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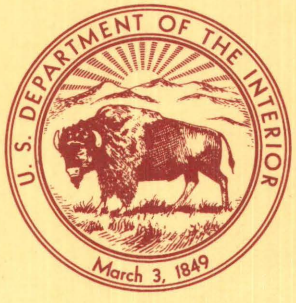

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Shorter Contributions to Paleontology and Stratigraphy

Edited by WILLIAM J. SANDO

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CONTENTS

[Letters designate the chapters]

Chapter A

Pachydesmoceras Spath, 1922, a Cretaceous Ammonite in Colorado

By WILLIAM A. COBBAN and W. JAMES KENNEDY

First record of the Cretaceous (Turonian) puzosiine ammonite genus *Pachydesmoceras* Spath, 1922, in the Western Interior of the United States

U.S. GEOLOGICAL SURVEY BULLETIN 1985

SHORTER CONTRIBUTIONS TO PALEONTOLOGY AND STRATIGRAPHY

CONTENTS

PLATE

Pachydesmoceras Spath, 1922, a Cretaceous Ammonite in Colorado

By William A. Cobban[1] *and* W. James Kennedy[2]

Abstract

A specimen of the ammonite *Pachydesmoceras linderi* (de Grossouvre) is described from an unnamed shale member of the Carlile Shale of Las Animas County, Colorado, and referred to the *Prionocyclus quadratus* zone of late Turonian age. It is the first record of the genus in North America and the second record of the subfamily Puzosiinae Spath, 1922, in the Turonian rocks of the Western Interior of the United States.

INTRODUCTION

The ammonite subfamily Puzosiinae Spath, 1922, is a long-ranging cosmopolitan group of ammonites that appears in the Hauterivian and extends to the upper Maastrichtian. Members of the subfamily are uncommon in Upper Cretaceous rocks of the Gulf Coast and Western Interior. The known record consists of (1) a single fragment of *Puzosia* (*Puzosia*) sp. from the middle Cenomanian *Acanthoceras bellense* zone in Texas (Kennedy and Cobban, 1990, p. 90); (2) *Puzosia* (*P.*) *serratocarinata* Kennedy and Cobban (1988, p. 595, figs. 2, 4), known from two fragments from the middle Turonian *Prionocyclus hyatti* zone of Chihuahua and five from Dallas and Travis Counties, Texas (Kennedy, 1988, p. 22, pl. 2, figs. 8–10, 12–14, 16–18; text fig. 26a); and (3) *Parapuzosia* (*Austiniceras*) *seali* Clark (1960, p. 235, pl. 34, figs. 1–3), known from the holotype from Dallas County and a specimen from Travis County, Texas, both from the middle Turonian *Prionocyclus hyatti* zone. *Parapuzosia bosei* Scott and Moore (1928, p. 274, pl. 36, figs. 1–3; pl. 37, fig. 2) is represented by a number of specimens from the lower Campanian of Travis, Williamson, Dallas, and Kinney Counties in Texas (Young, 1963, p. 52). *Parapuzosia* (*P.*) aff. *bradyi* of Young (1963, p. 52, pl. 7, figs. 2, 3; pl. 9, figs. 1, 3, 4; pl. 11, fig. 1; text fig. 8d) is known by a few specimens from the probable lower Campanian of central and Trans-Pecos Texas; *Parapuzosia* (*P.*) *terryi* Young (1963, p. 53, pl. 10, figs. 2–4) is represented only by the holotype from the Campanian of Terry County, Texas. *Parapuzosia paulsoni* Young, 1963, is, in our view, a *Pachydiscus*. North of Texas, only *Parapuzosia bradyi* Miller and Youngquist (1946, p. 481, pl. 73, figs. 1, 2; pl. 74, figs. 1, 2; pl. 15, figs. 1–3) is known; it is from the lower Campanian of central Montana.

The present record of a *Pachydesmoceras* is thus only the second occurrence of the Puzosiinae in the Western Interior. *Pachydesmoceras* comes from southern Colorado, an area that was commonly the northern limit of penetration of cosmopolitan genera into the Western Interior seaway—for example, *Vascoceras* and *Pseudaspidoceras* in the lower Turonian (Cobban and Scott, 1972), *Texanites* in the Santonian (Scott and Cobban, 1964), and *Menabites* in the lower Campanian (Chapter C, this volume). *Pachydesmoceras* ranges from late Albian to early Coniacian and has been recorded from northwestern and central Europe (Germany, France, Spain, Switzerland, Rumania, Yugoslavia), Morocco, Iran, southern India, Madagascar, Zululand (South Africa), Japan, California, and New Zealand. Given its large geographic range, it can hardly be classed as one of the "tropical" or tethyan ammonites of Kauffman (1984) that are supposed to have periodically spread into the Western Interior. Rather, exclusion of Puzosiinae and many other cosmopolitan groups reflects the same complex environmental factors that were special to the Western Interior seaway for much of the Late Cretaceous and that excluded or greatly reduced the diversities of groups such as coleoids, brachiopods, ectoprocts, cnidarians, poriferans, and echinoderms.

The specimen described below is kept in the National Museum of Natural History (USNM) in Washington, D.C., and carries USNM catalogue number 433910. R.E. Burkholder, recently retired from the U.S. Geological Survey, photographed the specimen. E.G. Kauffman of the University of Colorado, Boulder, kindly donated the specimen.

Kennedy acknowledges the financial support of the Natural Environment Research Council (U.K.) and the

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assistance of the staff of the Geological Collections, Oxford University Museum, and the Department of Earth Sciences (Oxford).

SYSTEMATIC PALEONTOLOGY

Superfamily DESMOCERATACEAE Zittel, 1895
Subfamily PUZOSIINAE Spath, 1922

Genus *Pachydesmoceras* Spath, 1922

Type species.—*Ammonites denisonianus* Stoliczka, 1865, p. 133, pl. 65, fig. 4; pl. 66; pl. 66a, by original designation (Spath, 1922, p. 127).

