposed as a guide fossil for the lowest Turonian rocks of England (Hancock and Kennedy, 1980, p. 541; Wright and Kennedy, 1981, table 1, p. 120), and the species was later noted in

France (Kennedy and others, 1983, p. 177). Both *W. coloradoense* and *Vascoceras birchbyi* have been used as zonal fossils to the lower Turonian in the western interior (Cobban and Scott, 1972, tables 3, 4; Cobban, 1984, fig. 2, p. 82, 83).

Types.—Holotype USNM 395819, paratype USNM 395820.

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PLATE 1

Contact photographs of the plates in this report are available at cost from U.S. Geological Survey Library, Federal Center, Denver, CO 80225

PLATE 1

[All figures natural size]

Figures 1–3. *Bassites reesidei* Cobban, n. sp. (p. B1).

Rear, side, and front views of the holotype USNM 395819, from the Bridge Creek Member of the Greenhorn Limestone at USGS Mesozoic locality 12773 in the SW 1/4 sec. 14, T. 23 S., R. 42 W., Hamilton County, Kans.

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BASSITES

CHAPTER C

The Upper Cretaceous (Cenomanian) Ammonites *Metengonoceras Dumbli* (Cragin) and *M. Acutum* Hyatt

By William A. Cobban

Description and illustrations of important
international zonal fossils

U.S. GEOLOGICAL SURVEY BULLETIN 1690
Shorter Contributions to Paleontology and Stratigraphy

CONTENTS

PLATES

[Plates follow References Cited]

FIGURES

The Upper Cretaceous (Cenomanian) Ammonites *Metengonoceras Dumbli* (Cragin) and *M. Acutum* Hyatt

By William A. Cobban

Abstract

Metengonoceras dumbli (Cragin) was originally described from the upper part of the Woodbine Formation of Texas. The species has since been found in western France and West Africa (Nigeria and Niger). Age range of the species is middle and late Cenomanian in France and middle Cenomanian in Texas. *Metengonoceras acutum* Hyatt, which was described from the Britton Formation of Texas, is known with certainty only in the United States and only in upper Cenomanian rocks. The species is closely related to *M. dumbli,* from which it differs mainly in retaining a sharp venter on the adult body chamber.

INTRODUCTION

Metengonoceras dumbli (Cragin) and *M. acutum* Hyatt are closely related, nearly smooth, very slender ammonites that have narrow, wedge-shaped whorl sections and peculiar, crowded sutures. The species have been difficult to separate because only the holotype of *M. acutum* has been illustrated, and only a couple of the American examples of *M. dumbli* have been figured. Crushed specimens from Iowa and fragments from Minnesota originally assigned to *M. dumbli* (Cobban, 1983, p. 11) now seem better assigned to *M. acutum*. The purpose of the present paper is to more fully describe and illustrate the two species and to document their geographic and stratigraphic ranges.

All but one of the specimens illustrated in this report are kept in the National Museum of Natural History, Washington, D.C., where they have USNM catalog numbers. The exception is an example of *M. acutum* from Iowa, which is in the Yale Peabody Museum of Natural History, New Haven, Conn. R.E. Burkholder, of the U.S. Geological Survey, made the photographs.

LOCALITIES OF COLLECTIONS

U.S. Geological Survey localities of the collections of fossils that are illustrated or mentioned in this report are given below. The U.S. Geological Survey Mesozoic locality number, names of collectors, year of collection, locality, and stratigraphic assignment are as follows (prefix D indicates Denver Mesozoic locality numbers; others are Washington, D.C., Mesozoic locality numbers):

20314. H.R. Bergquist, 1946. Bluffs along Templeton Branch of Cornelius Creek about 4.8 km (3 mi) north of Bells, Grayson County, Tex. Woodbine Formation, about 15 m (50 ft) below top of Templeton Member.

22604. J.H. Renfro and R.F. Renfro. Mountain Creek about 3.2 km (2 mi) northeast of Britton, Tarrant County, Tex. Britton Formation.

22606. J.H. Renfro and R.F. Renfro. Highway 287 cut 8 km (5 mi) northwest of Midlothian, Ellis County, Tex. Britton Formation.

D98. J.P. Conlin and W.A. Cobban, 1954. Bed of a tributary to Big Bear Creek on the Woodland Hill farm, 2.4 km (1 1/2 mi) east of Euless, Tarrant County, Tex. Woodbine Formation, from Lewisville Member.

D3963. W.A. Cobban, 1957. SW 1/4 sec. 30, T. 20 S., R. 65 W., Pueblo County, Colo. Graneros Shale, from a ferruginous concretion 9.4 m (31 ft) below top.

D5777. E.R. Landis and W.A. Cobban, 1967. SE 1/4 sec. 8, T. 5 S., R. 2 E., Socorro County, N. Mex. Mancos Shale, from a thin bed of very fine grained sandstone in the lower part.

D9481. J.D. Powell, 1968. East-flowing tributary to Templeton Branch of Cornelius Creek about 4.8 km (3 mi) north of Bells, Grayson County, Tex. (same locality as Stephenson, 1952, p. 41, loc. 164). Woodbine Formation, from Templeton Member.

D12634. Blaine Conley, 1965. Mesabi Range, Itasca County, Minn. Coleraine Formation.

SYSTEMATIC PALEONTOLOGY

Family ENGONOCERATIDAE Hyatt, 1900
Genus METENGONOCERAS Hyatt, 1903

Type species.—*Metengonoceras inscriptum* Hyatt, 1903, p. 180, pl. 25, figs. 5–9; pl. 26, figs. 1–4. Subsequent designation, Roman, 1938, p. 491.

Diagnosis.—This genus includes very compressed, almost smooth ammonites that have tiny umbilici and narrow, flattened venters, which may round on the adult body chamber. Ornament consists of falcoid growth lines and, on some specimens, weak arcuate ribs a little above the middle of the flank and rarely faint umbilical bullae. Sutures are very closely spaced and have numerous auxilary and adventive elements with most saddles undivided and the larger lobes moderately frilled.

Metengonoceras dumbli (Cragin)

Plate 1, figures 3–6, 8; plate 2, figures 1–3, 9, 10; text-figure 1.

1893. *Sphenodiscus dumbli* Cragin, p. 243, pl. 44, fig. 6.
1893 [1894]. *Sphenodiscus* cf. *pedernalis* L. von Buch. De Grossouvre, p. 140, text-fig. 58.
1903. *Metengonoceras dumbli* (Cragin). Hyatt, p. 185, pl. 27, figs. 3–14.
1908. *Metengonoceras* sp. De Grossouvre, p. 11, text figs. 1–3.
1910. *Metengonoceras dumblii [sic]* (Cragin). Grabau and Shimer, p. 214, text fig. 1489a–d.
1912. *Metengonoceras* sp. De Grossouvre, p. 33, text-fig. 5.
1912. *Metengonoceras Douvillei* de Grossouvre, p. 34, pl. 3, fig. 3; text-fig. 6.
1912. *Metengonoceras Arnaudi* de Grossouvre, p. 35, text-fig. 7.
1912. *Metengonoceras tolveiense* de Grossouvre, p. 36, pl. 3, fig. 4; text-fig. 8.
1921. *Metengonoceras dumblii* [*sic*] (Cragin). Grabau, text-fig. 1756a–d.
1924. *Epengonoceras dumbli* (Cragin). Spath, p. 508.
1925. *Metengonoceras Arnaudi* Grossouvre. Diener, p. 229.
1925. *Metengonoceras Douvillei* Grossouvre. Diener, p. 229.
1925. *Metengonoceras Dumblei* [*sic*] Cragin. Diener, p. 229.
1925. *Metengonoceras tolociense* [*sic*] Grossouvre. Diener, p. 229.
1925. *Metengonoceras* sp. ind. Grossouvre. Diener, p. 229.
1928. *Epengonoceras dumbli* (Cragin). Adkins, p. 264.
1931. *Epengonoceras dumbli* (Cragin). Reeside and Weymouth, p. 14.
1935. *Epengonoceras Dumbli* Cragin. Furon, p. 55.
1942. *Epengonoceras dumbli* (Cragin). Moreman, p. 217.
1943. *Metengonoceras Dumbli* Cragin. Schneegans, p. 136, text-fig. 17.
1951. *Metengonoceras dumblei [sic]* (Cragin). Adkins and Lozo, pl. 2, fig. 5.
1952. [1953]. *Metengonoceras dumbli* (Cragin). Stephenson, p. 206, pl. 55, figs. 1–4.
1956. *Metengonoceras* (*Epengonoceras*) aff. *dumbli* (Cragin). Reyment, p. 58.
1957. *Epengonoceras dumbli* (Cragin). Barber, p. 9, pl. 25, figs. 9, 10.
?1972 [1973]. *Epengonoceras dumbli* (Cragin). Cobban and Scott, p. 59, pl. 8.
1976 [1978]. *Metengonoceras dumbli* Cragin. Kennedy and Hancock, pl. 13, fig. 5a–c.
1976 [1978]. *Epengonoceras dumbeli* [*sic*] (Cragin). Young and Powell, p. XXV.18.
1981. *Metengonoceras dumbli* (Cragin). Kennedy and others, p. 32, pl. 3, figs. 1–5; pl. 7, figs. 4–6; text figs. 4A–G, 5B–F.

Types.—Lectotype USNM 29403, from Grayson County, Texas; hypotypes USNM 401493–401500, from Grayson and Tarrant Counties, Texas.

Description.–Cragin (1893, p. 243) had nearly 20 specimens of *Metengonoceras dumbli* from several localities in northeastern Texas, but his only illustration was the external suture of one specimen. Hyatt (1903, p. 185, pl. 27, figs. 3–14) described and illustrated "a superb specimen" from the Cragin collection, and this specimen has been designated the lectotype by Kennedy and others (1981, p. 34). The specimen is an internal mold 94 mm in diameter with an umbilical ratio of 0.08. An incomplete body chamber occupies the last half whorl; diameter at its base is about 69 mm. Whorls are very compressed and much higher than wide with the greatest width low on the flank. The venter is sharp on the outer whorl of the phragmocone and on the adjoining part of the body chamber. Most of the venter of the body chamber is not preserved, but the younger end is rounded and has a narrow midventral flattening. Ornament other than faint falcoid growth lines is lacking. Both the external and internal sutures were described and illustrated in detail by Hyatt (1903, p. 187, pl. 27, figs. 9–14). The lateral lobe and the adventitious lobes have narrow necks and then expand with two or three branches on each side. Saddles that separate these lobes are rounded and undivided. Most of the lobes between the lateral one and the umbilicus are narrow and mostly bifid, and the saddles that separate them are broad, shallow, and bifid to undivided. There are 13 lobes in the external suture.

A large topotype figured by Stephenson (1952, p. 207, pl. 55, figs. 2–4) has a diameter of 142 mm with a diameter of 108 mm at the base of the body chamber. The venter of the phragmocone of this internal mold is sharp, whereas the venter at the larger end of the body chamber is well rounded.

The largest collection of *M. dumbli* at hand consists of nine well-preserved internal molds from the Templeton Member of the Woodbine Formation at USGS Mesozoic locality D9481 near Bells, Grayson County, Tex. Diameters (rounded) at the base of body chambers are 64, 65, 66, 79, 83, 84, 88, 89, and 94 mm. Although internal molds of the outer whorls of the phragmocones have sharp venters, specimens that retain a little shell material reveal narrow, flat to concave venters (pl. 1, figs. 4, 6) as noted by Stephenson (1952, p. 206). External sutures of four of these specimens are shown in figure 1. The external lobe (E), which is not centered on the middle of the venter, is short and bifid and usually has a narrow neck. The lateral lobe and the first two adventitious lobes are bifid and have two branches on each side. Other adventitious lobes are smaller and mostly bifid. The first inner lobe adjacent to the lateral one is a little smaller than that one but branched much like it. The rest of the inner lobes are smaller and usually bifid. Saddles that separate these lobes are either bifid or undivided. There are about eight lobes between the lateral one and the umbilical seam. For illustrations of sutures of four other specimens of *M. dumbli* from northeastern Texas, the reader is referred to Kennedy, Juignet, and Hancock (1981, text fig. 5B–F).

Metengonoceras acutum Hyatt

Plate 1, figures 1, 2, 7; plate 2, figures 4–8; plate 3

1893. *Placenticeras* (*Sphenodiscus*) sp. undet. Winchell, p. 221.
1903. *Metengonoceras acutum* Hyatt, p. 184, pl. 26, fig. 8; pl. 27, figs. 1, 2.
1925. *Metengonoceras acutum* Hyatt. Diener, p. 229.
1928. *Metengonoceras*(?) *acutum* Hyatt. Adkins, p. 264.
1931. *Epengonoceras acutum* (Hyatt). Reeside and Weymouth, p. 16.
?1935. *Metengonoceras nigeriensis* Furon, p. 55, pl. 3, fig. 1a, b; text-fig. 16.
1942. *Protengonoceras planum* Hyatt. Moreman, p. 217.
1942. *Epengonoceras acutum* (Hyatt). Moreman, p. 218.
?1943. *Metengonoceras nigeriensis* Furon. Schneegans, p. 137.
1944. *Epengonoceras* cf. *E. dumblei* [*sic*] (Cragin). Bergquist, p. 30.
1981. *Metengonoceras acutum* (Cragin). Kennedy and others, p. 36, text-fig. 5A.
1983. *Metengonoceras dumbli* (Cragin). Cobban, p. 11, pl. 6; pl. 7, fig. 8; pl. 8, figs. 6, 7.

Types.—Hypotypes USNM 401501–401503, from Itasca County, Minnesota and Ellis and Tarrant Counties, Texas; YPM 593, from Woodbury County, Iowa.

Description.—This species seems to have been based on two specimens, one of which (the holotype), was illustrated by side and end views and the external suture (Hyatt, 1903, pl. 26, fig. 8; pl. 27, figs. 1, 2). The holotype is an internal mold of most of an outer septate whorl that has a diameter of about 100 mm and an umbilicus of 5 mm (0.05). Hyatt (1903, p. 184) briefly described the species as "The form is much compressed and involute, with more acute venter than in *M. inscriptum*. The umbilical shoulders also in this species are more prominent and entire, and short but distinct, broad, fold-like costae are present near the umbilical shoulders, but do not cross them. There are no tubercles on the fragments observed." The external suture, which closely resembles that of *M. dumbli*, has a small off-centered, bow-tie-like external lobe and 10 narrow-necked lobes separated by broad, mostly undivided saddles. The lateral lobe and the first two adventitious lobes have two or three simple branches on each side. Other lobes are smaller, narrower, and bifid or trifid. One of the lobes midway between the lateral one and the umbilicus is peculiar in that it is deeply bifid.

Remarks.—Hyatt (1903, p. 185) noted that his specimens were preserved as red calcareous claystone, which T. W. Stanton (personal commun.) informed him was typical of "brownish-red concretions * * * in weathered portions of the Eagle Ford shales." A few fragments of internal molds of *Metengonoceras* are preserved in this manner in the USGS Mesozoic collections from northeastern Texas (pl. 2, figs. 4–8). These fragments are from rocks now assigned to the Britton Formation. Fragments of body chambers are narrower than those of *M. dumbli* and have sharp venters. Fragments of internal molds of body chambers from the Coleraine Formation of northeastern Minnesota also have sharp venters and seem referable to *M. acutum* (pl. 1, figs. 1, 2, 7). An internal mold of most of a very large body chamber from the lower part of the Mancos Shale in south-central New Mexico (USGS Mesozoic loc. D5777) has a sharp venter and seems assignable to *M. acutum*.

Types.—The holotype was at the Harvard Museum of Comparative Zoology at the time of Hyatt's study. Kennedy, Juignet, and Hancock (1981, p. 36) were unable to locate it. The specimen apparently came from the Britton Formation on Elm Fork of the Trinity River in Dallas County, Tex.

GEOGRAPHIC DISTRIBUTION

Metengonoceras dumbli has been recorded from the United States, France, and West Africa. A discoidal ammonite from Colombia that was identified as "*Spengonoceras* ef *dumblei* Gracin" (Ujueta, 1962, pl. 1, fig. 3) appears to be too poorly preserved for even generic determination.

American records are from northeastern Texas (Cragin, 1893, p. 244; Hyatt, 1903, p. 187; Moreman, 1942, p. 217; Stephenson, 1952, p. 207; Kennedy and others, 1981, p. 36), southeastern Colorado (Cobban and Scott, 1972, p. 59), Iowa (Cobban, 1983, p. 11), and Minnesota (Bergquist, 1944, p. 30; Cobban, 1983, p. 11). The specimens from Iowa and Minnesota are herein reassigned to *M. acutum*.

Metengonoceras dumbli has been well documented from western France (Kennedy and others, 1981, p. 32, pl. 3, figs. 1–5; pl. 7, figs. 4–6; text fig. 4A, B, D–G). Specimens from this area were described by de Grossouvre (1912) as *M. douvillei, M. arnaudi*, and *M. tolveiense*. All can be interpreted as synonyms of *M. dumbli*.

African records of *M. dumbli* are from Niger (Furon, 1935, p. 55) and northeastern Nigeria (Barber, 1957, p. 9). The form from Niger that was described as *M. nigeriensis*

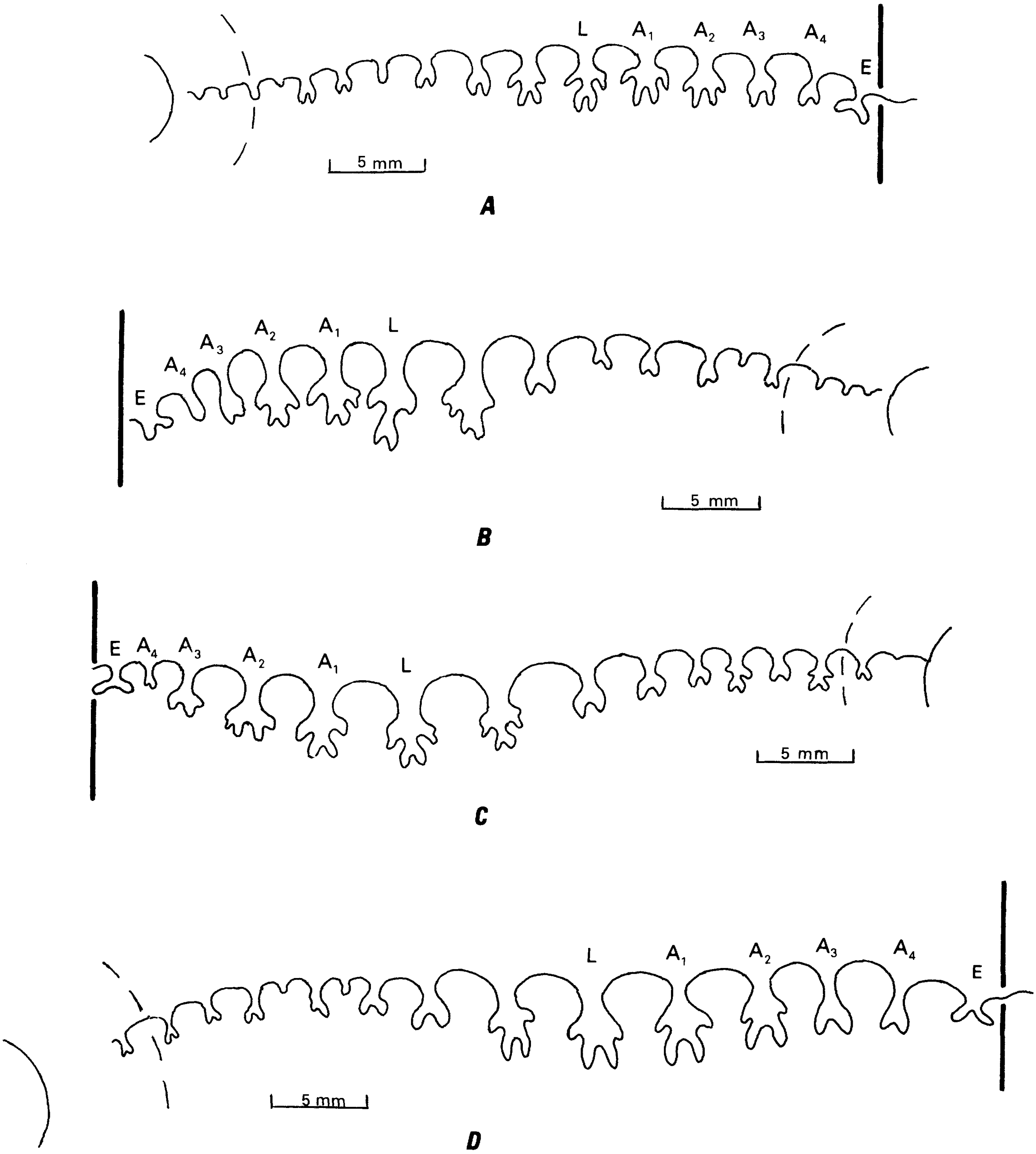

Figure 1. External sutures of *Metengonoceras dumbli* (Cragin) from USGS Mesozoic locality D9481. *A*, Hypotype USNM 401497 at a diameter of 57.5 mm. *B*, Hypotype USNM 401498 at a diameter of 63 mm. *C*, Hypotype USNM 401499 at a whorl height of 39.5 mm. *D*, Hypotype USNM 401500 at a diameter of 87 mm. E is the external lobe, L is the lateral lobe, and A_1–A_4 are adventitious lobes. Heavy straight line marks the middle of the venter; curved solid line marks the umbilical seam; curved dashed line marks the umbilical shoulder.

by Furon (1935, p. 55, pl. 3, fig. 1a, b; text-fig. 16) and later assigned to *M. dumbli* by Schneegans (1943, p. 136) is herein interpreted as a probable *M. acutum* Hyatt. Furon's type has a more sharpened venter than that of typical *M. dumbli*.