***Pachydesmoceras linderi* (de Grossouvre)**

Plate 1

1893 [1894]. *Pachydiscus linderi* A. de Grossouvre, p. 188, pl. 18, pl. 24, fig. 4.
1899. *Pachydiscus linderi* de Grossouvre. Simionescu, p. 20.
1922. *Nowakites linderi* (Grossouvre). Spath, p. 24.
1939. *Nowakites linderi* de Gross. Basse, p. 47, fig. 3 on p. 42.
1961. *Pachydesmoceras linderi* Gross. Collignon, p. 41, 89, pl. 10, fig. 1.
1965. *Pachydesmoceras linderi* de Grossouvre. Collignon, p. 8, pl. 379.
1966 [1967]. *Pachydesmoceras linderi* de Grossouvre. Collignon, p. 33, pl. 18, fig. 4.
1981 [1983]. *Pachydesmoceras* aff. *linderi* (de Grossouvre). Collignon, p. 188.
1988. *Pachydesmoceras linderi* (de Grossouvre). Matsumoto, p. 22, 121, 124.

Type.—Holotype by original designation is the original of de Grossouvre (1893, p. 188, pl. 18) from the lower part of the "étage Coniacien," near Padern (Aude), France. A paratype is the original of de Grossouvre (1893, pl. 24, fig. 4) from the Marnes à *Micraster* (Coniacian) of Bugarach, Aude, France.

Material.—Hypotype USNM 433910 is from U.S. Geological Survey Mesozoic locality D12185, from a lenticular limestone bed in an unnamed shale member at the top of the Carlile Shale 4.8 km north of Thatcher in the SE1/4 sec. 22, T. 28 S., R. 60 W., Las Animas County, Colorado. Upper Turonian, *Prionocyclus quadratus* zone. Collected by E.G. Kauffman of the University of Colorado, Boulder.

Description.—The specimen is a wholly septate fragment of a large ammonite having a maximum preserved whorl height of 110 mm, preserved in part as an internal mold in biosparite; calcite-replaced shell is present in some areas. The whorl section appears to have been compressed oval to lanceolate, having a whorl breadth to height ratio of 0.5, although the compression is in part due to crushing; the greatest breadth is low on the flanks. The umbilicus is shallow and of moderate width and has a low, rounded wall. The inner flanks are broadly rounded, the outer flanks flattened and convergent, and the venter narrowly rounded. Seventeen primary ribs are preserved on the fragment. They arise at the umbilical seam and strengthen across the umbilical wall and shoulder, but no true bullae are developed. The ribs are prorsiradiate and slightly flexuous on the flanks; they strengthen across the flank and project forward over the ventrolateral shoulder, where they become slightly concave. Short intercalated ribs are inserted irregularly on the outermost flank; they strengthen across the ventrolateral shoulder and have a ventral development comparable to that of the primary ribs. The sutures are not exposed.

Discussion.—*Pachydesmoceras linderi* most closely resembles *Pachydesmoceras denisonianum* (Stoliczka, 1865, p. 133, pl. 66a only; *fide* Matsumoto, 1988, p. 109) from the Uttatur Group of Odium in southern India. But *P. linderi* is much more evolute and has fewer, distant ribs that are markedly concave (see Collignon, 1961, pl. 8; Matsumoto, 1988, p. 109, figs. 48–49). Species such as the Cenomanian *Pachydesmoceras rarecostatum* Collignon (1961, p. 40, pl. 9, fig. 1) from Madagascar are very evolute and have depressed whorl sections and very widely separated, coarse primary ribs. *Pachydesmoceras hourcqui* Collignon (1961, p. 42, pl. 11), an upper Turonian species from Madagascar, has only 13 primary ribs on the outer whorl and as many as 5 intercalated ribs. *Pachydesmoceras radayoi* Collignon (1964, p. 58, pl. 333, fig. 1498), from the middle Cenomanian of Madagascar, is highly distinctive, having only 13 distant flared primary ribs per whorl. *Pachydesmoceras hottingeri* Collignon (1966, p. 82, pl. 2), from the Albian of Morocco, is very finely and densely ribbed, the ribs being branched on the outer flank and having occasional constrictions; the species belongs to some other genus of Puzosiinae. *Pachydesmoceras maroccanum* Collignon (1966, p. 26, pl. 12, fig. 4), from the Cenomanian of Morocco, has flexuous and crowded ribs, some of them markedly stronger than others; it is immediately distinguished from the present species. *Pachydesmoceras pachydiscoide* Matsumoto (1954, p. 101, pl. 9, fig. 2), from the Turonian of Sakhalin, has constrictions and very distant long ribs at a size comparable to the holotype of *P. linderi*. *Pachydesmoceras colusaense* (Anderson, 1902, p. 96, pl. 5, figs. 128, 129; pl. 10, fig. 200; Anderson, 1958, p. 236, pl. 10, fig. 1; Matsumoto, 1959, p. 62), from the probable upper Albian of California, is much more densely and flexuously ribbed than the present species and has prominent constrictions when young. Differences from Japanese species are clear from the recent account of Matsumoto (1988).

Occurrence.—Turonian and Coniacian of the Corbières, Aude, France; undifferentiated Senonian of the eastern Carpathians; upper Turonian of Morocco and Madagascar; upper Turonian of Las Animas County, Colorado.

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PLATE 1

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

PLATE 1

Pachydesmoceras linderi (de Grossouvre) (p. A2)

[Figure natural size]

Hypotype USNM 433910, from the top of the Carlile Shale at USGS Mesozoic locality D12185 in the SE¼ sec. 22, T. 28 S., R. 60 W., Las Animas County, Colorado.

PACHYDESMOCERAS LINDERI

Chapter B

New Records of the Ammonite Subfamily Texanitinae in Campanian (Upper Cretaceous) Rocks in the Western Interior of the United States

By WILLIAM A. COBBAN and W. JAMES KENNEDY

Descriptions and illustrations of rare occurrences of a cosmopolitan ammonite subfamily

U.S. GEOLOGICAL SURVEY BULLETIN 1985

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PLATES

New Records of the Ammonite Subfamily Texanitinae in Campanian (Upper Cretaceous) Rocks in the Western Interior of the United States

By William A. Cobban[1] *and* W. James Kennedy[2]

Abstract

All known members of the stratigraphically important and cosmopolitan ammonite subfamily Texanitinae are documented from the Campanian rocks of the Western Interior of the United States for the first time. *Submortoniceras tequesquitense* Young, 1963, occurs in the upper part of the Mancos Shale in Santa Fe County in north-central New Mexico; *Menabites (Delawarella) vanuxemi* (Morton, 1830) occurs in the Mancos Shale at Sandoval County, New Mexico; and *Menabites (Delawarella) danei* Young, 1963, occurs at the top of the Apache Creek Sandstone Member of the Pierre Shale in Pueblo County, Colorado.

INTRODUCTION

The ammonite subfamily Texanitinae Collignon, 1948, is a group of at least 15 genera/subgenera of strongly ribbed and tuberculate ammonites that are known from rocks of middle Coniacian to late Campanian age. The Texanitinae have a wide distribution outside the Western Interior of the United States—from the Gulf and Atlantic Coasts, California, Venezuela, Colombia, South Africa (Zululand), Madagascar, North Africa, Angola, Nigeria, the Middle East, western and central Europe (from Spain to Bornholm in the Baltic), and Japan. Texanitines are particularly diverse and common in Zululand and Madagascar, the Gulf Coast, and Japan and have been used as zone fossils over most of their area of occurrence, providing indices for some of the "standard" zones of Coniacian, Santonian, and Campanian Stages (de Grossouvre, 1894, 1901; Kennedy, 1984). By contrast, the group is largely missing from the Western Interior region, as are so many cosmopolitan ammonite groups (Cobban, in press). *Protexanites* ranged as far north as southern Montana during the late Coniacian. *Texanites*, *Plesiotexanites*, and *Reginaites* are known from rare individuals in the Santonian in New Mexico, and *Texanites* extends to southeastern Colorado. For the Campanian, the longest stage of the Cretaceous, the only possible described specimen is a fragment referred to the exclusively Campanian genus *Submortoniceras* Spath, 1926, by Miller (1970, p. 542, pl. 2, figs. 4, 5), from the *Clioscaphites choteauensis* zone in the Niobrara Formation in Rooks County, Kansas. But the *C. choteauensis* zone is Santonian in age (Obradovich and Cobban, 1975), and the specimen may well be no more than a crushed *Texanites* or *Plesiotexanites*. The four specimens described herein are thus the only unequivocal records of the Texanitinae from the Campanian of the Western Interior seaway; the only other specimen known to us is a generically indeterminate fragment from U.S. Geological Survey (USGS) Mesozoic locality D11394 in the NE¼NE¼ sec. 13, T. 28 N., R. 22 E., Colfax County, New Mexico, associated with *Scaphites hippocrepis* III.

SYSTEMATIC PALEONTOLOGY

Superfamily ACANTHOCERATACEAE de Grossouvre, 1894
Family COLLIGNONICERATIDAE Wright and Wright, 1951

Subfamily TEXANITINAE Collignon, 1948

Genus *Menabites* Collignon, 1948

Type species.—*Menabites menabensis* Collignon, 1948, p. 64, pl. 17, figs. 3, 4; pl. 18, fig. 1, by subsequent designation by Wright, 1957, p. L432.

Subgenus *Delawarella* Collignon, 1948

Type species.—*Ammonites delawarensis* Morton, 1830, p. 244, pl. 2, fig. 4, by original designation.

***Menabites (Delawarella) danei* (Young, 1963)**

Plate 1, figures 3, 4

Manuscript approved for publication March 21, 1991.

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[2]Geological Collections, University Museum, Parks Road, University of Oxford, Oxford OX1 3PW, U.K.

1929. *Mortoniceras delawarense* (Morton). Dane, pl. 10, figs. 1, 2.
1963. *Delawarella danei* Young, p. 114, pl. 57, fig. 6; pl. 62, figs. 1, 2; pl. 64, figs. 1, 5; pl. 65, figs. 1, 2; pl. 66, figs. 3, 4; text figs. 24c, 33b.

Types.—Holotype by original designation is Texas Memorial Museum no. 30646, from "a formation equivalent to the Gober Chalk," 1.6 km west of the Oklahoma boundary on the highway from Foreman, Ark., to Tom, Okla., in McCurtain County, Oklahoma (Young, 1963, p. 114). Hypotypes National Museum of Natural History (USNM) 441430 and 441431 from the Pierre Shale of Pueblo County, Colorado.

Description.—The two specimens from Colorado are crushed but retain original shell material. USNM 441430 (pl. 1, fig. 3) is 82 mm in diameter. Coiling is very evolute, the umbilical diameter being 33 percent. The umbilical wall is deeply notched to accommodate the submarginal tubercles of the preceding whorl. There are 9 or 10 strong, subspinose umbilical tubercles per whorl, which give rise to strong, coarse, prorsiradiate ribs, separated by deep, equal or somewhat wider interspaces. All ribs bear a strong, conical, submarginal tubercle that is the septate base of a spine, preserved in its entirety on some of the ribs on the inner whorl. Low, broad ribs link these submarginal tubercles to coarse external clavi that are approximately twice as numerous as the submarginals. This relationship is clearly demonstrated in USNM 441431 (pl. 1, fig. 4). Both specimens have a broad, shallow groove separating the clavi from a coarse, blunt siphonal ridge.