Metengonoceras acutum is not as abundant as *M. dumbli* and does not have as wide a geographic range. The questionable occurrence in Niger may be the only record outside the United States. Hyatt's type specimen of *M. acutum* and a few fragments in the U.S. Geological Survey's collections are from northeastern Texas. Other specimens are from northwestern Iowa and northeastern Minnesota. Part of a very large body chamber from the lower part of the Mancos Shale in south-central New Mexico may also represent this species.

STRATIGRAPHIC DISTRIBUTION

Metengonoceras dumbli seems to be confined to rocks of middle Cenomanian age in the United States (fig. 2) and to rocks of middle to late Cenomanian age in France (Juignet and others, 1978, fig. 11).

The oldest specimens are from the Lewisville Member of the Woodbine Formation at USGS Mesozoic locality D98 in Tarrant County, Tex. (same as loc. 55 of Stephenson, 1952, p. 37). Here several complete adults were found along with many specimens of *Conlinoceras tarrantense* (Adkins). This is the type locality of *Turrilites dearingi* Stephenson and *Forbesiceras conlini* Stephenson. Kennedy (1971, p. 31) regarded *T. dearingi* as a probable synonym of *T. acutus* Passy. In England, *T. acutus* and species of *Forbesiceras* are conspicuous members of the *Turrilites acutus* assemblage of the *Acanthoceras rhotomagense* Zone (Kennedy, 1971, p. 102). The *T. acutus* assemblage is the middle of three middle Cenomanian assemblages that make up the *A. rhotomagense* Zone. The oldest is the *Turrilites costatus* assemblage, and the youngest is the *Acanthoceras jukes-brownei* assemblage.

STAGE		ZONE	LOCALITY
CENOMANIAN (PART)	UPPER (PART)	*Sciponoceras gracile*	○ USGS 22604
		Metoicoceras mosbyense	○ USGS D12634
		Dunveganoceras pondi	○ YPM 2264
	MIDDLE	*Plesiacanthoceras wyomingense*	● USGS D9481
		Acanthoceras amphibolum	
		Acanthoceras bellense	
		Acanthoceras muldoonense	● USGS D3963
		Conlinoceras tarrantense	● USGS D98

Figure 2. Collections of *Metengonoceras dumbli* (●) and *M. acutum* (○) and their probable age assignments to the Cenomanian ammonite zonation of the western interior of the United States.

The next oldest level of *M. dumbli* may be represented by an unusually large specimen from the Graneros Shale at USGS Mesozoic locality D3963 near Pueblo, Colo. (Cobban and Scott, 1972, p. 59, pl. 8). Associated ammonites include *Acanthoceras muldoonense* Cobban and Scott.

The holotype and other specimens from the Templeton Member of the Woodbine Formation in northeastern Texas may be the youngest forms of *M. dumbli* in the United States. USGS Mesozoic locality 20314 (Stephenson, 1952, p. 41, loc. 164) near Bells, Grayson County, Tex., is important in dating the Templeton Member. Here *M. dumbli* was associated with the holotype of *Mammites*? *bellsanus* Stephenson (1952, p. 204, pl. 49, fig. 3; pl. 51, figs. 8–11) and *Metoicoceras crassicostae* Stephenson (1952, p. 210, pl. 58, figs. 6–8). *Mammites*? *bellsanus* is better assigned to *Plesiacanthoceras* Haas (1964) and is closely related to, but distinct from *P. wyomingense* (Reagan), an index fossil to the latest middle Cenomanian ammonite zone in the western interior of the United States. *Metoicoceras* is scarce in the zone of *P. wyomingense* in the western interior region, but some juveniles and bits of larger specimens associated with *P. wyomingense* suggest some species much like *M. crassicostae*. The Templeton Member is probably about the age of the zone of *P. wyomingense*.

French specimens of *Metengonoceras* assigned to *M. dumbli* by Kennedy, Juignet, and Hancock (1981) may be all from a late Cenomanian zone equivalent to the zone of *Sciponoceras gracile* in the western interior of the United States. Ammonites from the Sables à *Catopygus obtusus* include *S. gracile*, *Metengonoceras* cf. *M. dumbli*, *Metengonoceras* sp., *Euomphaloceras septemseriatum* (Cragin), *Calycoceras naviculare* (Mantell), and *Metoicoceras geslinianum* (d'Orbigny) (Kennedy and others, 1981, p. 30). The species of *Euomphaloceras*, *Calycoceras*, and *Metoicoceras* also occur in the western interior zone of *S. gracile*. Amédro, Badillet, and Devalque (1982, p. 172) list the additional species *Allocrioceras* sp. and *Vascoceras diartianum* (d'Orbigny), both of which also occur in the American zone of *S. gracile*. Juignet, Kennedy, and Lebert (1978, p. 92) have also listed *M. dumbli* from the older Sables et Grès du Mans, which contains an *Acanthoceras rhotomagense* (Brongniart) fauna of middle Cenomanian age.

The oldest specimens of *Metengonoceras acutum* (pl. 3) are from ferruginous, siltstone concretions in the basal part of the Graneros Shale at Riverside in northwestern Iowa. Flattened adult specimens were considered as *M. dumbli* (Cobban, 1983, p. 11), but an assignment to *M. acutum* seems more likely because of their acute venters on body chambers. *Dunveganoceras pondi* Haas is found with them.

Fragments of sharp-ventered internal molds in ferruginous concretions in the Coleraine Formation of the Mesabi Range in northeastern Minnesota seem assignable to *M. acutum*. The are associated with *Dunveganoceras hagei* Warren and Stelck and *Metoicoceras bergquisti* Cobban. According to Warren and Stelck (1955, p. 63), *D. hagei* is the youngest of five zones of *Dunveganoceras*. Of the species in the western interior of the United States, *D. hagei* is most closely related to *D. conditum* Haas from the upper part of the late Cenomanian zone of *Metoicoceras mosbyense* Cobban.

Hyatt's specimens of *Metengonoceras acutum* came from a locality on the Elm Fork of Trinity River in Dallas County, Tex. This is locality 16 of Moreman (1942, p. 197). Here the Britton Formation crops out, and all fossils from it indicate the late Cenomanian zone of *Sciponoceras gracile* (Shumard). A graphic section at this locality with some of the megafossils is shown by Norton (1965, pl. 2), who found a questionable *M. acutum* in the middle of the Britton. Other ammonites from the middle of the Britton include *Euomphaloceras* (*Kanabiceras*) *septemseriatum* (Cragin), *Metoicoceras geslinianum* (d'Orbigny), and *Allocrioceras annulatum* (Shumard) (names updated from those listed by Norton). A collection from the Britton Formation near Britton Tex. (USGS 22604) contains half a whorl of a body chamber of *M. acutum* (pl. 2, figs. 4, 8) along with specimens of *E. septemseriatum*, *M. geslinianum*, *A. annulatum*, *Sciponoceras gracile* (Shumard), and *Scaphites brittonensis* Moreman.

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PLATES 1–3

Contact photographs of the plates in this report are available at cost from U.S. Geological Survey Library, Federal Center, Denver, CO 80225

PLATE 1

[All figures natural size]

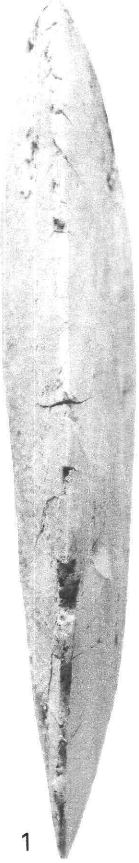
Figures 1, 2, 7. *Metengonoceras acutum* Hyatt (p. C3).

Rear, bottom, and side views of hypotype USNM 401501, from USGS Mesozoic locality D12634 in the Mesabi Range, Itasca County, Minn.

3–6, 8. *Metengonoceras dumbli* (Cragin) (p. C2).

From USGS Mesozoic locality D9481 north of Bells, Grayson County, Tex.

- 3, 4. Hypotype USNM 401493.
- 5, 6, 8. Hypotype USNM 401494.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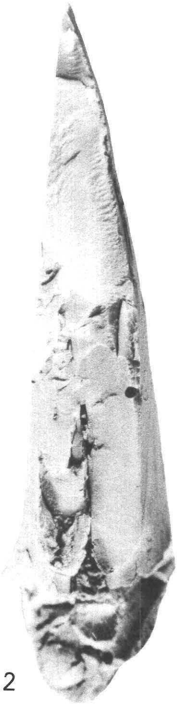
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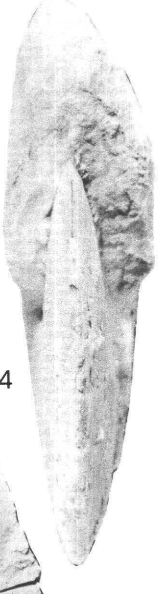
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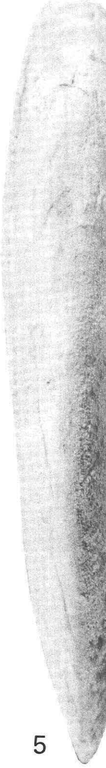
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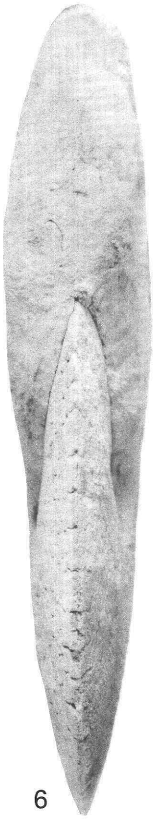
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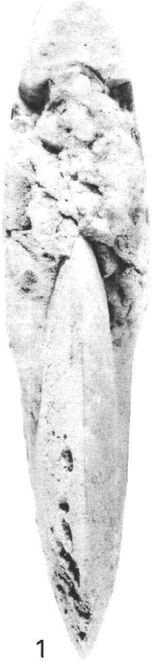
METENGONOCERAS

PLATE 2

[All figures natural size]

Figures 1–3, 9, 10. *Metengonoceras dumbli* (Cragin) (p. C2).
From USGS Mesozoic locality D98 on Big Bear Creek near Euless, Tarrant County, Tex.
1–3. Hypotype USNM 401495.
9, 10. Hypotype USNM 401496.
4–8. *Metengonoceras acutum* Hyatt (p. C3).
5–7. Hypotype USNM 401502, from USGS Mesozoic locality 22606 near Midlothian, Ellis County, Tex.
4, 8. Hypotype USNM 401503, from USGS Mesozoic locality 22604 near Britton, Tarrant County, Tex.



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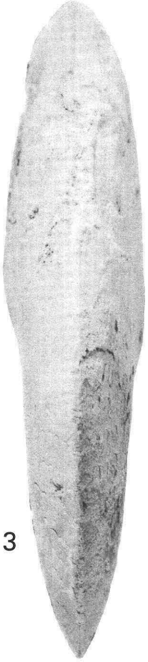

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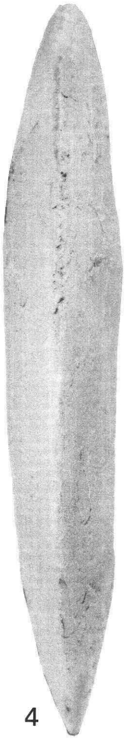

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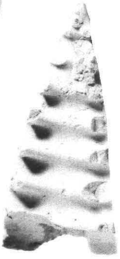

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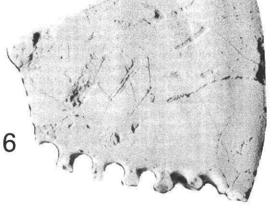

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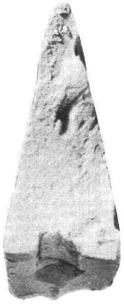

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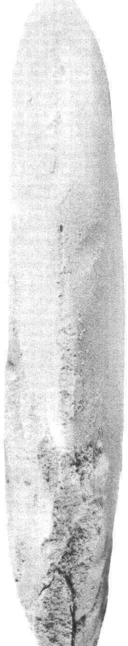

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METENGONOCERAS

PLATE 3

[Figure is natural size]

Metengonoceras acutum Hyatt (p. C3).

Hypotype Yale Peabody Museum 593, from the basal part of the Graneros Shale at the Sioux City Brick and Tile Company's clay pit in North Riverside, Iowa.

METENGONOCERAS

CHAPTER D

Middle Devonian Coral Faunules from Illinois and Their Bearing on Biogeography

By William A. Oliver, Jr.

U.S. GEOLOGICAL SURVEY BULLETIN 1690

Shorter Contributions to Paleontology and Stratigraphy

CONTENTS

PLATES

[Plates follow References Cited]

FIGURE

TABLES

Middle Devonian Coral Faunules from Illinois and Their Bearing on Biogeography

By William A. Oliver, Jr.

Abstract

Two rugose coral faunules from a single well in Coles County, Ill., are of contrasting origins. A Lingle Limestone faunule is of Centerfield age (Givetian). It is dominated by characteristic Eastern Americas Realm corals, but includes three specimens of Old World Realm ptenophyllids. An upper Grand Tower Limestone faunule is derived from the Michigan Basin Anderdon Limestone of late Onondaga age (Eifelian). This contains only two species of rugose corals, both having Old World Realm affinities. The Old World corals of both faunules are thought to have entered the Michigan Basin from the west and to have migrated from there into the Illinois Basin. An analogous superposition of Old World and Eastern Americas corals is known in the Logansport, Ind., area on the Kankakee Arch that separates the Michigan and Illinois basins.

INTRODUCTION

Two coral faunules from the subsurface Devonian strata of Coles County, Ill., are important because of their biogeographic affinities. An assemblage from the upper part of the Lingle Limestone is of Centerfield (Givetian) age and dominated by genera and species characterisitic of the Eastern Americas Realm, Appohimchi Province, although it includes two ptenophyllids that have Old World relationships.

An older assemblage, from the top of the Grand Tower Limestone (Eifelian) in the same well, includes two coral species, both of which indicate an Old World source. These are part of a fauna previously related to the Michigan Basin Anderdon Limestone by Linsley and Kesling (1982).

The Old World elements in both faunules probably entered the Illinois Basin from the Michigan Basin where Old World faunas are intermixed or interbedded with more common Eastern Americas species. Old World access to the Michigan Basin was apparently from the Williston Basin which was part of the Old World Realm.

Both faunules were recovered from the Herkimer No. 5 well in Coles County, Ill. (fig. 1, loc. 1). Pertinent parts of the stratigraphic sequence in the well are shown in table 1, extracted from drilling records in the files of the Illinois Geological Survey. The Lingle corals were taken from a core 3 1/2 inches in diameter, from the interval 3,121–3,125 feet; this is 4–9 feet below the top of the formation and some 42 feet above its base. The "Anderdon" corals were bailed by the driller from a cave ("crevasse") at 3,167–3,172 feet. The drilling record describes "gallons of corals every run" but only some 20 specimens are in the preserved collections.

Acknowledgments

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LINGLE CORALS

Stratigraphy

The regional stratigraphy of the Middle Devonian in central and southern Illinois was discussed by North (1969). In Coles County, the Lingle (15 m; 50 feet thick) is overlain by the New Albany Shale Group and overlies the Grand Tower Limestone (North, 1969, fig. 13). The corals came from the upper 2 m (8 feet) of the Lingle (table 1).

Cooper and others (1942) correlated the Lingle Limestone with the Beechwood Limestone Member of the Sellersburg Limestone of Kentucky and the Centerfield Limestone Member of the Ludlowville Formation of New York. Cooper's "Lingle" is only the upper part of the Lingle Limestone as defined by North (1969), but it is the part represented by the Lingle corals described here which are clearly of Centerfield affinities. North identified the subsurface Lingle in Coles County as the Tripp Limestone Member overlying a thin Howardton Limestone Member (North, 1969, p. 20, fig. 13). However, in the southwest Illinois outcrop area, these units constitute the lower, pre-Centerfield, part of the Lingle, and North's interpretation of the subsurface Devonian (1969, p. 12, fig. 6) must be questioned. The Lingle Limestone as a whole is of Hamilton age, probably ranging from Mottville (basal Skaneateles Shale) to Centerfield (basal Ludlowville Formation) or slightly higher, in New York terms (Cooper and others, 1942,

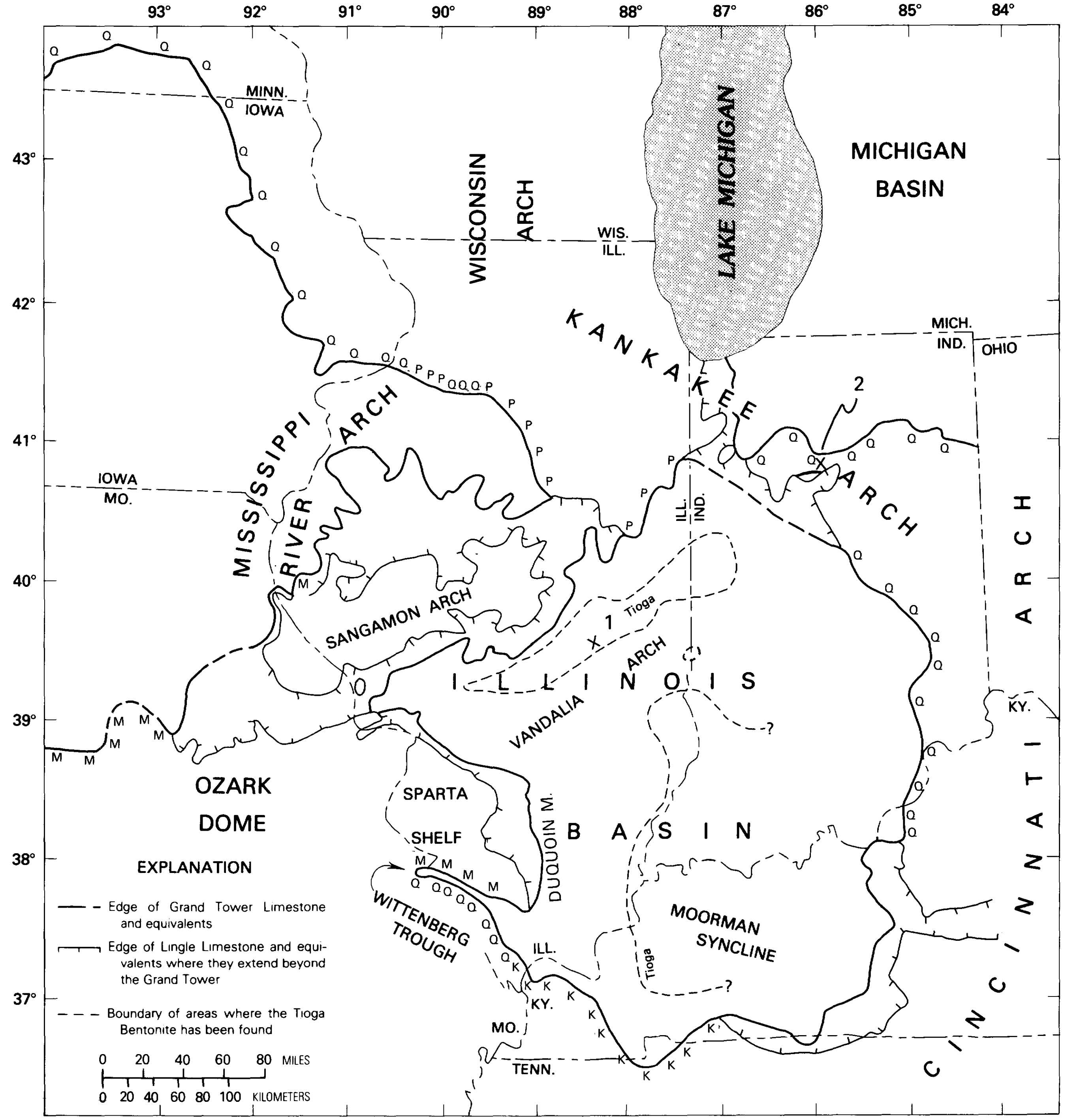

Figure 1. Distribution of Grand Tower and Lingle Limestones and correlative units and their relation to major structures (from North, 1969). Principal localities are marked: 1, Herkimer No. 5 well, Coles County, Illinois; 2, Logansport, Indiana area. The age of the formations truncating the Grand Tower are indicated by a letter: Q, Quaternary; K, Cretaceous; P, Pennsylvanian; M, Mississippian and Upper Devonian.