Discussion.—*Menabites* (*Delawarella*) *danei* is a highly distinctive species, characterized by the persistence of a trituberculate *Australiella* stage to a large diameter (as seen in both the present specimens) and very coarse ornament overall. These features distinguish it from *Menabites* (*Delawarella*) *delawarensis* (Morton, 1830) and *M.* (*D.*) *vanuxemi* (Morton, 1830), as well as other North American representatives of the subgenus discussed by Young (1963).

Occurrence.—The holotype was presumed to be early Campanian by Young (1963); however, the top of the Gober Chalk (Roxton Limestone Member), which yielded other specimens cited by Young at Roxton in Lamar County, Texas, is some way above the base of the Campanian, because the Gober Chalk yields *Hoplitoplacenticeras* aff. *plasticum* Paulcke, 1907, and late forms of *Scaphites* (*Scaphites*) *hippocrepis* DeKay, 1828, form III of Cobban (1969). The species also occurs higher, at the level of an omission surface and phosphate bed in the Ozan Formation 45.7 m above the top of the Gober Chalk at USGS Mesozoic locality D10154 in the channel of the North Sulphur River in Fannin County, Texas, associated with *Trachyscaphites spiniger spiniger* (Schlüter, 1872). The specimen figured by Dane (1929, pl. 10, figs. 1, 2) is from near the base of the Ozan Formation 8.8 km northwest of Foreman in Little River County, Arkansas. Hypotype USNM 441430 is from a calcareous concretion in the *Baculites obtusus* zone at the top of the Apache Creek Sandstone Member of the Pierre Shale at USGS Mesozoic locality D2812 in the SW¼ sec. 25, T. 19 S., R. 65 W., Pueblo County, Colorado. Hypotype USNM 441431 is from the same stratigraphic position but from USGS Mesozoic locality D1229 east of U.S. Highway 85–87 bridge over Steele Hollow 12 km north of Pueblo in the SE¼ sec. 12, T. 19 S., R. 65 W., Pueblo County, Colorado.

Menabites (*Delawarella*) *vanuxemi* (Morton, 1830)

Plate 1, figure 5; plate 2, figures 1–3

1830. *Ammonites vanuxemi* Morton, p. 244, pl. 3, figs. 4, 5.
1962. *Submortoniceras vanuxemi* (Morton). Reeside, p. 133, pl. 72, figs. 4, 5 (with full synonymy).
1963. *Submortoniceras vanuxemi* (Morton). Young, p. 98, pl. 54, fig. 3; pl. 56, fig. 2; pl. 57, fig. 7; pl. 58, fig. 3; pl. 67, fig. 3; pl. 69, figs. 1, 2, 6; text figs. 12c, e; 26d, e.
1980. *Submortoniceras vanuxemi* (Morton). Klinger and Kennedy, p. 232.

Types.—Holotype by monotypy is no. 19492 in the collections of the Academy of Natural Sciences of Philadelphia, from the Chesapeake and Delaware Canal in Delaware. It was refigured by Reeside (1962, pl. 72, figs. 4, 5). Hypotype is USNM 441432 from Sandoval County, New Mexico.

Description.—USNM 441432 is a large specimen, septate to 175 mm, and has a large part of the body chamber. Dimensions and ratios of the diameter at 137.0 mm are breadth, 46.5 mm (33.9 percent); height, 56.5 mm (41.2 percent); and umbilicus, 43.5 mm (31.7 percent). The whorl section is compressed (whorl breadth to height ratio, 0.82) and has broadly rounded inner flanks, flattened convergent outer flanks, abruptly rounded ventrolateral shoulders, and a carinate, bisulcate venter. Coiling is evolute; *U* is 31 to 32 percent of diameter, and 30 percent of the previous whorl is covered. The umbilicus is of moderate depth, having a flattened wall and an abruptly rounded umbilical shoulder. There are 22 or 23 small, sharp umbilical bullae per whorl that project into the umbilicus and are separated by deep interspaces that notch the umbilical wall. The bullae give rise to straight prorsiradiate primary ribs either singly or in pairs, totaling 35 or 36 per whorl. Each rib bears a small bullate lateral tubercle, a weaker, conical submarginal tubercle, and a stronger rounded to slightly clavate marginal tubercle. All ribs bear strong external clavi that are twice as numerous as the tubercles in the other rows, numbering more than 60 per whorl. A broad, shallow groove separates the clavi from a blunt siphonal ridge. The submarginal tubercles disappear

beyond a diameter of 80 mm, and the ribs are then quadrituberculate to the end of the phragmocone. Sutures are not seen.

Discussion.—Collignon (1948) and some subsequent authors referred Morton's *Ammonites vanuxemi* to the genus *Submortoniceras* Spath, 1926. But, whereas the latter is a compressed and involute derivative of *Texanites* (*Texanites*) Spath, 1932, *Menabites* (*D.*) *vanuxemi* is a homoeomorphous (in shell shape at least) species of *Menabites* (*Delawarella*). This conclusion is based on the distinctive multiplication of the external tubercles to twice the number per whorl of the marginals, a typical *M.* (*Delawarella*) feature not seen in *Submortoniceras*. This character alone serves to distinguish the species from the various superficially similar *Submortoniceras* known from the Gulf Coast region and described by Young (1963) and Wolleben (1967). The compressed whorls, feeble ornament, and involute coiling equally distinguish the species from other North American *M.* (*Delawarella*) species (Reeside, 1962; Young, 1963).

Occurrence.—According to Reeside (1962), this species is best known from the Merchantville Formation in New Jersey and the Merchantville Formation on the Chesapeake and Delaware Canal, where it is regarded as early Campanian in age. The species has also been recorded from the lower Campanian *Delawarella delawarensis* zone in Brewster, Travis, and Val Verde Counties in Texas (Young, 1963). *Menabites* (*D.*) *vanuxemi* also occurs at a much higher horizon, in the upper Campanian, associated with *Trachyscaphites spiniger spiniger* (Schlüter) in the Ozan Formation at USGS Mesozoic locality D10154 in Fannin County, Texas. Hypotype USNM 441432 is from the upper part of the Mancos Shale at USGS Mesozoic locality 16829 in the NW¼ sec. 26, T. 23 N., R. 1 W., Sandoval County, New Mexico.

Genus *Submortoniceras* Spath, 1926

Type species.—*Mortoniceras woodsi* Spath, 1921, p. 232, pl. 21, fig. 1, by original designation.

Submortoniceras tequesquitense Young, 1963

Plate 1, figures 1, 2

1963. *Submortoniceras tequesquitense* Young, p. 97, pl. 28, fig. 1; pl. 42, figs. 1, 2; pl. 44, figs. 4, 5; pl. 51, figs. 1, 2; pl. 52, figs. 1–4; pl. 57, fig. 4; pl. 70, fig. 1; text figs. 12b, 28b.

Type.—Holotype is no. 34742 in the collections of the Texas Memorial Museum in Austin and is from the upper part of the Dessau Formation "downstream from the concrete spillway of the new (1932) Del Rio-Eagle Pass highway crossing on Tequesquite Creek, Kinney County, Texas" (Young, 1963, p. 97). Hypotype USNM 441433 is from Santa Fe County, New Mexico.

Description.—USNM 441433 is a septate fragment that lacks the umbilical region. The maximum preserved whorl height is 45 mm. The whorl section appears to have been compressed and has broadly rounded inner flanks, flattened, convergent outer flanks, and a carinate, bisulcate venter. The flanks are ornamented by low, broad, prorsiradiate ribs, all of which bear weak, rounded lateral tubercles; slightly clavate, weak submarginal tubercles; somewhat stronger clavate marginal tubercles; and strong external clavi. A broad groove separates the clavi from a blunt siphonal ridge. Sutures are not seen.

Discussion.—That the tubercles in all rows present correspond in number show this specimen to be a *Submortoniceras* rather than a weakly ornamented *Menabites* (*Delawarella*). The fragment differs in no significant respects from *S. tequesquitense*. The well-differentiated ribs and tubercles separate this species from other North American species, such as the more weakly ornamented *S. sancarlosense* Young, 1963 (p. 100, pl. 55, figs. 1–4; pl. 62, fig. 3; text figs. 20g, 27d), *S. mariscalense* Young, 1963 (p. 104, pl. 59, fig. 3; pl. 60, figs. 1, 4–6; text figs. 14b, f), *S. uddeni* Young, 1963 (p. 105, pl. 5, figs. 1, 2, 4–9; pl. 60, figs. 2, 3, 7, 9, 10; text figs. 14d, e, 28c) and *S. vandaliaense* Young, 1963 (p. 102, pl. 55, figs. 6, 7; text fig. 26a). *Submortoniceras candelariae* Young, 1963 (p. 102, pl. 56, figs. 1, 3, 4; pl. 60, fig. 8; text figs. 20b; 28a, f; 29a, e; 34a, f) is a *Texanites* (*Plesiotexanites*) (Matsumoto, 1970, p. 279).

Occurrence.—*Submortoniceras tequesquitense*, the index fossil of the lowest lower Campanian zone in the sequence erected by Young (1963) for Texas, is known from Kinney, Travis, and Williamson Counties, according to Young. The J.P. Conlin Collection, now in the Branch of Paleontology and Stratigraphy at the USGS in Denver, has good specimens from the Porvenir area in Presidio County, Texas. Hypotype USNM 441433 is from the upper 16 m of the Mancos Shale in sec. 6, T. 21 N., R. 9 E., Santa Fe County, New Mexico.

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PLATES 1, 2

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

PLATE 1

Submortoniceras and *Menabites*

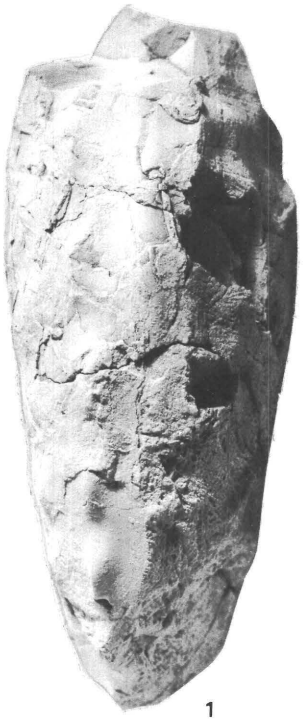
[All figures natural size]

Figures 1, 2. *Submortoniceras tequesquitense* Young (p. B3). Hypotype USNM 441433, from the Mancos Shale at USGS Mesozoic locality D3665 in sec. 6, T. 12 N., R. 9 E., Santa Fe County, New Mexico.

3, 4. *Menabites* (*Delawarella*) *danei* Young (p. B1).

3. Hypotype USNM 441430, from the Pierre Shale at USGS Mesozoic locality D2812 in the SW¼ sec. 25, T. 19 S., R. 65 W., Pueblo County, Colorado.
4. Hypotype USNM 441431, from the Pierre Shale at USGS Mesozoic locality D1229 in the SE¼ sec. 12, T. 19 S., R. 65 W., Pueblo County, Colorado.

5. *Menabites* (*Delawarella*) *vanuxemi* (Morton) (p. B2). Hypotype USNM 441432, from the Mancos Shale at USGS Mesozoic locality 16829 in the NW¼ sec. 26, T. 23 N., R. 1 W., Sandoval County, New Mexico. See plate 2 for other views.