Table 1. Subsurface Devonian stratigraphy in Herkimer No. 5 well, Coles County, Illinois

[Sec. 11, T. 12 N., R. 7 E.; Illinois Geological Survey, core #2687. Coral faunules are from 3,121 to 3,125 feet and from the "crevasse" at 3,167 to 3,172 feet. Data from driller's logs in files of the Illinois State Geological Survey. Surface elevation, 696 feet]

	Depth below surface, in feet
Surface	0
Carboniferous	108–3,009
New Albany Shale Group	3,009–3,117
Lingle Limestone	3,117–3,167
Limestone	3,117–3,120
Diamond Core #1	3,120–3,134
Limestone, coralliferous	3,120–3,121
Limestone, fossiliferous	3,121–3,123
Favosite coral bioherm	3,123–3,125
Limestone, fossiliferous	3,125–3,133
Limestone, shaly	3,133–3,134
Limestone, varied descriptions and cored in part	3,134–3,167
Grand Tower Limestone	3,167–3,172
"Crevasse" or cave	3,167–3,172
Bottom of hole	3,172

p. 1770; Collinson and others, 1968, p. 956; North, 1969; Willman and others, 1975, p. 118). Within the Hamilton of eastern North America, the Centerfield fauna is the most widespread, having been recognized from New York and Pennsylvania to Tennessee, Kentucky, Illinois, Michigan, and southwestern Ontario (Cooper and others, 1942, chart; Cooper and Warthin, 1942).

Previous Work on Rugose Corals

Fraunfelter (1970) described numerous silicified corals from the outcropping Lingle Limestone in southwestern Illinois and reviewed previous work on the corals (1970, p. 7–10). Fraunfelter noted that only one coral species had previously been described from the Lingle (*Microcyclus discus* Meek and Warthin, a pre-Centerfield species from the lower Lingle or St. Laurent Limestone) although numerous faunal lists had included corals. Fraunfelter seems to have used "Lingle" in the same restricted sense as Cooper; he assigned the lower, Skaneateles-age beds to the St. Laurent Limestone. In his columnar section (Fraunfelter, 1970, fig. 2), collections a–f seem to be St. Laurent and g–n, Lingle. On this basis, the rugose corals that Fraunfelter described from the Centerfield-age "Lingle" are listed in table 2, for comparison with the corals in the Coles County core. Comparison of Fraunfelter's corals with those from Coles County is difficult because Fraunfelter's specimens were silicified and separated from the limestone matrix, whereas the new faunule is calcitic and known from thin sections only.

Table 2. Rugose corals identified and described from the outcropping "Lingle" Limestone by Fraunfelter, 1970

[Collections are from southwestern Illinois and adjacent Missouri]

Amplexiphyllum pauciseptum Fraunfelter
Bethanyphyllum robustum (Hall)
Billingsastraea ingens (Davis)
Craterophyllum brevicyathum Fraunfelter
Cystiphylloides americanum (E. and H.)
Eridophyllum archiaci (Billings)
Heliophyllum confluens Hall
H. gurleyi Greene
H. halli E. and H.
Heterophrentis simplex (Hall)
Hexagonaria percarinata (Sloss)
Iowaphyllum alpenense (Rominger)
I. ? sp.
Odontophyllum cornutiformis Fraunfelter
Tabulophyllum variformis Fraunfelter

New Faunule

Rugose corals from the 3,121–3,125-foot interval in the Coles County core are listed in table 3 and briefly annotated in the following paragraphs. All specimens are from the collections of the Illinois State Geological Survey (ISGS), Champaign, and are numbered in their collections, as indicated.

***Siphonophrentis* sp. aff. *S. halli* (E. and H.)** (pl. 1, figs. 5–7)

The Coles County specimen has relatively short, amplexoid septa that suggest *Siphonophrentis* (or *Breviphrentis*) rather than the closely related *Heterophrentis*. The tabulae are more widely spaced than in New York specimens of *S. halli* (see Hall, 1877, pl. 20, fig. 8), but in this and other characters the specimen falls well within the range of variation in this species accepted by Stumm, 1965 (pl. 14) for Beechwood specimens. This may be *Heterophrentis simplex* of Fraunfelter (1970, p. 13, pl. 1, fig. 4). The Coles County specimen is ISGS 72P–13A, from 3,123 feet.

***Tabulophyllum* sp. cf. *T. conatum* (Hall)** (pl. 1, figs. 13–15)

Four specimens, none complete, are assigned to *Tabulophyllum*. Two of these are closest to *T. conatum* (Hall, 1877, pl. 31, fig. 2, 5, 6, 11–13, other figs. uncertain) from the New York Centerfield in having abbreviated minor septa and more-or-less uniform majors. Most characteristic is ISGS 72P–17 (3,123 feet) with moderately attenuate septa but ISGS 72P–1 (3,121 feet) is probably the same species. *T. variformis* Fraunfelter from the outcropping "Lingle," is similar to *T. conatum*, differing mainly in its larger size.

***T.* sp. cf. *T. zaphrentiforme* (Davis)** (pl. 1, figs. 8–12)

Stumm (1965, p. 50, pl. 45, figs. 10–13) redescribed

Table 3. Corals (and one stromatoporoid) identified from Herkimer No. 5 well, Coles County, Illinois

[Realm affinities indicated to right: EAR, Eastern Americas Realm; OWR, Old World Realm; MB, Michigan Basin]

Lingle Limestone, upper part	
Siphonophrentis sp. aff. *S. halli* (E. and H.)	EAR
Tabulophyllum sp. cf. *T. conatum* (Hall)	EAR
T. sp. cf. *T. zaphrentiforme* (Davis)	EAR
Heliophyllum sp. cf. *H. halli* E. and H.	EAR
Bethanyphyllum sp. aff. *B. robustum* (Hall)	EAR
Prismatophyllum arachnoideum (Stumm)	EAR
Eridophyllum sp. cf. *E. archiaci* (Billings)	EAR
E. n. sp. A	EAR
Acanthophyllum sp.	OWR
Ptenophyllid coral, genus and species undetermined	OWR
Grand Tower Limestone, "Anderdon" beds	
Amphipora nattressi (Grabau)	MB
Grypophyllum n. sp. A	OWR
Holmophyllia n. sp. A	OWR

this species as having an enlarged and long counter septum, but illustrated it only with exterior views of silicified specimens. New York Centerfield *Tabulophyllum* specimens are divisible into two species. Typical *T. conatum* Hall (see above) have more-or-less uniform septa although a cardinal fossula is commonly developed. A second species has a more prominent fossula and a long and enlarged counter septum and is tentatively referred to *T. zaphrentiforme* Davis (although *T.*? *gradatum* Hall, 1877, pl. 31, figs. 15–16, may be conspecific and, if so, has priority). The two New York species are distinct in other characters also. Davis' and Stumm's specimens are from the Beechwood and equivalent units in Kentucky and southern Indiana. The most characteristic Coles County specimen is ISGS 72P–3 (3,121 feet); ISGS 72P–21 (3,125 feet) is tentatively referred to this species also.

Heliophyllum sp. cf. *H. halli* E. and H.

One fragment of a calice rim shows the characteristic long, cross-bar carinae of *Heliophyllum* and is probably this species. Fraunfelter listed *H. halli* from the "Lingle," but it is not clear whether his illustrated specimens are from the "Lingle" or St. Laurent. ISGS 72P–15; 3,123 feet.

Bethanyphyllum sp. aff. *B. robustum* (Hall) (pl. 2, figs. 1–6)

New York Centerfield specimens have abundant vepreculae on the sides of septa at all stages of growth (Hill, 1981, p. F305–306, figs. 199–1a–d). Specimen ISGS 72P–10 is very like Centerfield specimens in other respects but vepreculae are common only in early stages where septa are dilated; mature septa have fewer vepreculae. Fraunfelter cited *B. robustum* from the "Lingle" (1970, p. 20, pl. 2, fig. 14) but his identification is uncertain because the significance of the vepreculae had not been noted when he did his work. Identification of this form is based on ISGS 72P–10 (from 3,122 feet) but a second, less complete, specimen (ISGS 72P–19; 3,124 feet) is probably the same species.

Prismatophyllum arachnoideum (Stumm) (pl. 3)

Cerioid craspedophyllids with an aulos are uncommon (Oliver, 1981), only two species having been described (Stumm, 1954; Oliver, 1976, p. 108, 1981). Coles County specimens are referable to *P. arachnoideum* (Stumm, 1954, p. 6, pl. 2, figs. 1–2), from the Stone Mill Limestone (=Centerfield) in New York. The only other known occurrence of the species is in the Joshua Submember of the Otisco Shale Member of the Ludlowville Formation (which overlies the Centerfield in central New York). Coles County specimens have the small aulos (missing in some corallites) and other characters of the species. Two specimens, ISGS 72P–18 and 72P–20, are both from 3,124 feet; a third specimen (ISGS 72P–22B) is "probably from this core" (ISGS label).

Eridophyllum sp. cf. *E. archiaci* (Billings) (pl. 1, fig. 1–4)

Two cylindrical fragments are similar to forms illustrated by Ehlers and Stumm (1949, p. 29, pl. 4, figs. 3–7; pl. 8, figs. 1–6) from the Hungry Hollow Formation, Ontario, and the Four Mile Dam Formation, Michigan. The species has also been described from the "Lingle" Limestone in southwestern Illinois (Fraunfelter, 1970, p. 22), the Beechwood Limestone Member in Kentucky–Indiana (Stumm, 1965, p. 45), the Tenmile Creek Dolomite in northwestern Ohio (Stumm, 1968, p. 41), and is known from the Centerfield Limestone Member of New York. All these units are Centerfield in age. Coles County specimens are ISGS 72P–8A and 72P–12 (both 3,122 feet); 2 or 3 crushed corallites at 3,121 feet (ISGS 72P–5) may be the same species.

Eridophyllum new species A (pl. 4)

Numerous cylindrical corallites of a typical *Eridophyllum* are in the Coles County core at 3,122 and 3,123 feet. Corallites range from 2.3 to 5.4 mm in diameter (commonly 2.5–4.0 mm) with 12–21 major septa (commonly 14–17). The aulos occupies approximately a quarter the diameter and is open in the direction (assumed) of the cardinal septum. All specimens are discrete and no connections between individuals have been noted, but the species is most likely phaceloid. Except for its small size,this is a fairly typical Eastern Americas Realm *Eridophyllum*. Other known *Eridophyllum* species have significantly larger diameters (1–2 cm) and it seems likely that the Coles County specimens represent an undescribed species.

Two clusters are known (ISGS 72P–14, 12 or more corallites, and 72P–13B, 15 or more corallites) both from 3123 feet. Additional single corallites are: from 3122 feet, ISGS

72P–7B, 72P–9, 72P–11; from 3,123 feet, ISGS 72P–15, 72P–16. In addition, a single corallite was found in the Duncan No. 7 Taylor well (Coles County, sec. 11, T. 12 N. R. 7 E.) at 3,150 feet.

***Acanthophyllum* sp.** (pl. 2, figs. 11–12)

Specimen ISGS 72P–4 (3,121 feet) is incomplete but has the characteristic tabularium, thin wall, and microstructure of *Acanthophyllum*, a common Old World genus not otherwise reported from the Devonian of the Eastern Americas Realm. A second specimen (ISGS 72P–8B, 3,122 feet) has a somewhat wider tabularium but is probably conspecific.

Ptenophyllid coral, genus and species not determined (pl. 2, figs. 7–10)

A single specimen (ISGS 72P–7A, 3,122 feet) has the characteristic tabularium of *Acanthophyllum* and other ptenophyllids. The specimen is unusual in having prominent spines on the sides of the septa in both the dissepimentarium and tabularium. In other respects, the specimen is similar to *Acanthophyllum* and it may be conspecific with ISGS 72P–4, and 72P–8B.

"ANDERDON" CORALS

Stratigraphy

During drilling of the Herkimer No. 5 well, a cavity was struck at 3,167 feet. At this point, the drill stem and bit dropped 5 feet and drilling was stopped so that the rocks beneath the cavity were not sampled. At 3,167 feet, the drill had penetrated 50 feet of limestone below the New Albany Shale Group (Cluff, Reinbold, and Lineback, 1981) (table 1). This is the approximate thickness of the Lingle Limestone in the area (North, 1969, figs. 13, 16). Given this, the 5-foot cavity was close to the contact between the Lingle Limestone and the underlying Grand Tower Limestone and could be in the basal Lingle, uppermost Grand Tower or both. However, fossils bailed from the cavity are of Grand Tower age (Linsley and Kesling, 1982, and this paper), so the cavity interval is assumed to be in the uppermost Grand Tower (table 1). It seems logical to suggest that cave formation took place beneath an unconformity separating the Lingle and Grand Tower Limestones.

Fossils bailed from the cave were listed by Linsley and Kesling (1982, p. 1079) as "a multitude of broken fragments of twiglike stromatoporoids, hundreds of steinkerns of ostracodes. . ., numerous gastropods, several bivalves, and a few solitary corals." Brachiopods and charophytes were also mentioned. The gastropods and ostracodes were described by Linsley and Kesling (1982) and the fauna was recognized as that of the Michigan Basin Anderdon Limestone (upper Detroit River Group). The exact age of the Anderdon is in dispute but, in general terms, it would be Onondaga, rather than Hamilton. Therefore, Linsley and Kesling's suggestion that the cavity fauna is from the upper Grand Tower is very reasonable. It is here referred to as the "Anderdon" fauna because of its exotic nature and importance.

New Coral Faunule

The collections of the ISGS include some 20 rugose corals. Of these, 11 were considered suitable for thin sectioning and are identified as two species (table 2); others are incomplete or fragmental but most of these clearly belong to one of the sectioned species. The two species are annotated below.

Accompanying the rugose corals are hundreds of small fragments of "twiglike stromatoporoids." Only a few of these have been studied but all may belong to a single species of *Amphipora*, also annotated below. The driller's log refers to "gallons of corals"; very possibly the "corals" are *Amphipora* fragments rather than rugose corals as might otherwise have been expected. Correspondence in the ISGS files regarding the bailed collection indicate that there were only a few corals in the original collection when received.

***Amphipora nattressi* (Grabau)**

This stromatoporoid was redescribed and illustrated by Galloway and Ehlers (1960, p. 99–101, pl. 11), from the Anderdon Limestone of the "Anderdon Quarry," near Amherstburg, Ontario. The "multitude of broken fragments of twiglike stromatoporoids" noted by Linsley and Kesling are mostly or entirely this species. Possibly, the "gallons of corals" referred to by the driller were these fragments of ramose stromatoporoids rather than rugose corals.

***Grypophyllum* n. sp. A** (pl. 5)

This is a typical ptenophyllid, but not a typical *Grypophyllum*, although it seems to fit more comfortably in that genus here than in other described genera. The transverse section is characteristic except that spines are variably developed on the sides of the septa within the dissepimentarium, and minor septa are well developed and complete. In longitudinal section, the dissepiments are large, irregular, unequal, and steeply inclined; the tabularium is ptenophylloid. In these characters, the longitudinal section resembles the *Neomphyma* illustrated by Hill (1981, p. F239, fig. 150–1a).

Grypophyllum n. sp. A differs from described species of the genus in the characters indicated. *G. gracile* Wedekind has very large, inclined dissepiments but they are not irregular. *G.* n. sp. A differs from the ptenophyllids in the Lingle faunule in having a well-developed, thick outer wall, and in the longitudinal characters noted. The presence of spines on the sides of the septa appears to be coincidental, as they are quite different in detail.

Grypophyllym is widespread in rocks of Middle Devonian (Eifelian and Givetian) age in the Old World Realm, although, at present, it is known only from the Givetian of western North America (A.E.H. Pedder, oral communication, May 1985). It also occurs in the Early Devonian (Emsian) of the Urals (Pedder and Oliver, 1979, table 1).

In eastern North America, only one occurrence is known in addition to the one described here. *Grypophyllum* sp. cf. *G. denckmani* is known from the topmost part of the Cedar Valley Limestone at Marble Rock, Iowa (J.E. Sorauf, oral communication, May 3, 1985).

Eight specimens of *G*. n. sp. A are known; four were thin sectioned (ISGS 72P–23 to 72P–26) but four additional fragments are conspecific.

***Holmophyllia* n. sp. A** (pl. 6)

This genus is characterized by having septa composed of trabeculae that are partly discrete and partly fused to form continuous units. Hill (1981, p. F105) synomized *Holmophyllia* with *Holmophyllum*. The latter is characterized by discrete spines that pierce several layers of dissepiments or trabeculae. I agree with McLean (1975, p. 185–186) that the morphologic difference seems important enough to justify recognition of both genera. McLean noted a generic range for *Holmophyllia* of Middle? and Upper Silurian to Lower Devonian, but Hill illustrated an Eifelian species from the Urals (1981, p. F104, fig. 46–1f, g) that seems closer to *Holmophyllia* than *Holmophyllum.*

Typical *Holmophyllum* s.s. have been described from Upper Silurian rocks of Maine (Stumm, 1963), Quebec (Oliver, 1963), and western Canada (Pedder, 1978) but no *Holmophyllia*, or Devonian forms of either genus, have previously been described from North America.

Six sectioned specimens are assigned to *Holmophyllia* n. sp. A (ISGS 72P–27 to 72P–32); sectioned specimen 72P–33 and two to eight additional fragments are probably the same species.

BIOGEOGRAPHY

Introduction

The Middle Devonian world is divisible into three biogeographic realms: 1) The Eastern Americas Realm (EAR) was relatively small, consisting of northern South America and eastern North America (ENA; east of the Transcontinental Arch and south of the Canadian Shield). 2) The Old World Realm (OWR) included western and Arctic North America, Eurasia, northern Africa, and Australia. 3) The Malvinokaffric Realm included central and southern South America and Africa, and Antarctica. Both the EAR and OWR had rich and varied rugose coral faunas that were significantly different from each other on the generic level (Oliver, 1977). The Malvinokaffric was a high-latitude area containing no significant coral faunas (Oliver, 1980).

The EAR is considered to have been a single biogeographic province (Appohimchi) during the Eifelian but is divided into the Michigan Basin–Hudson Bay Lowland Province and the Appohimchi Province during the Givetian (Oliver, 1977, p. 107–114; Oliver and Pedder, 1979, p. 135–137). The southern boundary of the Michigan Basin Province is the Kankakee Arch (fig. 1) and the Illinois Basin is part of the Appohimchi Province. In contrast to these two EAR provinces, nine or more provinces can be recognized at various times in the much larger Old World Realm (Oliver and Pedder, 1984).

The basis for recognizing two separate EAR provinces in the Givetian is the presence in the Michigan Basin–Hudson Bay Lowland area of Old World genera that are not known farther east or south in the Appohimchi Province. Oliver (1977, p. 114) suggested that the Old World forms must have emigrated from the west or north and most likely from the Williston Basin. A few genera were apparently introduced earlier. Old World *Dendrostella* is locally common in Eifelian rocks (Detroit River Group) on the eastern margin of the Michigan Basin, and *Disphyllum* s.s. is known from the Dundee Limestone (upper Eifelian) within the Basin. The latter also occurs in rocks of the same age (Famine Limestone, Quebec) in the Appohimchi Province where it is the only Old World genus known to have migrated this far; it also presumably entered by way of the Michigan Basin (Oliver, 1977, p. 114).

The Coles County faunules are of interest because, in this small area, a Michigan Basin/Old World fauna was followed in later time by a dominantly EAR fauna. A similar superposition of Old World and Eastern Americas faunas is known near Logansport, Ind. The relationship of the two faunas in the Michigan Basin as a whole requires further study.

Lingle Faunule

The Lingle rugose corals from Coles County (table 3) are predominantly genera and species that are common in the Appohimchi Province in rocks of Centerfield age; several belong to EAR endemic genera. There are two exceptions; both *Acanthophyllum* sp. and the undetermined ptenophyllid are Old World corals and exotic in central Illinois.

The distribution of ptenophyllids (Family Ptenophyllidae) in eastern North America is shown in table 4. Several species in four genera are common in latest Silurian (Pridolian) rocks of the central and northern Appalachians. Two of the genera survived into the Lochkovian but then the family seems to have become extinct in the EAR, because no ptenophyllids have been recognized in the reasonably well-known coral faunas of Emsian to Eifelian age (except as noted herein). Middle Devonian ptenophyllids are rare and, except for Coles County, Ill., limited to the Michigan Basin.

Table 4. Ptenophyllids in the Eastern Americas Realm (EAR)

[Stages from left to right: Pri, Pridolian; L, Lochkovian; Pra, Pragian; Em, Emsian; Ei, Eifelian; G, Givetian. Occurrences: A, Appalachian Basin; I, Illinois Basin; M, Michigan Basin]

Genera	Stage						Middle Devonian occurrence in EAR
	Pri	L	Pra	Em	Ei	G	
Acanthophyllum	A					I	Lingle Limestone, Ill.
Entelophylloides	A						
Embolophyllum	A	A					
Spongophylloides	A	A					
Grypophyllum					I		"Anderdon" faunule, Ill.
G. cf. *denckmanni*						M	Cedar Valley Limestone, Iowa
Australophyllum						M	Miami Bend Limestone, Ind.
Ptenophyllid undet.						I	Lingle Limestone, Ill.

"Anderdon" Faunule

The two "Anderdon" corals from Coles County are not known to occur elsewhere in the Devonian EAR. *Grypophyllum* is an Old World ptenophyllid genus (table 4) that is assumed to have reached Illinois after migrating into the Michigan Basin from the west. *Holmophyllia* is not otherwise known to occur in Devonian rocks in North America, but the genus may occur in the Eifelian of the Urals and is known from the Lower Devonian of other Old World areas.

The associated gastropods are a Michigan Basin assemblage (Linsley and Kesling, 1982) and are largely endemic (Linsley, 1968). Most of the gastropods were described by Linsley (1968) from the Anderdon Limestone in southeastern Michigan (south of Detroit) and in adjacent parts of Ontario and Ohio. In this area, many of the gastropods are associated with *Amphipora nattressi* (Grabau) and other stromatoporoids in biostromes. The Illinois occurrence may have been in a similar bed.

Logansport, Indiana

The Logansport area is on the Kankakee Arch that separates the Illinois and Michigan Basins, some 225 km northeast of Coles County (fig. 1, loc. 2). In this area, the Miami Bend Limestone of Cooper and Phelan (1966) is immediately overlain by the Logansport Limestone (see Cooper and Phelan for a detailed description of the stratigraphy). The Logansport Limestone was recognized as Centerfield in age by Cooper and Warthin (1942) and contains numerous corals, most of which are EAR endemics. The coral fauna is basically that of the Centerfield (New York) and Beechwood (Kentucky) as discussed in connection with the Lingle corals.

In contrast, the Miami Bend Limestone contains an Old World fauna that is closely related to that of the Rogers City Limestone of Michigan and the Winnipegosis Formation of Manitoba (Cooper and Phelan, 1966; see Oliver, 1977, p. 112–114, for discussion of the coral fauna). The Miami Bend and Rogers City are early Givetian in age and provide the closest and most direct tie of a Michigan Basin Old World fauna to the Old World Realm Williston Basin. An updated list of Miami Bend rugose corals (table 5) includes three EAR species, six OWR species and one new form. None of the OWR forms is known from the Appohimchi Province. Winnipegosis corals have not been described or illustrated, so direct comparison is not feasible. However, the OWR Miami Bend genera are all known from western or Arctic Canada with the possible exception of cf. *Chlamydophyllum*. *Australophyllum* is a ptenophyllid and is listed on table 4 for completeness.

Table 5. Corals from the Miami Bend Limestone (of Cooper and Phalen, 1966)

[Realm affinities indicated to right: EAR, Eastern Americas Realm; OWR, Old World Realm]

Heterophrentis sp.	EAR
Heliophyllum halli E. and H.	EAR
Bethanyphyllum sp. cf. *B. robustum* (Hall)	EAR
Chostophyllum sp.	OWR
Hexagonaria borealis Stumm	OWR
cf. *Chlamydophyllum* sp.	OWR
Australophyllum sp.	OWR
Stringophyllum? sp.	OWR
Lekanophyllum sp.	OWR
New genus, new species	Endemic?

Michigan Basin

Coral faunas in the Michigan Basin Traverse Group are a mixture of EAR endemics, Old World genera, and cosmopolitan forms with the EAR forms predominating (Oliver, 1977, p. 114). Many of the Traverse rugose corals have been described, but it is not clear whether the Old World genera tend to be stratigraphically isolated, as in Coles County and the Logansport area, or whether they were living in association with EAR corals. This is a major biogeographic question that has yet to be answered.

Discussion

Oliver (1977, p. 107–114) and Oliver and Pedder (1979, p. 135–138) have detailed and discussed the movement of Old World rugose corals into the Michigan Basin during Eifelian and Givetian times. Only a few forms are known to have moved out of the Basin into other parts of the EAR. The Coles County corals discussed in this paper are the first Old World genera recorded from the Middle Devonian within the Illinois Basin.

SUMMARY AND CONCLUSIONS

Two small coral faunules from a single well in Coles County, east-central Illinois, have contrasting compositions. The lower ("Anderdon") faunule is Eifelian in age and contains Old World corals in association with Michigan Basin gastropods and other invertebrates. The upper (Lingle) faunule is of Centerfield (Givetian) age and is dominated by typical Eastern Americas Realm genera, including two Old World forms. The two faunules supplement previous knowledge of Old World coral distributions within the Eastern Americas Realm and support earlier conclusions that the dilution of EAR faunas that began in Eifelian time was through migration into the Michigan Basin–Hudson Bay Lowlands area from the west, probably from the Williston Basin. Dilution was great enough during the Givetian to enable the subdivision of the Eastern Americas Realm into the Michigan Basin–Hudson Bay Lowlands Province and the Appohimchi Province. By the end of the Middle Devonian, all EAR endemic genera were extinct and Frasnian corals in the area are part of a cosmopolitan fauna.

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PLATES 1–6

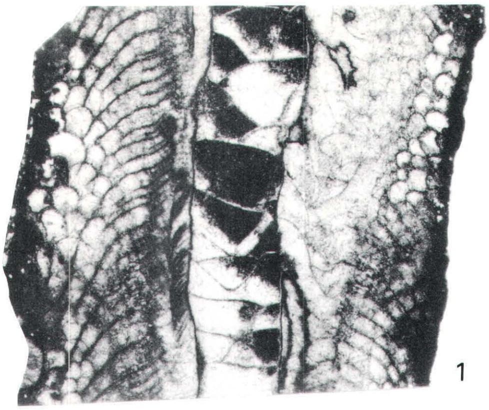
Contact photographs of the plates in this report are available at cost from U.S. Geological Survey Library, Federal Center, Denver, CO 80225

PLATE 1

Corals from the Lingle Limestone

[Transverse and longitudinal thin sections]

Figures 1–4. *Eridophyllum* sp. cf. *E. archiaci* (Billings), all ×5. 1,2, ISGS 72P–12; 3,4, ISGS 72P–8.
5–7. *Siphonophrentis* sp.aff. *S. halli* (E. and H.). ISGS 72P–13; 5,6, ×1.5; 7, ×2.5, detail of fig. 6.
8–12. *Tabulophyllum* sp. cf. *T. zaphrentiforme* (Davis). 8–10, ISGS 72P–3, ×5. 11–12, ISGS 72P–21, ×2.5.
13–15. *Tabulophyllum* sp. cf. *T. conatum* (Hall). 13, ISGS 72P–17, ×2.5; 14,15, ISGS 72P–1, ×5.



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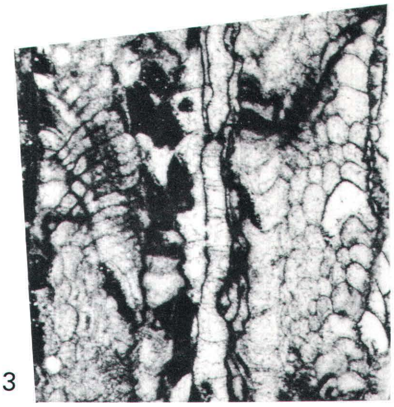

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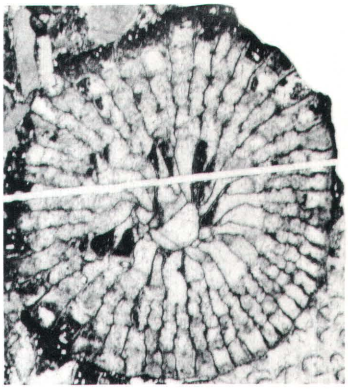

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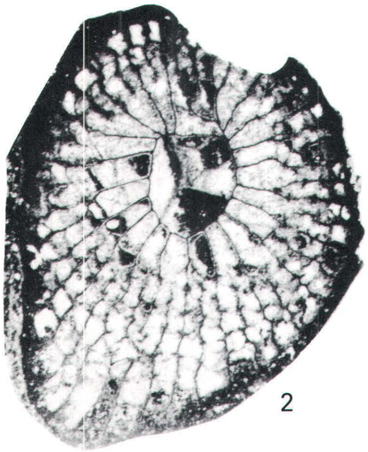

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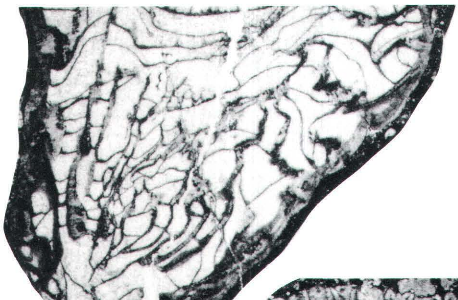

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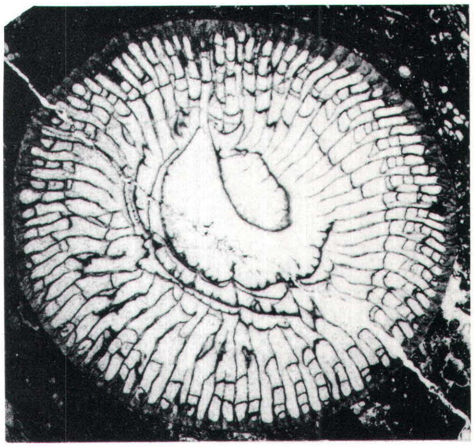

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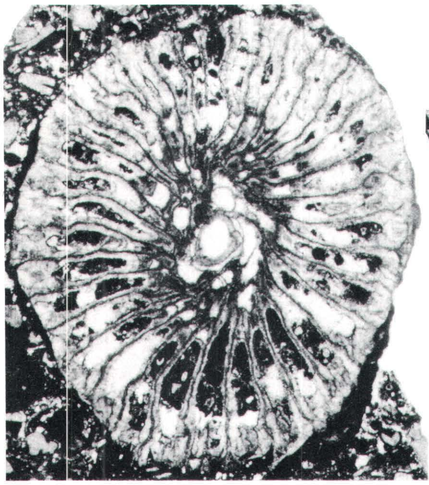

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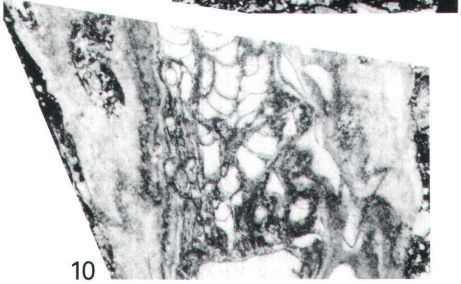

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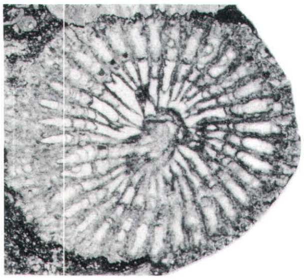

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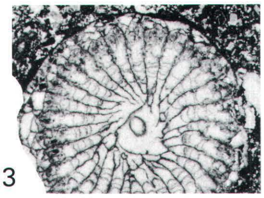

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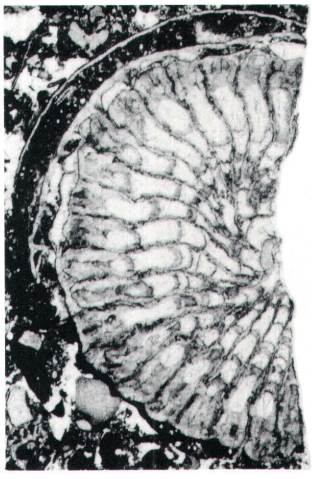

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CORALS FROM THE LINGLE LIMESTONE

PLATE 2

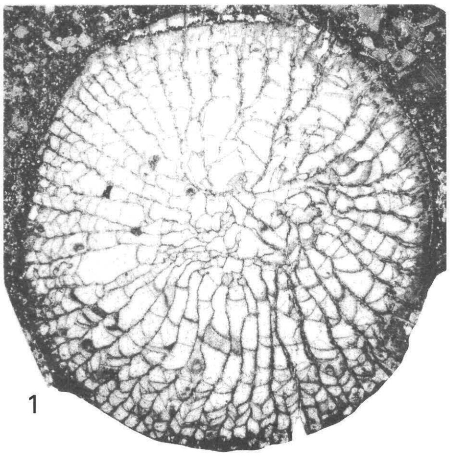
Corals from the Lingle Limestone

[Transverse and longitudinal thin sections]

Figures 1–6. *Bethanyphyllum* sp. aff. *B. robustum* (Hall). ISGS 72P–10. 1–3, ×2.5; 4–6, ×10. Figs. 4, 5, and 6 are details of sections in figs. 1, 2, and 3, respectively.

7–10. Ptenophylloid coral, genus and species not determined. ISGS 72P–7A. 7, longitudinal section, ×2.5. 8, tabularium of same, ×5. 9, transverse section, ×2.5. 10, detail of same showing septal spines, ×10.

11–12. *Acanthophyllum* sp. ISGS 72P–4; ×5 and ×2.5.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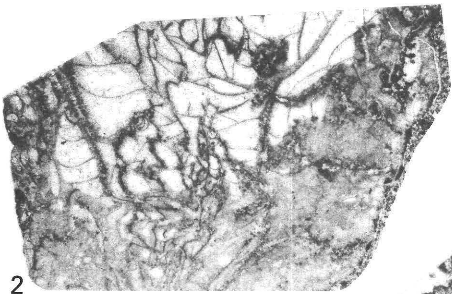
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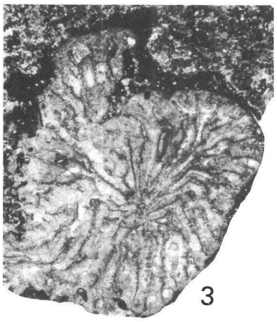
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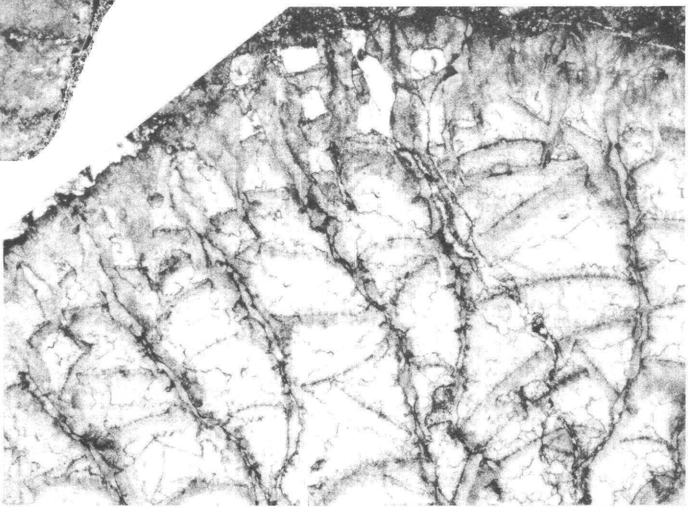
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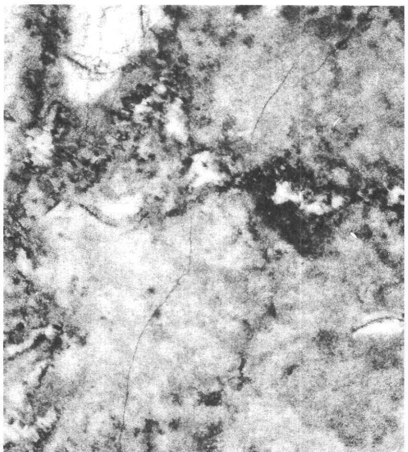
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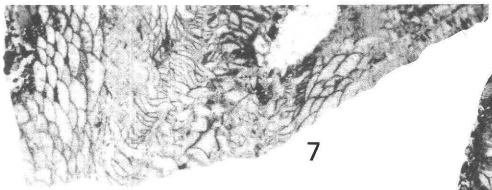
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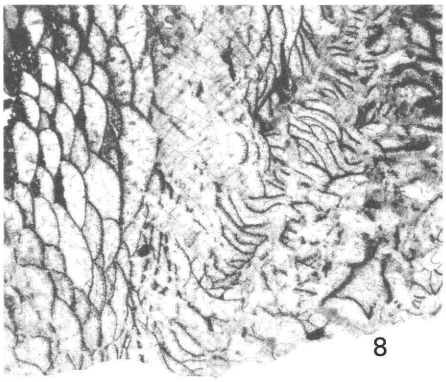
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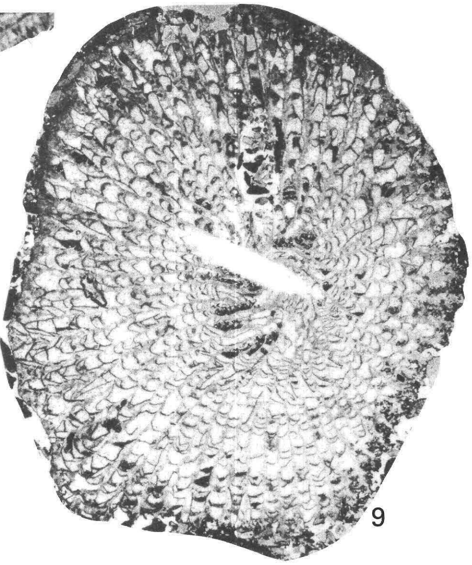
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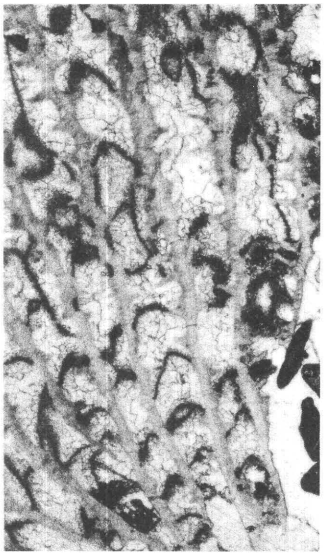
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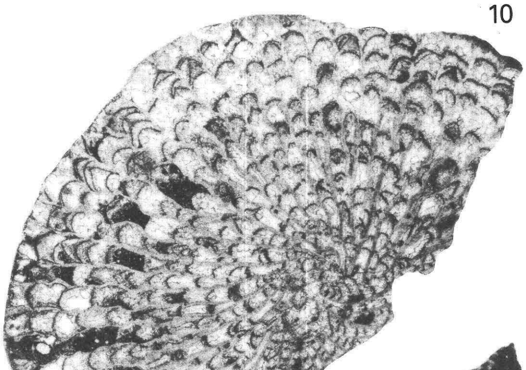
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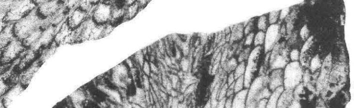
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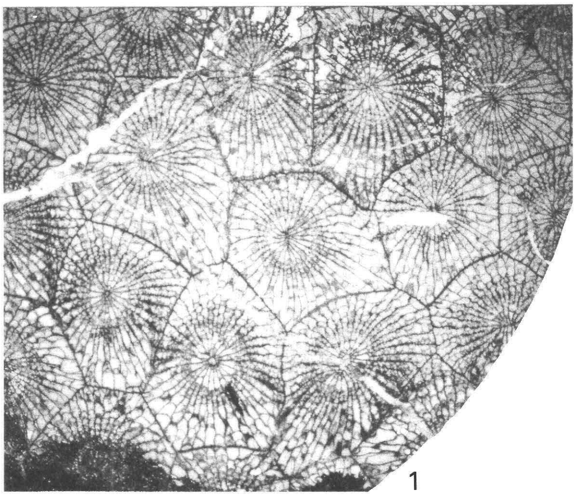
CORALS FROM THE LINGLE LIMESTONE

PLATE 3

Corals from the Lingle Limestone

[Transverse and longitudinal thin sections]