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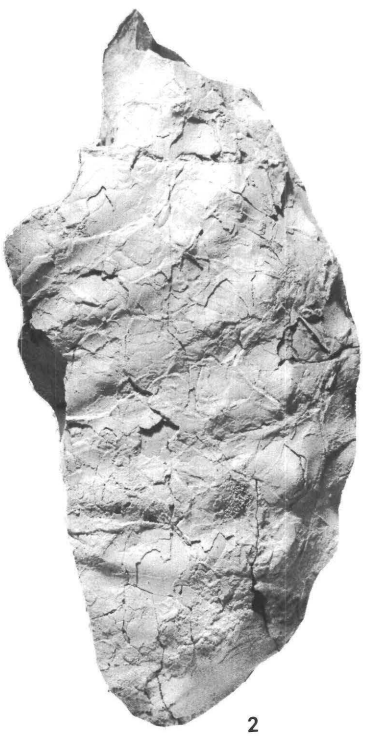

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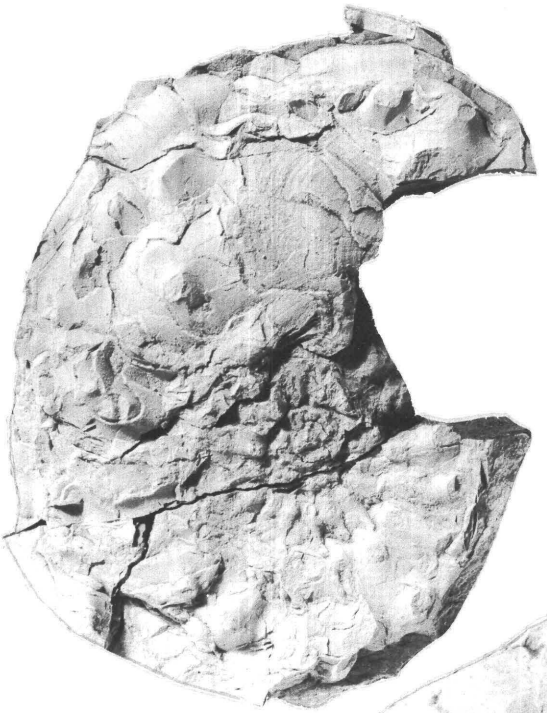

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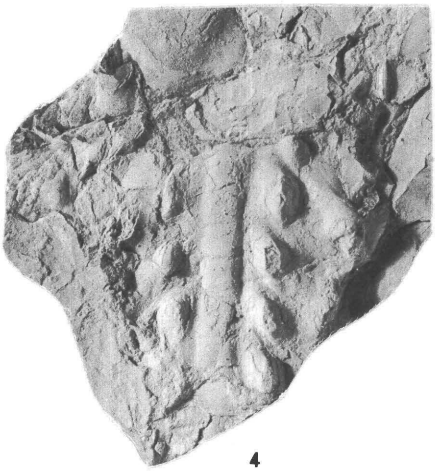

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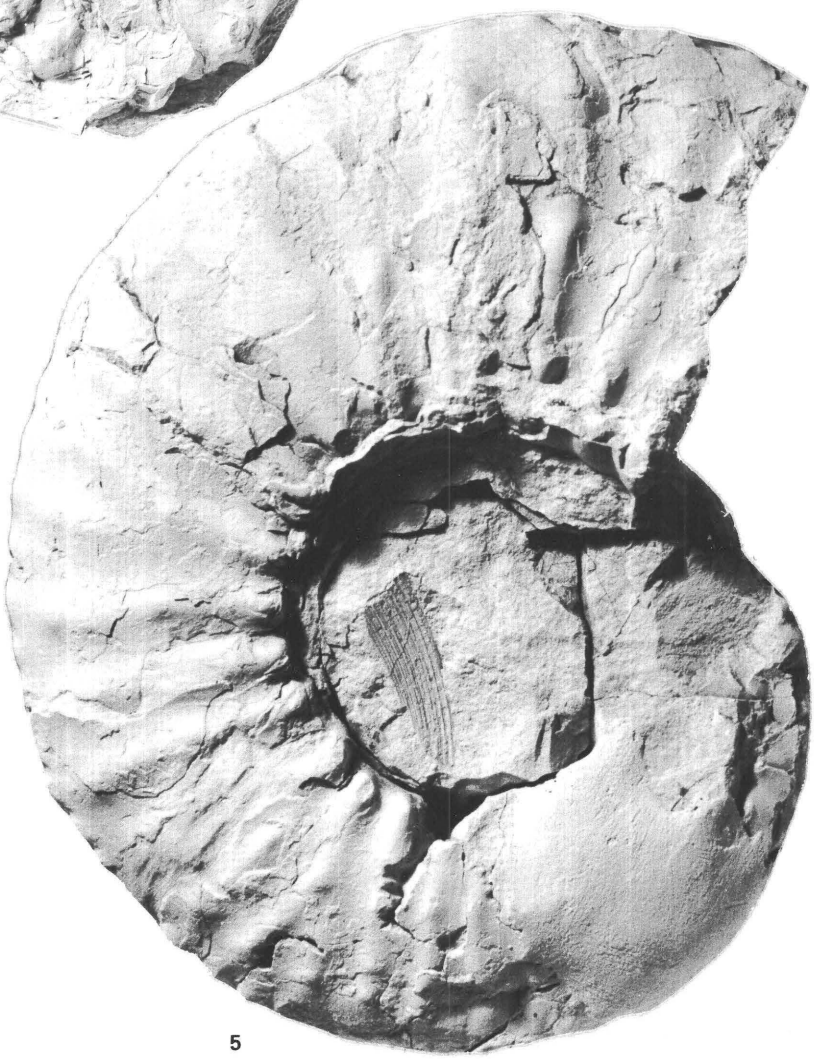

5

SUBMORTONICERAS AND *MENABITES*

PLATE 2

Menabites (*Delawarella*) *vanuxemi* (Morton) (p. B2).

[All figures natural size]

Figures 1–3. Hypotype USNM 441432, from the Mancos Shale at USGS Mesozoic locality 16829 in the NW¼ sec. 26, T. 23 N., R. 1 W., Sandoval County, New Mexico. See plate 1, figure 5, for another view.