Figures 1–7. *Prismatophyllum arachnoideum* (Stumm). 1, 2, ISGS 72P–20, ×1.5, ×2.5; 3, 4, ISGS 72P–22B, ×2.5; 5–7, ISGS 72P–18, ×2.5, ×5.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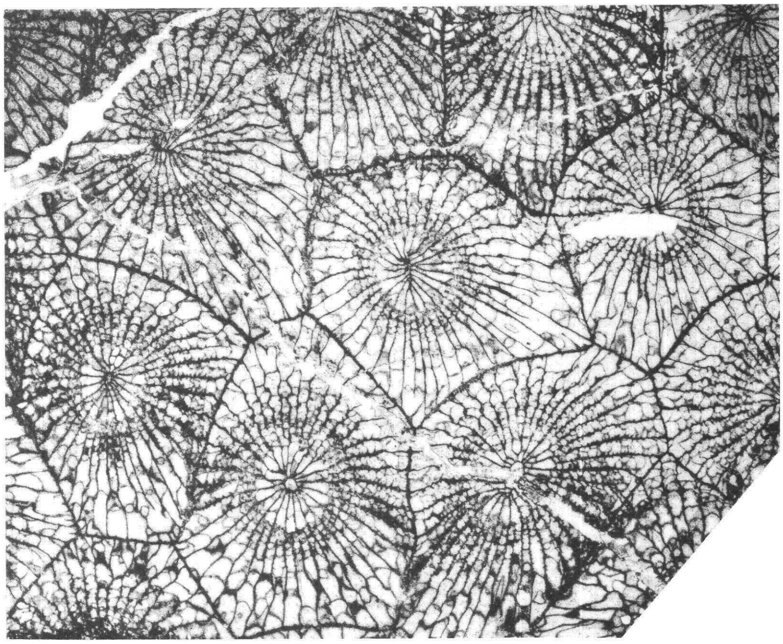
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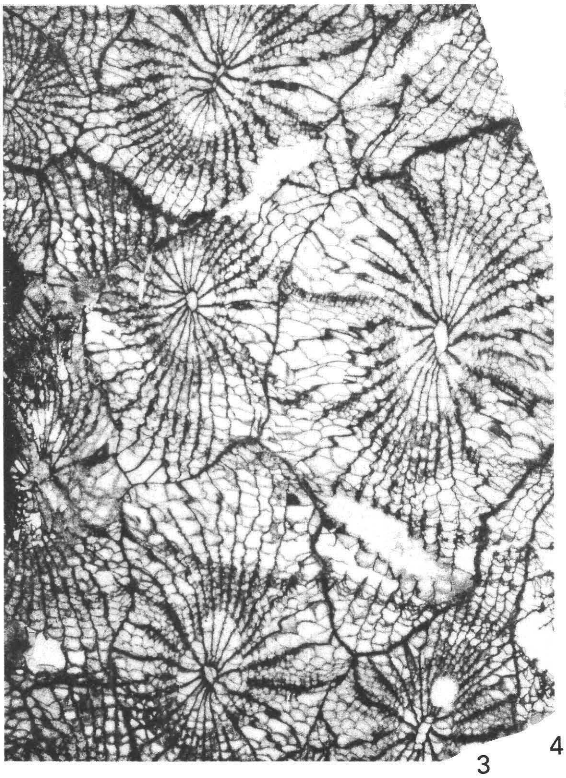
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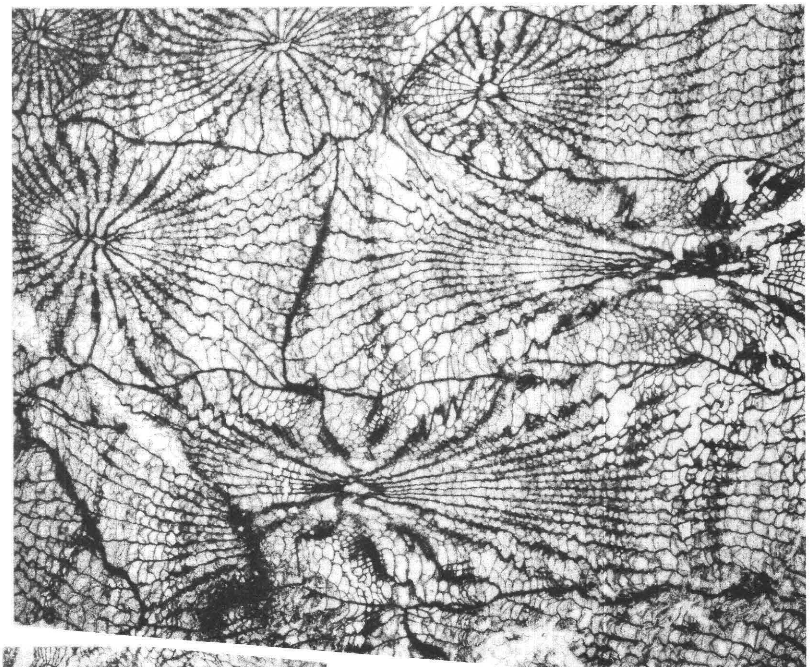
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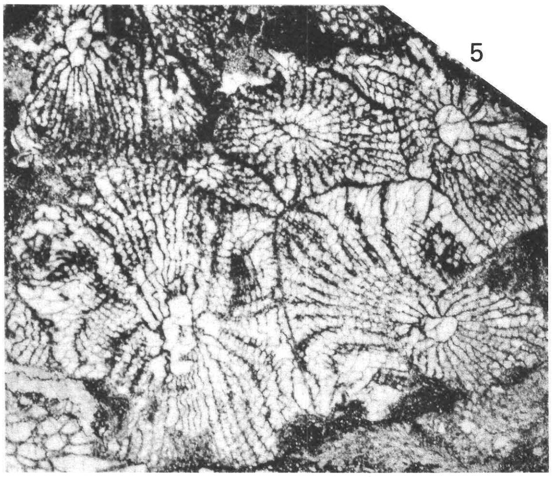
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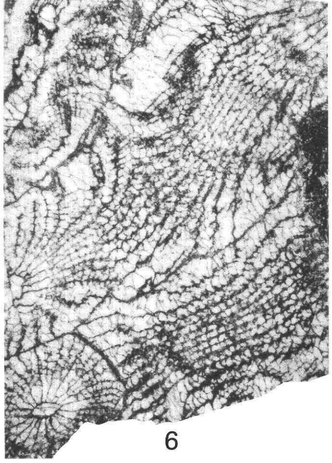
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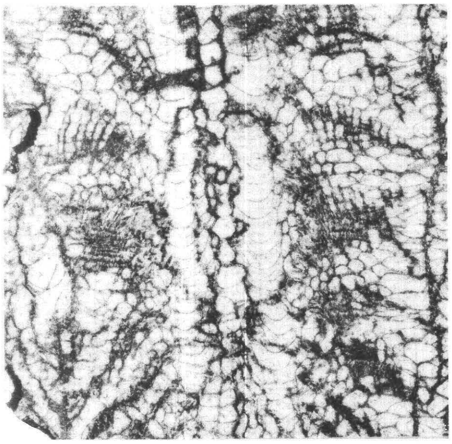
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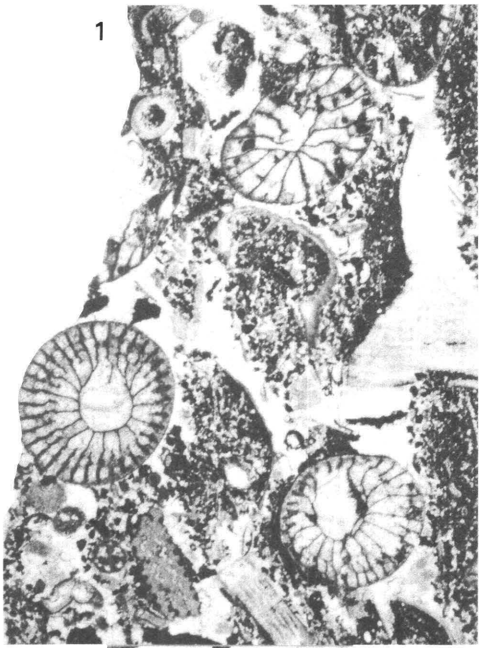
CORALS FROM THE LINGLE LIMESTONE

PLATE 4

Corals from the Lingle Limestone

[Transverse and longitudinal thin sections]

Figures 1–13. *Eridophyllum* n. sp. A. 1–5, ISGS 72P–14; 1–3, ×5; 4–5, ×10. 6–13, ISGS 72P–13B, all ×10.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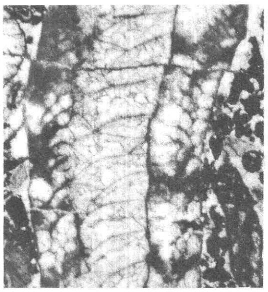
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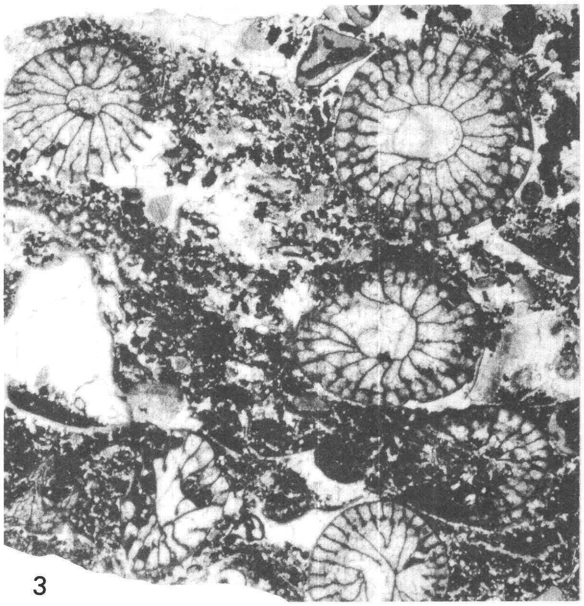
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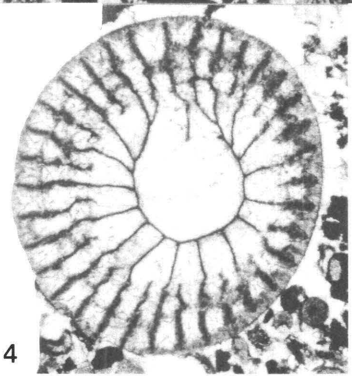
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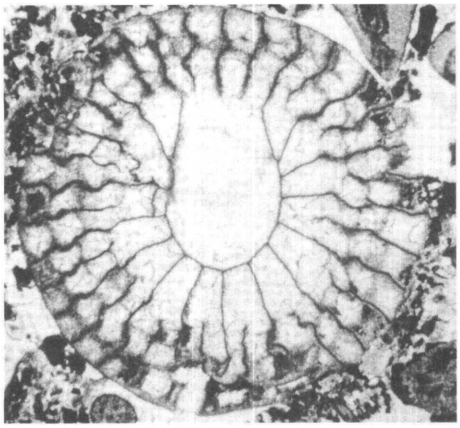
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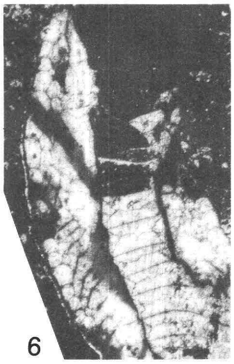
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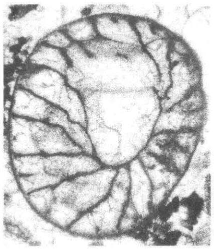
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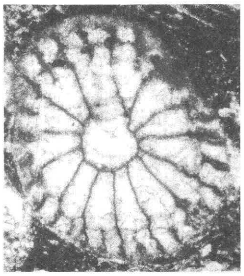
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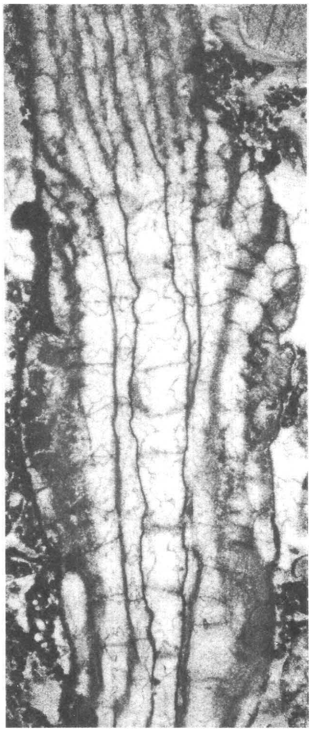
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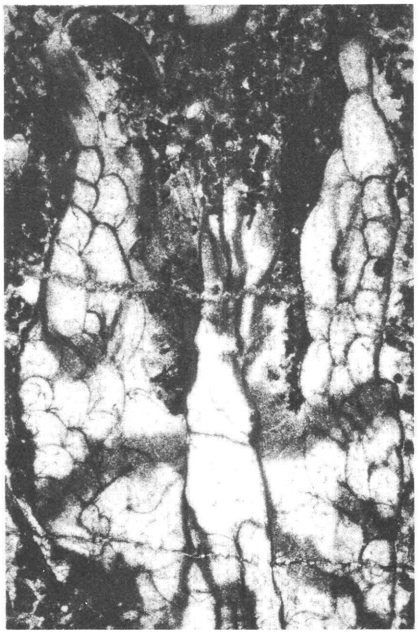
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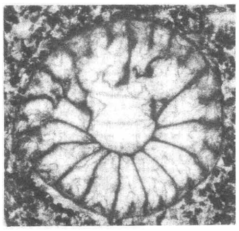
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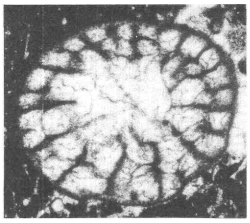
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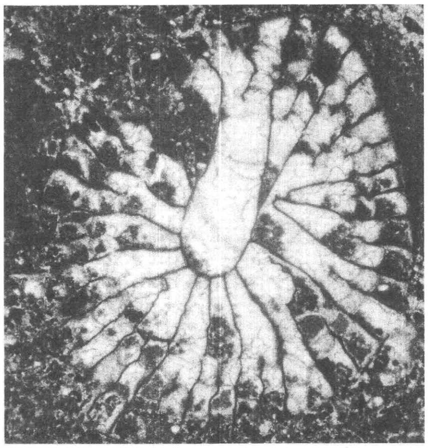
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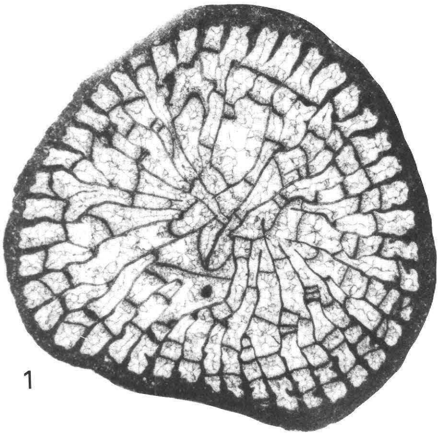
CORALS FROM THE LINGLE LIMESTONE

PLATE 5

“Anderdon” Corals

[Transverse and longitudinal thin sections]

Figures 1–11. *Grypophyllum* n. sp. A. All ×5. 1, 2, ISGS 72P–23. 3–5, ISGS 72P–24. 6, 7, ISGS 72P–25. 8–11, ISGS 72P–26.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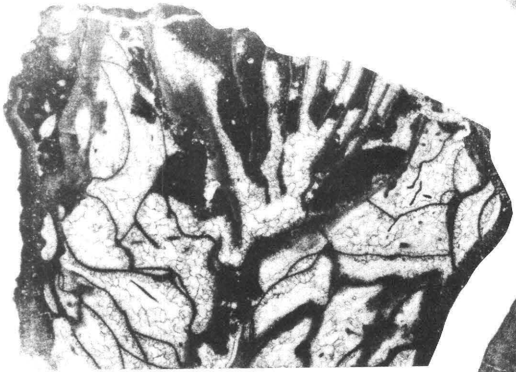
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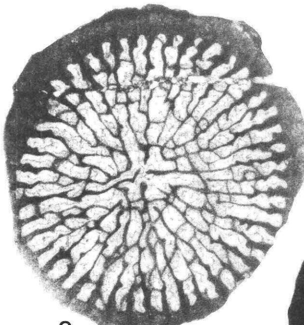
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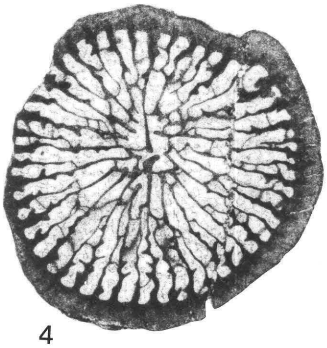
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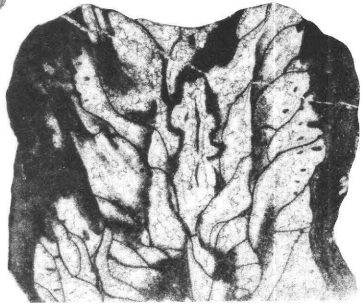
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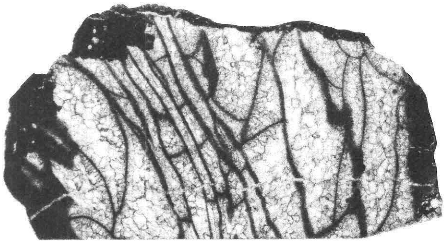
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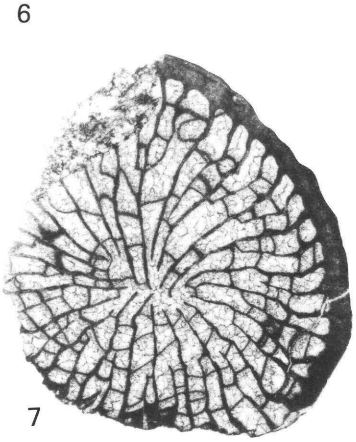
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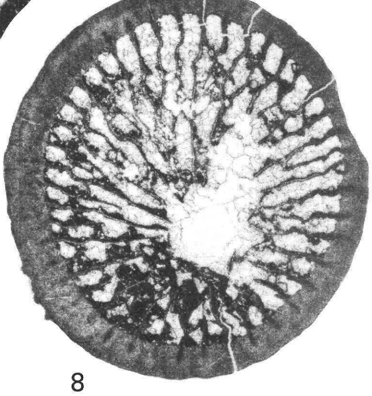
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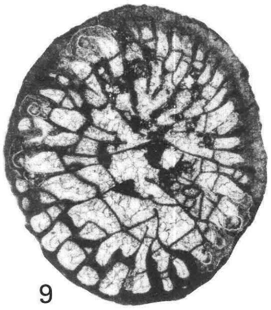
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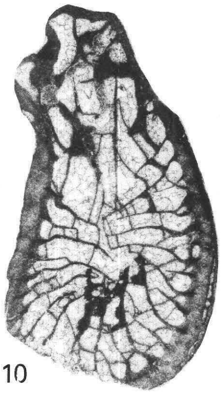
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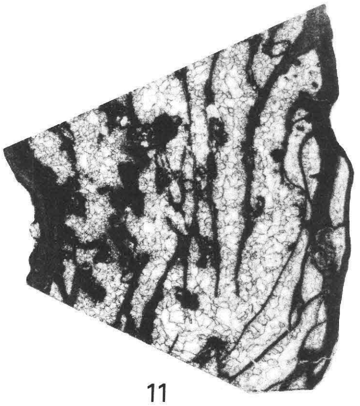

11

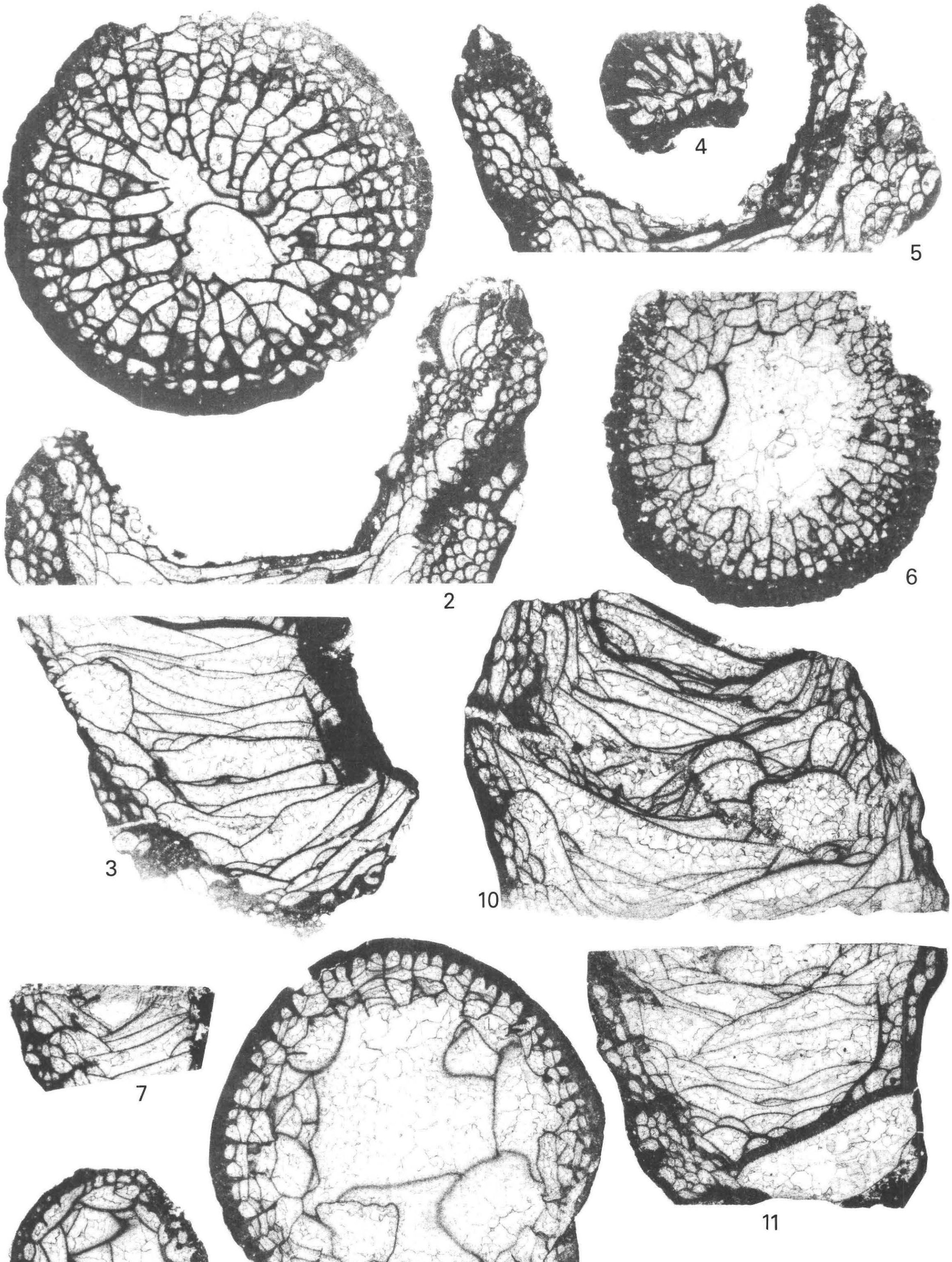
"ANDERDON" CORALS

Plate 6

“Anderdon” Corals

[Transverse and longitudinal thin sections]

Figures 1–11. *Holmophyllia* n. sp. A. All ×5. 1–3, ISGS 72P–27. 4–6, ISGS 72P–28. 7, 8, ISGS 72P–29. 9–11, ISGS 72P–30.



"ANDERDON" CORALS

CHAPTER E

Paleobathymetric Significance of Ostracodes from the Paine Member of the Lodgepole Limestone (Early Mississippian), Northeast Utah

By I.G. Sohn and William J. Sando

U.S. GEOLOGICAL SURVEY BULLETIN 1690

Shorter Contributions to Paleontology and Stratigraphy

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Paleobathymetric Significance of Ostracodes from the Paine Member of the Lodgepole Limestone (Early Mississippian), Northeast Utah

By I.G. Sohn *and* William J. Sando

Abstract

Silicified ostracodes recovered from the Paine Member of the Lodgepole Limestone at Brazer Canyon, northeast Utah, form the basis for the first description of these fossils from the Lodgepole Limestone. The faunule represents a new species, *Chamishaella lodgepoleana* Sohn, which appears to have been transported from shallow water into the deep-water environment of the Paine Member.

INTRODUCTION

Although ostracodes have been collected previously from the Lodgepole Limestone, that material was too sparse and too poorly preserved for description and detailed taxonomic analysis. Discovery of abundant, well-preserved silicified ostracode carapaces and dissociated valves in insoluble residues of 18 limestone samples from the Paine Member of the Lodgepole at Brazer Canyon, northeast Utah, provided an opportunity to gain some new insights into the nature and significance of these fossils in the Lodgepole.

The ostracodes were found in residues obtained by etching the limestone samples with dilute hydrochloric acid in order to recover silicified brachiopods, corals, and gastropods, which were visible in the field. Because recovery of ostracodes was not anticipated prior to etching, only the +16 mesh and larger residues were retained, and all of the limestone was processed before the ostracodes were discovered. Hence the samples do not permit evaluation of the younger growth stages of the species described nor possible other ostracode taxa of size smaller than about 0.9 mm in diameter. Moreover, any unsilicified ostracodes were destroyed by the etching process.

The described material is from the lower half of the Paine Member of the Lodgepole Limestone (0.6–37.8 m above the base) in a measured section at Brazer Canyon in NW$^1/_4$SE$^1/_4$ sec. 20, T. 11 N., R. 8 E., Randolph quadrangle (15 min.), Crawford Mountains, Rich County, Utah. This sequence was formerly called member 1 of the Lodgepole Limestone by Sando and others (1959, section 2 in figs. 2, 3, and 4) and was reinterpreted as Paine Member by Gutschick and others (1980, fig. 3, column 12). Detailed stratigraphic data on the collections are given in table 1. Samples from the Paine Member above USGS 16836–PC did not yield ostracodes.

The ostracode faunule consists exclusively of large smooth forms described herein as a new species of *Chamishaella* Sohn, 1971. In addition to describing this new species, the purpose of this report is to assess its paleoecologic significance with respect to the bathymetric model for the Paine Member based on other criteria.

Acknowledgments

We thank the following colleagues: Drs. J. M. Berdan and J. T. Dutro, Jr., U.S. Geological Survey, made valuable suggestions that improved this paper. Dr. Kristan Fauchald, Smithsonian Institution, provided information on the encrusting worms. Dr. O. L. Karklins, U.S. Geological Survey, identified the bryozoan fragment. The scanning-electron micrographs are by Mr. Walter M. Brown, Smithsonian Institution, and the prints are by Mr. H. E. Mochizuki, U.S. Geological Survey.

ENVIRONMENT OF DEPOSITION INFERRED FROM OTHER EVIDENCE

The Paine Member in the area studied constitutes the lower part of the Lodgepole Limestone and consists of thin-bedded, dark-colored, cherty, silty micrite and biomicrite. Shelly benthos (corals, brachiopods, and gastropods), crinoidal columnals, bryozoan, and echinoid fragments are generally rare; conodonts, radiolarians and sponge spicules are common in this lithofacies. Benthonic calcareous algae are absent.

Wilson (1969) proposed a "deeper-water" origin for the Paine Member based on analogy with other strata of known deep-water origin having similar faunas, sedimentary structures, and petrographic features. Smith (1972, 1977) postulated a "deep-water" origin for the Paine Member based on: "1) dominance of lime mud, 2) even horizontal lamination,

Table 1. Stratigraphic positions of ostracode collections from the Paine Member of the Lodgepole Limestone at Brazer Canyon

USGS colln. no.	Meters (feet) above base of Lodgepole Limestone
16801–PC	0.0–0.6 (0–2)
16802–PC (float)	Do
16803–PC	0.6–1.2 (2–4)
16804–PC (float)	Do
16805–PC	1.2–1.8 (4–6)
16806–PC	1.8–2.4 (6–8)
16808–PC	2.4–3.0 (8–10)
16809–PC (float)	Do
16810–PC	3.0–3.6 (10–12)
16816–PC	6.6–7.2 (22–24)
16818–PC	7.8–8.4 (26–28)
16825–PC	10.8–11.4 (38–40)
16827–PC	12.0–12.6 (40–42)
16829–PC	13.2–13.8 (44–46)
16831–PC (float)	15.6 (52)
16835–PC	33.5–34.8 (110–114)
16836–PC	37.8 (123.9)

3) large "intraformational truncation surfaces" that may represent submarine mass movements, 4) sparse, specialized fauna of delicate, but commonly unbroken, bryozoans and brachiopods, as well as articulated crinoids, 5) *Zoophycus* trace fossils, 6) position of the unit on an unstable shelf with a well-documented tectonic history, 7) overall stratigraphic and sedimentologic similarity to better documented deep-water carbonates, and 8) pronounced lack of shallow-water depositional features." (Smith, 1977, p. 194–195). According to Smith (1977), depositional relief on bioherms associated with the deep-water limestones of the Paine indicate water depths of 70–100 m. Similar conclusions about deep-water origin of the Paine Member were also reached by Cotter (1965) and Stone (1972). Sando (1980), using benthonic algae as a determinant of the euphotic zone, concluded that the depth of Paine deposition must have been more than 100 m below sea level, the effective lower limit of the euphotic zone in clear tropical seawater.

Thus, the evidence cited on the depositional environment of the Paine Member unanimously favors a deep-water origin at depths from 70 to more than 100 m below sea level on a slope offshore from the ancient shelf margin (Gutschick and others, 1980). We will now determine whether the ostracodes herein described conform to this paleoecologic model.

EVIDENCE FROM THE ORIENTATION AND EPIBIONT RELATIONSHIPS OF DISSOCIATED VALVES

The ostracodes in the Paine Member are smooth forms that occur as rare carapaces and mostly as dissociated valves (pls. 1, 2). Some of the valves have attached worm tubes on the inside concave surfaces (pl. 1, figs. 17, 18; pl. 2, fig. 27); rare crinoid and bryozoa fragments were in the residues. Dr. Kristan Fauchald, Curator of Worms, Department of Invertebrate Zoology, Smithsonian Institution, examined the photograph illustrated in plate 2, figures 25–28, and identified the worm as a serpulid-like taxon. He stated that most serpulids attach themselves to the lower sides of rocks and shells for protection against predators, but they need to be able to project their tentacular crown into the water for both oxygen and food. The worm must have easy access to open water at all times, that is, not much sediment can be deposited inside the shell (written communication, Feb. 27, 1985).

Dr. O. L. Karklins identified a 3-mm fragment of a bryozoan from USGS colln. 16808–PC as belonging to an undeterminate genus in the family Rhomboporidae Simpson, 1894. Blake's (1981) review of the paleoecology of Bryozoa concluded that, like the serpulids, bryozoans are dependent on water current for food and oxygen, confirming a slow rate of sedimentation.

Nineteen valves with worms on the inside (concave side) were recovered from collections 16802–PC (USNM 401112), 16808–PC (USNM 401113), 16809–PC (USNM 401143), and 16810–PC (USNM 401114), 13 of which are from colln. 16809–PC, (pl. 1, fig. 18; pl. 2, fig. 27). The worm tubes are attached across the entire length and (or) breadth of the concave surface. Dr. Fauchald estimated that it would take 1 or 2 months for the worm to grow that long. This indicates that the valves had to be oriented with the convex side down in order for the worms to extend their tentacular crowns into the water, because if the valves were oriented with the concave side down, the worms could not have survived. Convex fossils are usually oriented with the concave side down for stability in the presence of currents (Adamczak, 1981, p. 1). The presence of 13 valves in one collection with worms on the concave side indicates the absence of wave or current action for at least a month in order for the worms to grow. It also suggests that the sedimentation rate was minimal or nonexistent for the same length of time. In addition, worm predators were rare or nonexistent during the time necessary to secrete a tube more than 1 mm long.

Dissociated valves in the collections do not necessarily indicate a high-energy environment. Examination of living ostracode cultures in glass or plastic containers without a sediment substrate discloses random orientation of single valves. Some valves are convex side up and some are concave side up. The molted or dead carapaces are dissociated by bacteria and predator activities including possible cannibalism. Ostracodes have been observed feeding on dead carapaces and in dissociated valves, but it is not known whether they eat bacteria or the ostracode tissue. Whatley (1983, p. 55) cited an example from the English upper Oxfordian, where the ostracodes lived on a soft, muddy substrate and were periodically overwhelmed and entombed by sudden influxes of arenaceous and oolitic material, probably the result of storms. In the intervals between the catastrophic episodes, more than 95 percent of the juveniles were represented by disarticulated valves, whereas at the levels of more rapid sedimentation, between 75 percent and 95 percent were articulated. Although Whatley referred to juveniles, the same phenomenon may be operative on adults. Dissociated valves are more abundant than carapaces in the collections from the Paine Member, and the range in size of the valves (table 2) indicates that more than one growth stage is represented. The presence of dissociated valves in the Paine Member of the Lodgepole Formation does not contradict a very slow rate of sedimentation inferred from other evidence.

Thus, the evidence from epibiont relationships and the preservation of the ostracode specimens shows that the valves probably came to rest, after death of the animals, in an environment characterized by a slow rate of sedimentation below wave base. This fits the bathymetric model for the Paine based on other evidence.

EVIDENCE FROM INFERRED PALEOECOLOGY OF PALEOZOIC MARINE OSTRACODES

The paleoecology of Paleozoic marine ostracodes is based on the known habitats of closely related living forms, speculations on the functions of structural features of the carapace, known or inferred habitats of associated fossils, and interpretation of the environment based on the enclosing sediments (Benson, 1961, p. Q60). Unfortunately, there are no modern counterparts of the deep-water epicontinental Paleozoic ostracode assemblages. Moreover, the living marine ostracode assemblages do not contain morphotypes similar to the large, smooth forms found in Paleozoic rocks. Few attempts have been made to determine the bathymetry of Paleozoic marine ostracode morphotypes, and the depth ranges of individual genera are poorly documented.

Becker (1971) proposed a model for the paleoecology of Middle Devonian ostracodes from the Eifel region that consisted of six biotopes ranging from shallow water less than 50 m in depth to a probable maximum of 100 m. This model was later revised (Becker, 1981, 1982) to include a shallow-water biotope (shelf = Eifeler Ökotyp) and a deep-water biotope (Becken = Thüringer Ökotyp). Large smooth ostracodes occur in Becker's Eifeler Ökotype, which is characterized by water depths of 50 m or less. Becker's deep-water biotope is characterized by ornamented forms.

Sohn (1979, p. 1250) postulated that *Pseudoleperditia gerki* Sohn, a large (as much as 4 mm), relatively smooth, calcareous ostracode from the Early Mississippian of Iowa, was a reef dweller that was washed into a backreef lagoon. Both Becker (1971) and Berdan (1984) considered the Leperditicopida (large smooth forms) to be lagoonal inhabitants.

Bless (1983) presented a paleoecologic model that consists of four main depositional realms for Late Devonian and Carboniferous ostracodes in western Europe, North Africa, and southeast Canada. The large smooth forms are found in shallow offshore and nearshore environments. *Chamishaella* is found in the nearshore environment in the Namurian of Libya. According to Bless, the basinal environment is characterized by thin-shelled entomozoans, diverse bairdiaceans, and heavily ornamented spinose ostracodes.

Sandberg and Gutschick (1980) listed ostracode genera in the foreslope facies of their model for the Deseret starved basin in the Osagean and Meramecian of Utah and adjacent States. The depositional relief of the foreslope was estimated at 100–200 m (Sandberg and Gutschick, 1980, p. 139). The ostracodes in this facies are silicified, robust, commonly articulated, and of low diversity. The assemblage consists of both smooth forms (*Paraparchites, Bairdia*) and ornamented forms (*Graphyadactyloides, Beyrichiopsis, Kirkbya,* and *Waylandella*). Only a few ostracode specimens were recovered from the deep basinal facies (at least 300 m deep).

PALEOECOLOGIC CONCLUSIONS

The weight of evidence from previous analyses of the paleoecology of marine Paleozoic large smooth ostracodes (Becker, 1971, 1981, 1982; Bless, 1983; Berdan, 1984; and Sohn, 1979) suggests that the living habitat of this morphotype was mainly or entirely in water depths of less than 50 m. Deeper waters were characterized by highly ornamented pelagic forms. However, the discovery of large smooth forms associated with ornamented forms in the foreslope facies of the Deseret Limestone (Sandberg and Gutschick, 1980) at depths estimated as 100–200 m demonstrates that the shallow-water morphotype can be found in deep-water environments under some circumstances. These anomalous occurrences are best explained by transportation of the carapaces after death by water currents or turbidity currents from the shallow-water living habitat down the

Table 2. Measurements (in mm) of illustrated and selected specimens
[C, carapace; R, right valve; L, left valve]

Specimen	Greatest length	Greatest height
USNM 401101, pl. 2, fig. 1–4, C	1.40	0.94
USNM 401103, pl. 2, figs. 9–11, R	1.54	1.00
USNM 401102, pl. 2, figs. 5–8, C	1.94	1.44
USNM 401109, unfig., R, USGS colln. 16808–PC	2.00	1.40
USNM 401106, pl. 2, figs. 21–24, R	2.42	1.42
USNM 401104, pl. 2, figs. 12–15, C	2.42	1.62
USNM 401105, pl. 2, figs. 16–20, C	2.50	1.52
USNM 401100, pl. 1, figs. 18, 19, R	2.65	1.66
USNM 401095, pl. 1, figs. 5–8, L	2.70	1.82
USNM 401093, pl. 1, figs. 1, 2, R	2.72	1.80
USNM 401094, pl. 1, figs. 3, 4, L	2.76	1.78
USNM 401097, pl. 1, figs. 11, 12, R	2.79	1.80
USNM 401096, pl. 1, figs. 9, 10, L	2.80	1.80
USNM 401110, unfig., R, USGS colln. 16810–PC	2.80	1.80
USNM 401107, pl. 2, figs. 25–28, L	2.80	1.90
USNM 401099, pl. 1, fig. 17, L	2.85	1.86
USNM 401111, unfig., C, USGS colln. 16836–PC	2.90	1.90
USNM 401098, pl. 1, figs. 13–16, C	3.00	2.04
USNM 401108, unfig., C, USGS colln. 16808–PC	3.30	2.10

foreslope to their final resting place in the sediment. This interpretation is consistent with evidence from the relationship of worm tubes found on the dissociated valves, which indicates quiet aerobic water conditions at the time that the worms lived on the valves.

The absence of ornamented, characteristically deep-water forms from the sample studied is probably the result of sample-preparation techniques. Sandberg and Gutschick's (1980) samples were processed with acetic acid, and the fine fractions of the residue were retained. Hence, their ostracode samples contained both autochthonous deep-water forms and allochthonous shallow-water forms. Only *Paraparchites* would have been retained in our collections in the +16 mesh residue. Because the Brazer Canyon samples were processed with hydrochloric acid, and only the +16 mesh fraction was retained, any characteristically deep-water forms may have been lost during sample processing.

SYSTEMATIC PALEONTOLOGY

Superfamily PARAPARCHITACEA Scott, 1959 emend. Sohn, 1971

Family PARAPARCHITIDAE Scott, 1959

[See Sohn (1971, p. A5) for a discussion
of the above classification.]

Genus CHAMISHAELLA Sohn, 1971

Chamishaella Sohn, 1971, U.S. Geol. Survey Prof. Paper 711–A, p. 11.

Paraparchites Ulrich and Bassler, 1906 part. of authors.

Type-species.—C. brosgei Sohn, 1971, U.S. Geol. Survey Prof. Paper 711–A, p. 12, pl. 6, figs. 1–32, early Meramecian, Brooks Range, Alaska.

Discussion—Chamishaella was established for large, smooth, straightbacked, subovate ostracodes with the left valve overlapping the right along the free margins, and the right valve overreaching the left along the dorsum. Species in this genus are dimorphic in that the greatest width is along the venter in heteromorphs (presumed females) (pl. 1, figs. 1–16, 18, 19). The tecnomorphs (presumed males and growth stages) are widest at or near the midheight (pl. 1, fig. 17?; pl. 2, figs. 1–28). The hinge structure of the genus has not been described previously, because dissociated valves were not available. The species described herein is based mostly on single valves that show the hinge structure to consist of a ridge in the overlapping valve which fits into a groove in the overreaching valve.

Table 3 lists all the known species in *Chamishaella,* their recorded size, age, and geographic occurrence. Species smaller than approximately 1 mm in greatest length probably are either based on immature individuals, or are misidentified.

Stratigraphic range.—Except for *C. sparsa,* which is recorded from the Moskovian (Westphalian), Mississippian and Lower Carboniferous (lower Tournaisian through lower Namurian).

Chamishaella lodgepoleana Sohn, n. sp.

Plate 1, figures 1–19; plate 2, figures 1–28

Etymology of name.—For the Lodgepole Limestone of the Madison Group.

Holotype.—Heteromorphic carapace, USNM 401098

Paratypes.—USNM 401093–401097, 401099–401122

Voucher specimens.—USNM 401123–401143

Type locality.—Brazer Canyon, Randolph Quadrangle, Utah.

Type level.—Paine Member of the Lodgepole Limestone, Upper *Siphonodella crenulata* Zone (coral zone IC).

Diagnosis.—Chamishaella with elongated lateral outline, weak overreach of right valve along dorsum, and weak incised hinge margin.

Description.—The greatest length is at or slightly above midheight, the greatest height is at approximately midlength, and the greatest width of heteromorphs is near the ventral margin; it is closer to midheight on tecnomorphs. The cardinal angles are obtuse. The dorsal portions of the end margins are straight to slightly convex and merge ventrally into the convex ventral margin. The anterior margin has a larger curvature than the posterior margin, and its greatest convexity is slightly lower than that of the posterior margin. Both end margins merge evenly into the convex ventral margin. The dimorphic swelling near the venter of heteromorphs overreaches and covers the contact margin (pl. 1, figs. 1, 4). The hinge consists of a ridge in the overlapping valve and a groove in the overreaching valve. Both valves have a narrow band near the end margins that marks the limit covered by the larger valve (pl. 1, figs. 1, 12, 14, 15; pl. 2, figs. 5, 14, 15, 23). The dorsal outline is subelliptical, tapering more towards the anterior end (pl. 1, figs. 7, 11; pl. 2, figs. 6, 8, 14, 16, 23), and the greatest

Table 3. Recorded size (in mm), age, and geographic occurrence of species of *Chamishaella*
[*, measured on illustration]

Species	Greatest length	Greatest height	Age	Occurrence
C. aenigmatica Sohn, 1971	2.15	1.40	Late Meramecian	Alaska.
C. auriculata (Prozner, 1951) Sohn, 1971	0.93	0.81	Viséan	U.S.S.R.
C. brosgei Sohn, 1971	2.42	1.90	Early Meramecian	Alaska.
C. cf. *brosgei* Sohn, 1971. Bless and Massa, 1982*	2.00	1.50	Early Namurian	Libya.
C. carbonaria (Hall, 1858) Sohn, 1972	3.25	2.45	Viséan	Indiana.
C. cf. *carbonaria* (Hall, 1858) Crasquin, 1984*	3.20	2.55	Late Tournaisian	Canada.
C. disjuncta (Morey, 1935) Sohn, 1971	0.70	0.40	Basal Mississippian	Missouri.
C. grekoffi Tschigova, 1977	1.17	0.84	Early Tournaisian	Europe.
C. aff. *inflata* (Münster, 1830) Sohn, 1971	2.42	1.46	Early Meramecian	Alaska.
C. kaisini Rome, 1973	1.10	0.70	Early Tournaisian	Belgium.
C. lima Tschigova, 1977	1.37	0.95	do	U.S.S.R.
C. lysi Tschigova, 1977	1.55	1.20	do	Europe.
C. nuda (Tkatcheva, 1972) Tschigova, 1977	0.975	0.925	Late Tournaisian	U.S.S.R.
C. obscura Tschigova, 1977	1.17	0.88	Early Tournaisian	U.S.S.R.
C. procera (N. Ivanova, 1975) Kotschetkova, 1980	1.20	0.99	do	U.S.S.R.
C. rare (Tschigova, 1958) new combination	1.20	0.93	Late Tournaisian	U.S.S.R.
C. sparsa Kotschetkova, 1984	1.125	0.87	Moscovian	U.S.S.R.
C. suborbiculata (Pozner, 1951) Sohn, 1971	1.21	1.01	Viséan	U.S.S.R.
C. tumida (Kummerow, 1939) Sohn, 1971	2.70	2.03	do	Germany.
C.? sp. Sohn, 1971	2.07	1.52	Early Meramecian	Alaska.

width is behind midlength (pl. 1, fig. 11; pl. 2, figs. 8, 14, 23, 28). The inner lamella is of even width (pl. 1, figs. 9, 10).