1 2 3

MENABITES (DELAWARELLA) VANUXEMI

Chapter C

Some Upper Cretaceous Ammonites from the Nacatoch Sand of Hempstead County, Arkansas

By WILLIAM A. COBBAN and W. JAMES KENNEDY

Description of a distinctive ammonite fauna from the Gulf Coast region

U.S. GEOLOGICAL SURVEY BULLETIN 1985

SHORTER CONTRIBUTIONS TO PALEONTOLOGY AND STRATIGRAPHY

CONTENTS

PLATE

Some Upper Cretaceous Ammonites from the Nacatoch Sand of Hempstead County, Arkansas

By William A. Cobban[1] *and* W. James Kennedy[2]

Abstract

Richly fossiliferous concretions from the middle, glauconitic member of the Nacatoch Sand of southwestern Arkansas include an ammonite assemblage here referred to as the *Nostoceras* (*Nostoceras*) *rugosum* zone. The index species is abundant, accompanied by *Solenoceras texanum* (Shumard, 1861), *S. nitidum* Cobban, 1974, and *Parasolenoceras pulcher* n.sp., all of which are described and illustrated; also present, but not described, are *Scaphites* (*Scaphites*) aff. *pumilis* Stephenson, 1941 and *Baculites claviformis* Stephenson, 1941.

INTRODUCTION

The fossils described in this report are from the Nacatoch Sand about 4 km northeast of Washington, Ark. The ammonite assemblage is dominated by *Nostoceras* (*Nostoceras*) *rugosum* n.sp., a form first illustrated by Owen (1860, pl. 8, fig. 2) and, thereafter, by Dane (1929, pl. 25, figs. 5, 6) and Freeman (1966, pl. 7, fig. 7). This species is associated with small numbers of the ammonites *Solenoceras texanum* (Shumard, 1861), *S. nitidum* Cobban, 1974, *Parasolenoceras pulcher* n.sp., *Baculites claviformis* Stephenson, 1941, and *Scaphites* (*Scaphites*) aff. *S. pumilis* Stephenson, 1941. We herein consider *N.* (*N.*) *rugosum* to characterize a distinct horizon, the *N.* (*N.*) *rugosum* zone, within the Upper Cretaceous of the Gulf coastal region. The Campanian-Maastrichtian ammonite sequence of this region is still poorly known, but the *N.* (*N.*) *rugosum* zone clearly lies above the distinctive *N.* (*N.*) *hyatti* zone of the Saratoga Chalk some 46 m or more below. Species in common between the Nacatoch and the Saratoga are *Solenoceras texanum* and *B. claviformis*. The *Scaphites* (*S.*) aff. *S. pumilis* is closely related to scaphites in the Saratoga. The *N.* (*N.*) *rugosum* zone is older than the *N.* (*N.*) *alternatum* zone (Cobban, 1974), which has only *Solenoceras nitidum* in common.

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The *N.* (*N.*) *hyatti* zone is regarded as late Campanian in ammonite terms, for reasons outlined by Cobban (1974), although traditional usage places the Campanian-Maastrichtian boundary at the boundary of the provincial Tayloran and Navarroan stages (for example, Brouwers and Hazel, 1978, fig. 10), below the Saratoga and within the Marlbrook Marl. Workers on nannofossils and planktonic forams also consider the Nacatoch Maastrichtian (for example, Pessagno, 1967) because it overlies the Saratoga, referred to the *Globotruncanita fornicata-stuartiformis* assemblage zone. These differences arise because the boundaries of zones based on different fossil groups around the limit of the Campanian and Maastrichtian stages fall at different levels in the Gulf Coast. There is a similar divergence in northwestern Europe and, indeed, no agreement as to where the Campanian-Maastrichtian boundary should be placed (see discussion by Birkelund and others, 1984, p. 16–17). We regard the *N.* (*N.*) *rugosum* zone as early Maastrichtian solely because it is younger than the zone of *N.* (*N.*) *hyatti*, which we consider as latest Campanian in ammonite terms. It may well prove necessary to revise this estimate when the position of the Campanian-Maastrichtian boundary is finally resolved.

Specimens described and illustrated here are kept in the National Museum of Natural History (USNM) in Washington, D.C. Plaster casts of some are kept at the Federal Center in Denver, Colo. The Arkansas Geological Commission in Little Rock provided transportation in the field in 1973 and 1974, and B.F. Clardy of the Commission greatly aided one of us (Cobban) in the field during those years.

NACATOCH SAND

The Nacatoch Sand is a complex suite of terrigenous clastic rocks that rests unconformably on the Ozan Formation, Marlbrook Marl, or Saratoga Chalk. The Nacatoch is overlain conformably by the Arkadelphia Marl. The best account of the stratigraphy of the Nacatoch is that of Dane (1929, p. 114–144), who noted that the formation thinned northeastward from 122 m near Saratoga in Howard County, just north of Hempstead County, to about 45 m

near Arkadelphia in Clark County. Dane (1929, p. 116, 117) divided the formation into three unnamed members: (1) a lower member of gray clay, sandy clay, marl, and very fine grained sandstone, (2) a middle member of greenish-gray, glauconitic, fossiliferous sandstone, and (3) an upper member of yellowish and reddish fine-grained, cross-bedded sandstone.

LOCALITY OF FOSSILS

The fossils described in this report came from large, greenish-gray, very fine grained, hard, calcareous sandstone concretions in the middle sandstone member at the locality described by Dane (1929, p. 119) as "[about] 3 miles northeast of Washington [along] the old military road...in the NE¼ sec. 14, T. 11 S., R. 25 W." Dane gave a measured section at this locality. The ammonite illustrated as *Turrilites* sp. undet. by Owen (1860, pl. 8, fig. 2) probably came from this locality, and the one illustrated by Dane (1929, pl. 25, figs. 5, 6) as *Nostoceras* sp. certainly came from here. Long after Dane's work, large collections of ammonites (chiefly *Nostoceras rugosum* n.sp.) were made at this locality by G.R. Scott in 1961 and by B.F. Clardy, R.E. Burkholder, and W.A. Cobban in 1973 and 1974. The collections of Scott, Clardy, and others have been assigned to USGS Mesozoic locality D7861.