Discussion.—The valves are larger than any of the species referred to *Chamishaella* except *C. carbonaria* (Hall, 1858), which is more rounded in lateral outline and wider in dorsal outline. *C. lodgepoleana* differs from the European *C. lysi* Tschigova, 1977, in lacking a step-like offset of the posterior part of the ventral margin, in larger size, and in more elongated lateral outline. Only large specimens were available for study, because the fine fraction of the acid residues was not recovered. There are more dissociated valves and fragments than carapaces, but the size range suggests that the specimens were not size-sorted as individuals. They could, however, have been transported by mudslides. The presence of encrusting worm tubes inside and outside of dissociated valves (pl. 1, figs. 7, 17, 18; pl. 2, figs. 25–28) indicates that the rate of sedimentation was slow enough to permit other animals to settle and grow on and in the valves.

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PLATES 1–2

Contact photographs of the plates in this report are available at cost from U.S. Geological Survey Library, Federal Center, Denver, CO 80225

PLATE 1

[Magnification approx. ×20]

Figures 1–19. *Chamishaella lodgepoleana* Sohn, n. sp.

1,2. Posterior and outside views of right valve, heteromorph, paratype, USNM 401093, USGS colln. 16809–PC.

3,4. Outside and posterior views of left valve, heteromorph, USNM 401094, USGS colln. 16810–PC.

5-8. Outside, posterior, dorsal (anterior to left), and interior views of left valve, heteromorph, paratype, USNM 401095, USGS colln. 16810–PC.

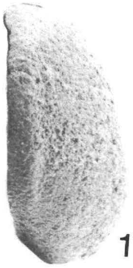
9,10. Dorsal oblique (anterior to left) and inside views of left valve, heteromorph, paratype, USNM 401096, USGS colln. 16827–PC. Note inner lamella.

11,12. Dorsal (anterior and left) and posterior views of right valve, heteromorph, paratype, USNM 401097, USGS colln. 16809–PC.

13–16. Left, anterior, posterior, and dorsal (anterior to top) views of carapace, heteromorph (adult female), holotype, USNM 401098, USGS colln. 16808–PC.

17. Inside of fractured and misshaped left valve, tecnomorph, paratype, USNM 401099, USGS colln. 16809–PC. Note encrusting worm emplaced probably after the valve was fractured.

18,19. Ventral oblique (anterior to left) and outside views of right valve, heteromorph, paratype, USNM 401100, USGS colln. 16809. Note over-reaching dimorphic swelling on fig. 18.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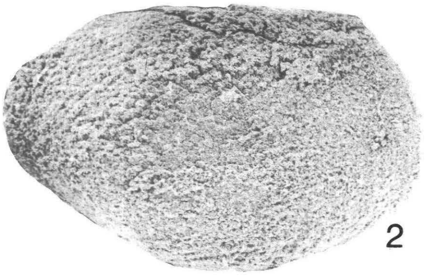
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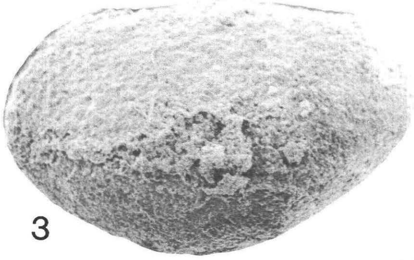
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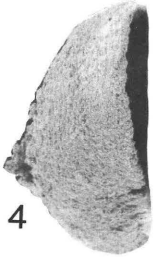
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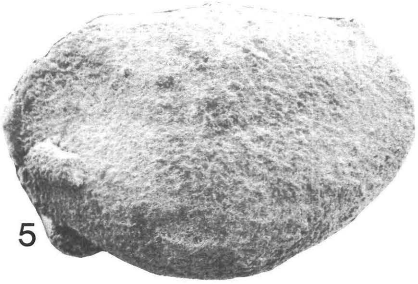
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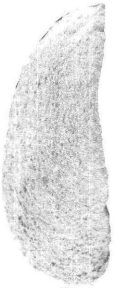
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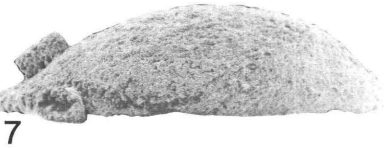
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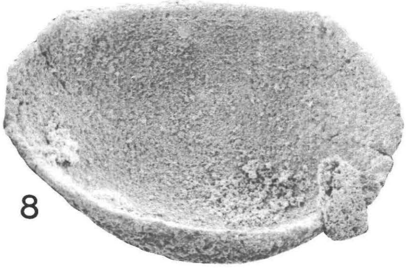
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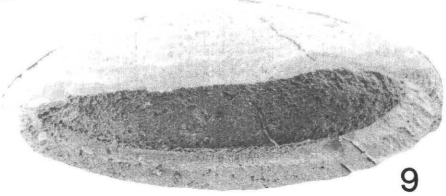
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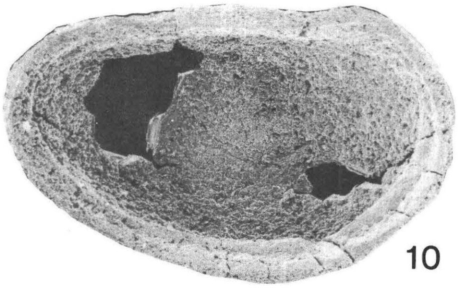
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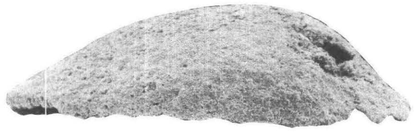
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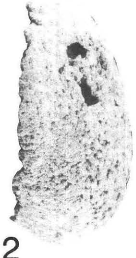
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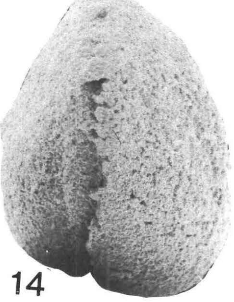
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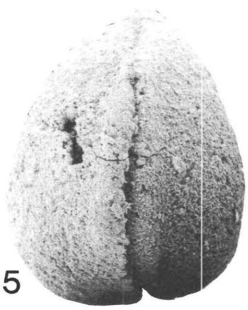
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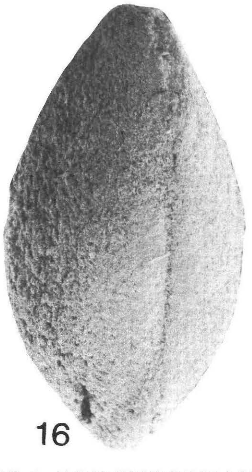
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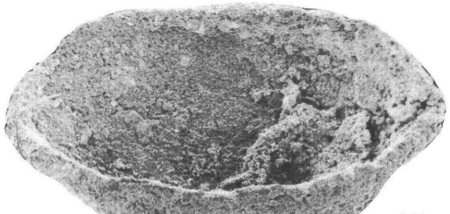
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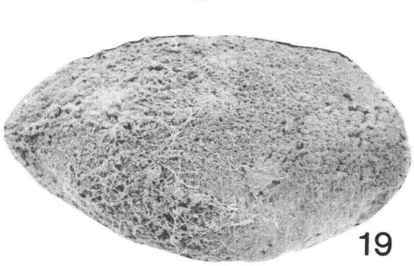
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CHAMISHAELLA LODGEPOLEANA

PLATE 2

[Magnification approx. ×20]

Figures 1–28. *Chamishaella lodgepoleana* Sohn, n. sp.

1–4. Left, posterior, right, and dorsal (anterior to right) views of carapace, smallest growth stage recovered, tecnomorph, paratype, USNM 401101, USGS colln. 16809–PC.

5–8. Posterior, dorsal (anterior to left), right, and ventral (anterior to right) views of carapace, tecnomorph, paratype, USNM 401102, USGS colln. 16810–PC.

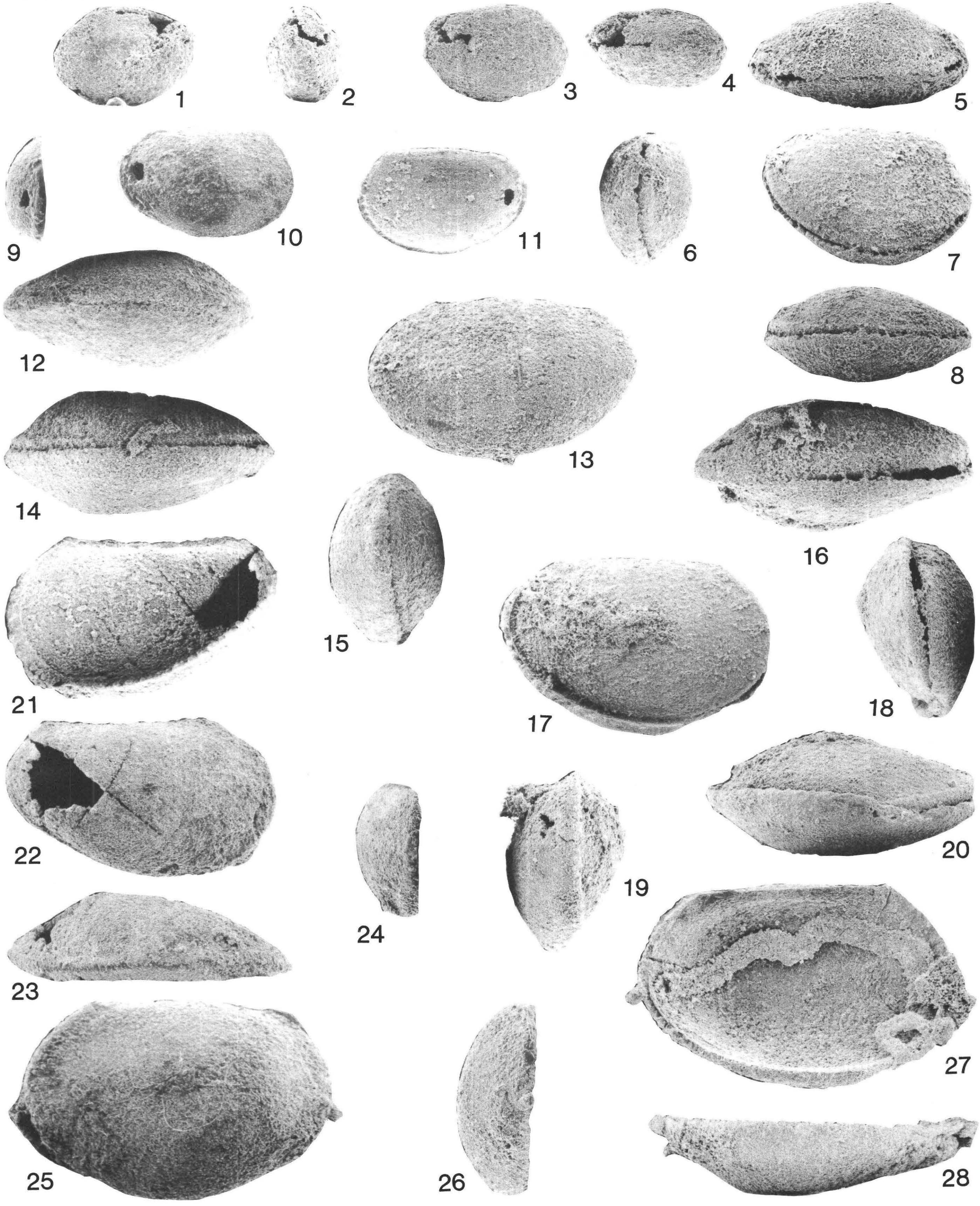
9–11. Posterior, outside, and inside views of right valve, tecnomorph, paratype, USNM 401103, USGS colln. 16810–PC.

12–15. Dorsal (anterior to left), left, ventral (anterior to right), and posterior views of carapace, tecnomorph, paratype, USNM 401104 USGS colln. 16810–PC.

16–20. Dorsal (anterior to right), right, anterior, posterior, and ventral (anterior to right) views of carapace with the right valve slightly dislocated, tecnomorph, paratype, USNM 401105, USGS colln. 16810–PC.

21–24. Inside, outside, ventral (anterior to right), and anterior views of cracked right valve, tecnomorph, paratype, USNM 401106, USGS colln. 16810–PC.

25–28. Outside, posterior, inside, and ventral (anterior to right) views of left valve, presumed male, paratype, USNM 401107, USGS colln. 16810–PC. Note encrusting worm on inside.



CHAMISHAELLA LODGEPOLEANA

CHAPTER F

Some Ordovician and Permian-Triassic Conodonts from Xizang (Tibet)

By Anita G. Harris, John E. Repetski, and Erle G. Kauffman

U.S. GEOLOGICAL SURVEY BULLETIN 1690

Shorter Contributions to Paleontology and Stratigraphy

CONTENTS

PLATES

[Plates follow References Cited]

FIGURES

Some Ordovician and Permian-Triassic Conodonts from Xizang (Tibet)

By Anita G. Harris, John E. Repetski, *and* Erle G. Kauffman

Abstract

Conodonts from Tibet extend the known geographic range of several taxa and demonstrate the utility of these fossils for Tibetan Paleozoic and Mesozoic geologic studies. One Late Permian or Triassic conodont dates its host-rock, which is an olistolith within an Upper Triassic unit. Samples from an Ordovician succession north of Nyalam yielded conodonts indicative of the North Atlantic conodont faunal province. One of these contains the index species *Pygodus serra* (Hadding), which provides a precise global correlation for this collection.

INTRODUCTION

Our present knowledge of conodont occurrence and distribution in Tibet is quite sparse due both to difficulty of access and, until recently, to the general lack of conodont study in this remote region. In May, June, and July 1980, the Academia Sinica of the People's Republic of China sponsored a stimulating international conference in Beijing (Peking) on the biological and geological evolution of the Qinghai-Xizang (Tibet) Plateau, during which a considerable amount of new and/or poorly known geologic data on this area were presented and then published (Liu Dong-Sheng and others, 1981). Of particular importance to stratigraphers in these volumes are updated stratigraphic summaries, biozonal schemes, and regional correlations for Tibet and surrounding regions. For the Paleozoic, especially significant papers are by Chen Ting-en (1981), Gupta (1981), Jin Yu-gan (1981), Wang Yu-jing and Mu Xi-nan (1981), Waterhouse and Gupta (1981), Wen Shi-xuan and others (1981), Wu Wang-Shi and Liao Wei-hua (1981), Zhang Lin-xin(1981), and the Scientific Guidebook to South Xizang (Tibet) (Organizing Committee; Scientific Guidebook to South Xizang; 1980). These works serve as bases for new international correlations. One of us (EGK) had the privilege to participate in this conference and the subsequent Tibet expedition.

The final phase of the Qinghai-Xizang Conference was a 2-week field trip across the Tibet Plateau, focusing on a transect between Lhasa, Xigaze, Lhaze, Tingri, Nyalam, and Zham (fig. 1), which crossed the famous Yarlung-Zangbo ophiolite belt, the Greater Himalayas, and provided a rare opportunity to study and collect fossils through representative, well-exposed Paleozoic and Mesozoic sequences. Visiting scientists were encouraged by the Chinese hosts to collect, identify, and report on relevant fossil material. This paper documents the conodonts collected in the transect across Tibet by one of us (EGK).

Paleozoic rocks occur in four settings in south-central Tibet. To the north of the Yarlung-Zangbo suture, which parallels the river of that name (fig. 1), Paleozoic carbonate and chert cobbles are common elements of Mesozoic (predominantly Cretaceous) inner-shelf conglomerates, proximal turbidites, and submarine fan systems in a rapidly deepening back-arc basin. Probable Paleozoic blocks are caught up in melange marginal to the ophiolite belts as well. South of the Yarlung-Zangbo suture (fig. 1), massive olistostromes, or "exotic blocks" of fossiliferous Permian shelf carbonates, as much as 4.4 km^2 in diameter, occur in basinal Triassic sandstones and shales apparently reflecting early phases of subduction of an encroaching Gondwanan plate margin into a deepening fore-arc basin or trench. Further south, between Chiatsun and Yarleb in the region north of Nyalam (fig. 1), south of the 5,100-m Yagru-Xongla Pass, an extensive *in situ* Paleozoic sequence was transected by this trip, and collections were made from Ordovician through Devonian marine strata.

In total, collections of Paleozoic rocks were made from 17 different localities during the expedition. Conodonts were recovered from 3 of 17 Paleozoic samples, and are reported on herein. This report is necessarily deficient in scope and geological context because of the reconnaissance sampling. We believe, however, that these findings add significant information concerning worldwide conodont and conodont-biofacies distribution. We hope that this note will stimulate further interest and research on the faunas and biostratigraphy of this geologically important, remote region.

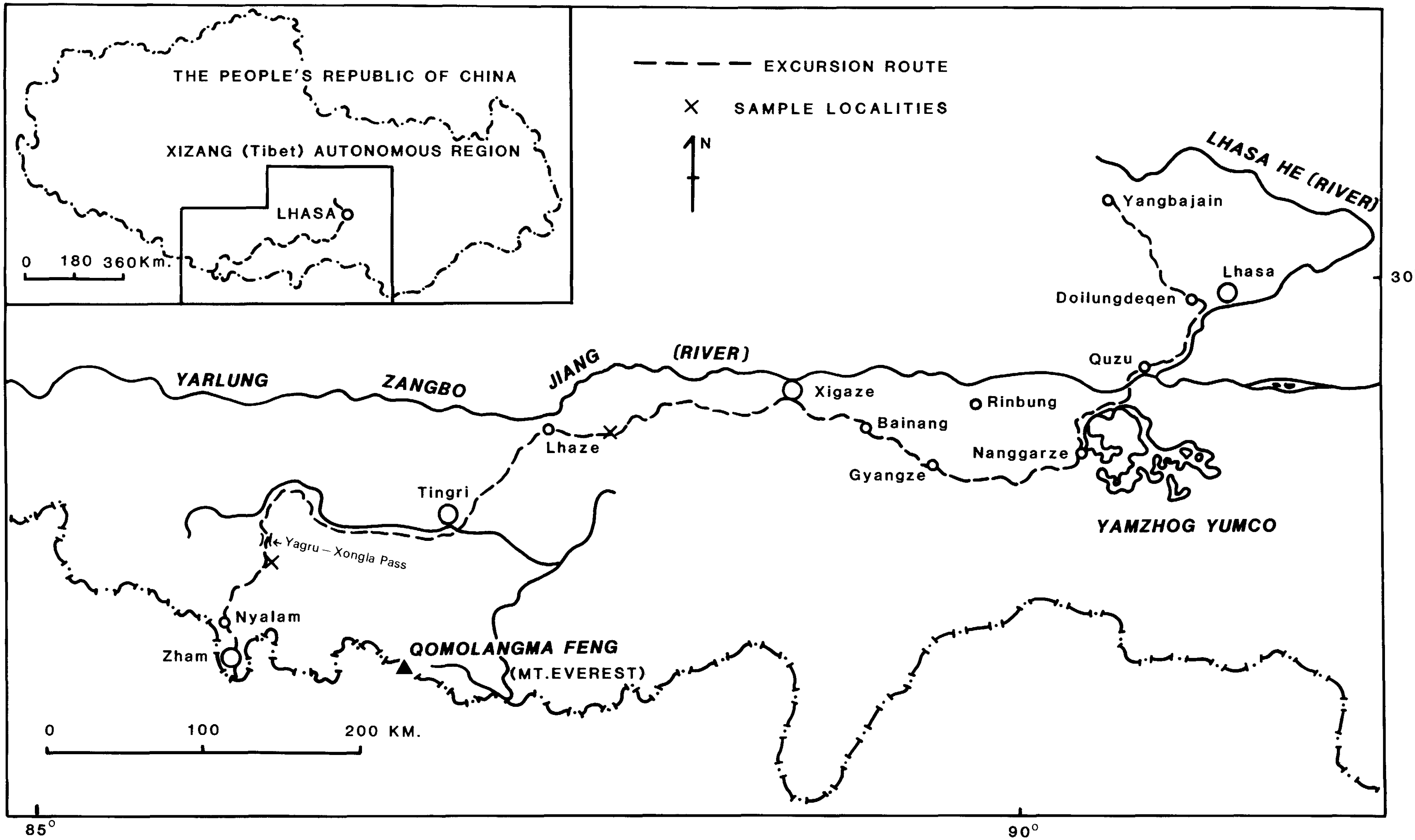


Figure 1. Map showing location of conodont samples along route of Academia Sinica excursion across Qinghai-Xizang (Tibet) Plateau (modified from Organizing Committee; A Scientific Guidebook to South-Xizang, 1980).

Acknowledgments

We wish to thank many paleontological colleagues in the People's Republic of China who provided guidance, fellowship, and who gave freely of their time and expertise during the Qinghai-Xizang (Tibet) Plateau expedition. In particular we express our gratitude to Prof. Liu Dong-sheng of the Academia Sinica, Secretary General of the conference, principal coordinator of the expedition, and chief editor of the proceedings, and Dr. S. Dillon Ripley, Secretary of the Smithsonian Institution and good colleague during the expedition, who provided funding through a grant to the junior author (EGK). Dr. Chen Jun yuan, Nanjing Institute of Geology and Paleontology, Academia Sinica, PRC, kindly read the manuscript during his visit to the U.S. National Museum in June 1982; his suggestions and discussions improved the manuscript and brought us to a better understanding of Ordovician stratigraphy in China. We also thank R.T. Lierman and H.E. Mochizuki (USGS) for their excellent technical assistance in preparing the figures and illustrations.

ANALYSIS OF PALEOZOIC CLASTS IN MESOZOIC STRATA

Paleontologic analysis of older clasts in the Mesozoic rocks of Tibet is an important tool in defining the geology of source areas. In regions as tectonically active as the Tibet Plateau, where older terranes have commonly been metamorphosed or destroyed, residual clast analysis may also yield the only evidence of facies, age, biozone(s), and correlations for older rock suites. Clasts further provide minimum ages for large-scale tectonic events which incorporate host rocks, or which produce olistostromes, debris flows, etc.

Thirteen of the samples processed in this study were individual clasts collected from Mesozoic (predominantly Cretaceous) conglomerates, melange, and olistostrome-bearing units. These clasts ranged from 15 to 146 grams each.

Possible Paleozoic clast samples came from (a) olistrostromes in the Upper Cretaceous Zonghuo Group (Kauffman locality KC–80–16 along the road between Nangagarze and Gyangze); (b) conglomerates of the Qiabuling Formation (Middle Cretaceous), upper part (Kauffman locality KC–80–18, 18 km west-northwest of Xigaze); (c) the "Castle" Conglomerate (Xigaze Group; Middle Cretaceous) at the base of the upper Ngamring flysch, behind the Zhaxilhunbo Temple in Xigaze (Kauffman locality KC–80–22–1); and (d) from cobbles in melange (Triassic?) facies at the top of Cuola Pass (Kauffman locality KC–80–23–1). All proved barren of conodonts.

Only one clast produced phosphatic microfossils (Kauffman locality KC–80–24–1: USGS collection number 29820–PC), a 143-g piece of limestone from a large olistostrome block embedded in dark, finely laminated "Upper Triassic Shale Formation." The sample was collected from an exposure in a river cut in a north-flowing tributary of the Yarlung-Zangbo River, 100 m northwest of the road between Xigaze and Lhaze, 40 km east of Lhaze, on the east side of Cuola Pass (fig. 1). This clast yielded only one posterior platform fragment of a *Neogondollela* (sp. indet.) of a Late Permian through Triassic morphotype (pl. 1). The color alteration index (CAI) of this fragment is 3 to 4, indicating that that host rock (but not necessarily the entire olistostrome unit) reached at least 120° to 180° C during its burial and tectonic history. The limestone olistostromes in this area are unnamed. Brachiopod faunas reported from these blocks include Permian species of *Neospirifer, Spiriferrella, Stenoscisma,* and *Marginifera*. This assemblage and the carbonate facies of the blocks are similar to those of crystalline limestones of the late Early Permian Baidingpu Formation in the Tethys-Himalyan Northern Sub-Belt of the Xigaze District (Wen Shi-xuan and others, 1981, Table 2; Organizing Committee; Scientific Guidebook to South Xizang, 1980, p. 66). The Late Permian to Triassic age of the conodont in the Cuola Pass exotic block may indicate younger Permian carbonates in the Tethyan-Himalayan Province than are known at present.

ORDOVICIAN CONODONTS FROM THE NYALAM ROAD SECTION

The best Paleozoic sequence encountered on this expedition is exposed along both sides of the road between Yagru Xongla Pass and Nyalam (fig. 1), and in particular between the villages of Chiatsun and Yarleb. Figure 2 outlines the stratigraphic section in this region. The Lower Ordovician (current conventional usage in China places the boundary between the Lower and Upper Ordovician at the Llanvirnian–Llandeilian Series boundary, *fide* Chen Jun-yuan, written commun., 1982), in ascending order, consists of the Rougicun Formation (a nonfossiliferous, poorly dated unit that may be wholly or partly of Cambrian age; *fide* Chen J.Y., oral commun., to JER, 1982), consisting of laminated argillaceous crystalline limestone and marble; and the "Lower Formation" (unnamed) of the Ordovician Chiatsun Group. The "Lower Formation", 726 m thick, is composed of fossiliferous dark-gray limestone with minor sandstone, siltstone, and dolomite, and contains a nautiloid fauna suggesting a middle Arenigian (Chen Jun-yuan, 1975), Early to early Middle Ordovician age (in North American usage) at the base (*Pomphoceras-Wutinoceras* Biozone), and an early Llanvirnian age at the top (*Dideroceras-Paradnatoceras* Biozone) (Organizing Committee; Scientific Guidebook to South Xizang, 1980, p. 82, 83). Limestone samples collected from the "Lower Formation" of the Chiatsun Group in outcrops along the east side of the road between Yagru Xongla Pass and Nyalam, 24 to 25 km north-northeast of Nyalam yielded conodonts from one sample (USGS colln.

9207–CO; 150-g sample processed). The conodont assemblage consists of three graciliform elements of *Panderodus* cf. *P. sulcatus* (Fåhraeus) (Pl. 2A, B) and one scandodontiform element of *Scolopodus* cf. *S. cornuformis* Sergeeva (Pl. 2C). These taxa are typical of the North Atlantic conodont province, reflecting cool and/or deeper water marine paleoenvironments. Further, they indicate a probable Llanvirnian age (Whiterockian to early Chazyan in North American usage), which is compatible with associated macrofaunas in the upper part of the "Lower Formation."

SYSTEM		NAMES OF STRATA		LITHOLOGY AND THICKNESS
PERMIAN	P	Selung Group	Chubujeka Formation	Siltstone intercalated with bioclastic limestone and shale 375 m
			Chubuk Formation	Sandstone, quartzose, intercalated with dark-gray shale; 20 m
CARBONIFEROUS	C_3	Gilung Formation	Chaya Quartzose Sandstone Member	Sandstone, quartzose; 700 m
			Stepanoviella—bearing sandy siltstone member; 1 m	
			Chataje Diamictite Member	Glacio-marine sediments; about 30 m
	C_{1+2}	Naxing Formation		Shale, gray intercalated with quartz sandstone and a little marlite; 1,888 m
		Yali Formation		Alternating beds of marlite and shale; 60 m
DEVONIAN	D_{2+3}	Pochu Group	Upper Formation	Shale, grayish-black intercalated with sandstone; 66 m
			Lower Formation	Sandstone, light-gray, quartzose 12.56 m
	D_1	Liangquan Formation		Shale, dark-gray; 40 m
SILURIAN	S_{2+3}	Pulu Group		Sandstone, quartzose intercalated with calcareous shale and limestone; 46 m
	S_1	Shiqipo Formation		Sandstone, graptolithic shale and limestone; 90 m
ORDOVICIAN	O_3	Hongshantou Formation		Shale, brown intercalated with fine sandstone; 70 m
	O_2	Chiatsun Group	Upper Formation	Limestone, argillaceous, purplish-red 97 m
	O_1		Lower Formation	Limestone intercalated with dolomitic limestone and calcareous sandstone; 726 m
		Rouqicun Formation		Limestone, striped and laminated, marble; 237–48 m
6–Z		North Col Formation		Phyllite, quartzite, marble, biotite quartz schist, greater than 1,000 m
				FAULT
AnZ (?)		Nyalam Group		Kyanite schist, staurolite schist, sillimanite gneiss, marble, ocular and striped migmatite, greater than 10,000 m

Figure 2. Pre-Mesozoic stratigraphy of Tethys-Himalayan southern sub-belt in Xigaze District (modified from Organizing Committee; Scientific Guidebook to South Xizang, 1980, Tables 1–3).

The "Upper Formation" (unnamed) of the Chiatsun Group consists of 97 m of purplish-red, argillaceous limestone containing abundant nautiloids, crinoids, and brachiopods representing most of the Middle Ordovician (Organizing Committee; Scientific Guidebook to South Xizang, 1980, p. 83, 84). The nautiloids represent the widespread Asian (Tethyan) biozone of *Sinoceras chinense* (with *S. densum* and *Beloitoceras xizangense*) of Middle Ordovician (Llandeilian to Caradocian) age (Chen Jun-yuan, 1975; Chen Ting-en, 1981, p. 164).

Three blocks from the Middle Ordovician "Upper Formation" of the Chiatsun Group were processed for conodonts. One of the three limestone blocks (USGS colln. 9206–CO; 411 g), yielded *Cornuodus* cf. *C. longibasis* (Lindström) (5 elements), *Dapsilodus? similaris* (Rhodes), *Drepanoistodus* spp. (7 elements), *Drepanodus arcuatus* Pander, *Panderodus* sp. (3 elements), *Periodon* cf. *P. aculeatus* Hadding, *Protopanderodus varicostatus* (Sweet and Bergström) (14 elements), and *Pygodus serra* (Hadding) (1 haddingodontiform and 6 pygodontiform elements). The CAI of these elements is 5$^1/_2$, indicating that the host rock reached at least 300° C during or after burial. The conodonts from both productive Ordovician samples show little if any structural deformation; most of the problems of identification were due to fragmental specimens and adventitious material.

This species association represents an early Middle Ordovician fauna that is typical of the *Pygodus serra* Biozone of the North Atlantic Province; it is thus compatible with the cephalopod biozone date. The *P. serra* Zone correlates with the uppermost part of the Whiterockian Stage through the lower half of the Chazyan Stage of the North American, Middle Ordovician, Champlainian Series (see Bergström, 1977). This fauna also correlates with part of the Middle Ordovician sequence from southern Jiangsu Province reported by Chen Ming-juan and Chen Yan-tang (1979). The lower part of the range of this conodont association overlaps the upper limit of the possible range of the species association found in USGS colln. 9207–CO. The two horizons could be the same or nearly the same age, but these faunules show that at least they are consistent in sequence.

Although most of the taxa in these two Ordovician faunules are long-ranging within the Ordovician, the presence here of the Middle Ordovician zonal index *Pygodus serra* is of considerable biostratigraphic significance. Because of its short range and widespread occurrence, *P. serra* represents a taxon that can be used in correlation of Middle

Ordovician strata virtually around the globe. It is now known from both sides of the Atlantic Ocean (Bergström, 1971; 1973; Bergström and Carnes, 1976; Bergström, Riva, and Kay, 1974; Dzik, 1978; Hunter, 1978; Lamont and Lindström, 1957; Löfgren, 1978), from along the western side of the North American Cordillera (Harris and others, 1979; Tipnis and others, 1978; USGS collections made by AGH from southeastern Alaska) and from Australia (Nicoll, 1980) and possibly New Zealand (Simes, 1980), the Ural Mountains, USSR (Nassedkina and Puchkov, 1979), Xinxiang, South China (An Tai-xiang, 1981), southern Jiangsu, China (Chen Ming-juan and Chen Yun-tang, 1979), the eastern Yangtze Gorges (Zeng Qing-luan and others, 1983), and now Tibet.

CONCLUSIONS

These small samples provide important data on geographic extensions of several conodont species, some of which are of proven utility for regional and intercontinental correlation of Ordovician sequences. They also demonstrate the potential of conodonts in identifying sources of rocks found as introduced clasts in Tibetan Mesozoic conglomerates, melange, and olistostromes. The Ordovician succession northeast of Nyalam has the potential to provide an important sequence of North Atlantic Province conodont faunas, and further work on this and other Paleozoic rocks in the region is strongly encouraged.

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PLATES 1–2

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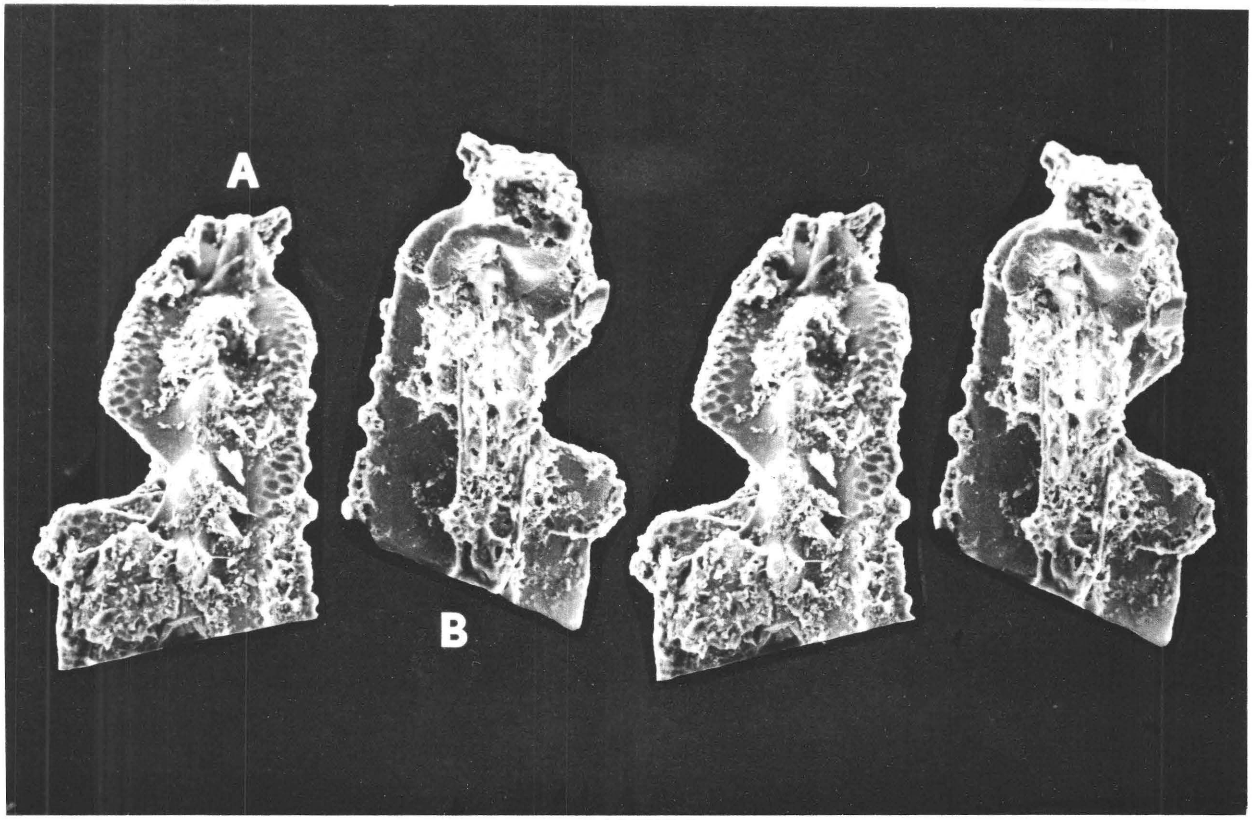
PLATE 1

Neogondolella sp. from locality KC–80–24-1. Stereo-pairs, upper (A) and lower (B) views of posterior platform fragment, USNM 398523, ×225.



NEOGONDOLELLA

PLATE 2

A, B. *Panderodus* cf. *P. sulcatus* (Fåhraeus); left lateral, ×200, and right lateral, ×165, respectively, views of graciliform elements USNM 398524 and 398525.

C. *Scolopodus* cf. *S. cornuformis* Sergeeva; inner lateral view of scandodontiform element, ×165, USNM 398526.

D. *Cornuodus longibasis* (Lindström); left lateral view, ×90, USNM 398527.

E. *Drepanodus?* sp.; lateral view of drepanodontiform element, ×66, USNM 398528.

F, G. *Protopanderodus varicostatus* (Sweet and Bergström); outer lateral, ×90, and inner lateral, ×100, views, respectively, of USNM 398529 and 398530. About half of the specimens in the collection have an anterobasal notch (pl. 2F).

H. *Drepanoistodus* sp; inner lateral view of drepanodontiform element, USNM 398531, ×100.

I, P. *Drepanodus arcuatus* Pander; inner lateral views of drepanodontiform, USNM 398532, ×100, and oistodontiform, USNM 398533, ×115, elements, respectively.

J. *Drepanoistodus?* sp.; lateral view of oistodontiform element, USNM 398534, ×115.

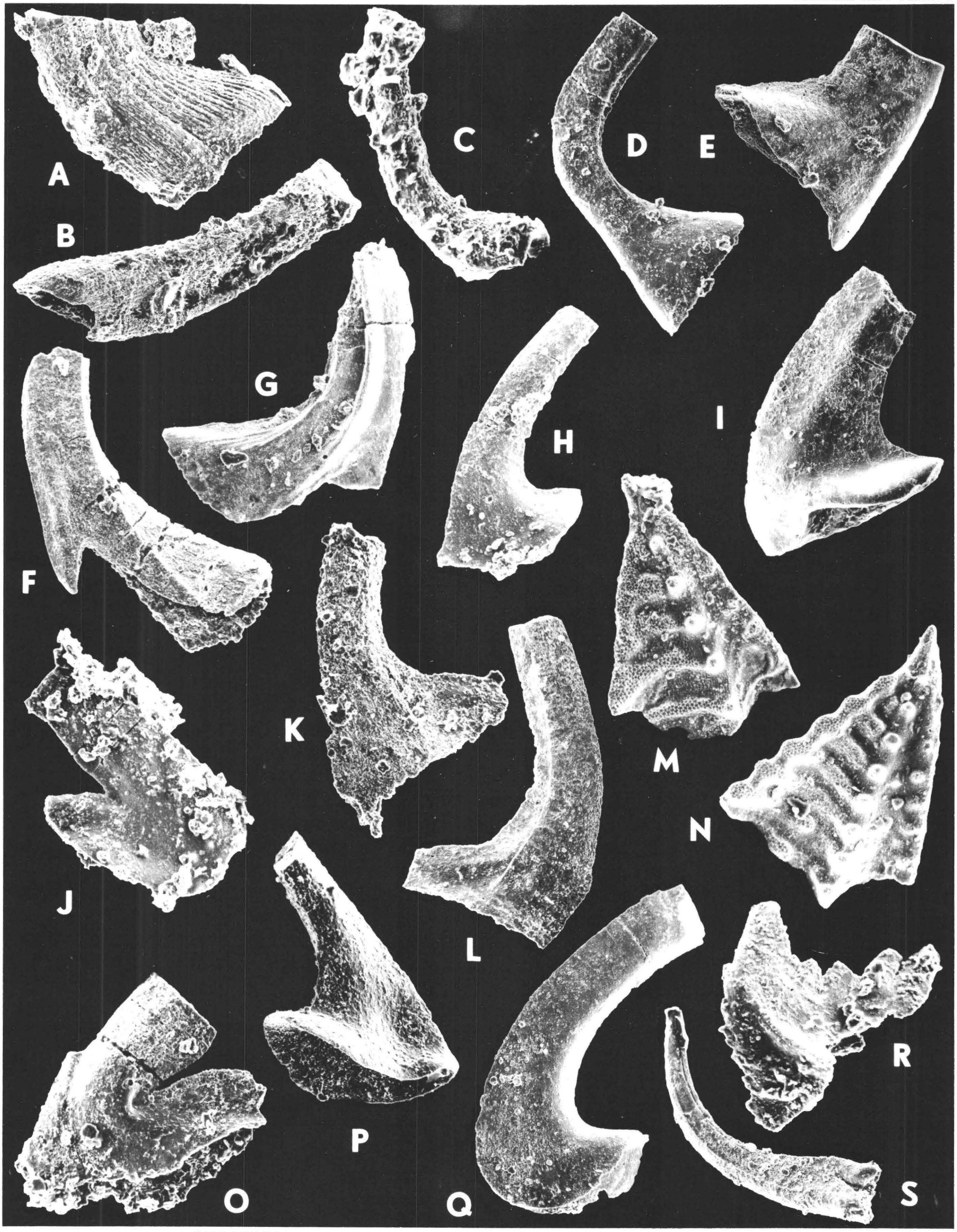
K, L. *Dapsilodus? similaris* (Rhodes); left, ×115 and right, ×80, lateral views of USNM 398535 and 398536, respectively.

M, N, R. *Pygodus serra* (Hadding); upper views of pygodontiform elements (M, N) USNM 398537 and 398538, both ×130 and lateral view of haddingodontiform element (R), USNM 398539, ×180.

O. *Periodon* cf. *P. aculeatus* Hadding; inner lateral view of falodontiform (=M) element, USNM 398540, ×130.

Q. *Drepanodus* sp.; inner lateral view of drepanodontiform element, USNM 398541, ×66.

S. *Panderodus* sp.; left lateral view, USNM 398542, ×80.



ORDOVICIAN CONODONTS FROM NYALAM ROAD SECTION