SYSTEMATIC PALEONTOLOGY

Suborder ANCYLOCERATINA Wiedmann, 1966
Superfamily TURRILITACEAE Gill, 1871

Family NOSTOCERATIDAE Hyatt, 1894

Genus and Subgenus *Nostoceras* Hyatt, 1894

Type species.—*Nostoceras stantoni* Hyatt, 1894, p. 569, by original designation.

***Nostoceras (Nostoceras) rugosum* n.sp.**

Plate 1, figures 13–34

1860. *Turrilites* sp. undet. Owen, pl. 8, fig. 2.
1929. *Nostoceras* sp. Dane, pl. 25, figs. 5, 6.
1966. *Nostoceras* sp. Freeman, pl. 7, fig. 7.

Derivation of name.—Rugosus is Latin for "wrinkled."

Types.—Holotype is USNM 442093; figured paratypes are USNM 442094 to 442100 and 442107; three unfigured paratypes are USNM 442101, all from the Nacatoch Sand at USGS Mesozoic locality D7861, 4.8 km northeast of Washington on the old Confederate military road in Hempstead County, Arkansas.

Description.—Coiling is both dextral and sinistral. The species is strongly dimorphic, microconchs being much rarer than macroconchs. Microconchs are 25 mm high, and macroconchs are 50 to 65 mm high. The spire is quite high and has an apical angle of 32° to 37°. Whorls of the spire are in close contact, so that the greater part of the upper whorl face is concave to accommodate the lower surface of the preceding whorl. Outer and lower whorl faces are broadly rounded between ribs. A variable number of ribs, generally 45 to 50 per whorl, are present at the juncture of the upper and outer whorl faces. The ribs are crowded, prorsiradiate, and separated by very narrow interspaces. Ribs join in pairs at prominent transversely elongated tubercles located just below midflank. Single, coarse ribs, straight and prorsiradiate and numbering about 27 per whorl, extend from these tubercles to a second smaller row of tubercles that lies at the juncture of the outer and lower whorl faces. Ribs are coarse, concave, and prorsiradiate on the lower whorl face and may link in pairs close to the umbilicus. The last whorl of the body chamber is uncoiled and slightly recurved. The looped ribs between the upper whorl suture and the upper row of tubercles are replaced by a single rib in many specimens, separated by a few looped pairs, or even delicate intercalated ribs. The tubercles disappear a short distance before the adult aperture. There are prominent constrictions on the spire, three to four per whorl, flanked by collared ribs. As many as three constrictions are present on the uncoiled part, and the adult aperture is commonly preceded by a strong constriction, followed by a short section having nontuberculate ribs (pl. 1, figs. 22, 32). Sutures were not seen.

Discussion.—The type lot includes only one microconch (pl. 1, figs. 15–17). This specimen preserves only three whorls, which are very finely ribbed and have tubercles only on the body chamber, in contrast to the macroconchs, which possess two rows of tubercles throughout. Microconchs in the Adkins collection (Texas Memorial Museum, Austin) show a range of variation from nontuberculate to unituberculate to bituberculate early growth stages, both within and between individuals. The high spire and the coarse bituberculate ribs, looped between the upper whorl suture and the upper row of tubercles, readily distinguish *Nostoceras* (*N.*) *rugosum* n.sp. from species such as *N.* (*N.*) *angolaense* Haughton (1925, p. 275, pl. 15, fig. 1), *N.* (*N.*) *approximans* (Conrad, 1855, p. 266; see Conrad, 1860, pl. 47, fig. 4), *N.* (*N.*) *colubriformis* (Stephenson, 1941, p. 412, pl. 81, figs. 1–3), *N.* (*N.*) *draconis* Stephenson (1941, p. 413, pl. 82, figs. 5–9), *N.* (*N.*) *gracilis* Lewy (1967, p. 166, pl. 2, fig. 1), *N.* (*N.*) *helicinum* (Shumard, 1861; see Stephenson, 1941, p. 410, pl. 80, figs. 11, 12), *N.* (*N.*) *hyatti* Stephenson (1941, p. 410, pl. 81, figs. 9–12), *N.* (*N.*) *mariatheresianum* Haas (1943, p. 6, figs. 1b, 9), *N.* (*N.*) *minimum* Lewy (1969, p. 118, pl. 1, fig. 6), *N.* (*N.*) *natalense* Spath (1921, p. 248, pl. 22, fig. 2; see Klinger, 1976, p. 68, pl. 30, fig. 3; pl. 31, figs. 1–3), *N.* (*N.*) *obtusum* Howarth (1965, p. 384, pl. 10, fig. 2; text fig. 17), *N.* (*N.*) *rehavami* Lewy (1967, p. 168, pl. 1, fig. 4; pl. 4, figs. 1–4), *N.* (*N.*) *rotundatum* Howarth (1965, p. 381, pl. 10, fig. 3), and *N.* (*N.*)

splendidum (Shumard, 1861, p. 190; see Stephenson, 1941, p. 415, pl. 82, figs. 1–4). There are close similarities to *N.* (*N.*) *alternatum* (Tuomey, 1854; see Cobban, 1974, p. 86, figs. 1w–rr, 5) from the Ripley Formation of Mississippi and Alabama, which has the same pattern of ornament, but the spire is much lower in *alternans*, the upper row of tubercles lies at the base of the outer whorl face, and the lower row is on the lower whorl face, close to the umbilicus. Long spines extend from the tubercles of the upper row and rest between the ribs of the succeeding whorl. The shape and appearance of this species are thus quite different from those of *N.* (*N.*) *rugosum*, in spite of the basically similar rib and tubercle arrangment. *Nostoceras* (*N.*) *mendryki* Cobban (1974, p. 13, pl. 10, figs. 1–17; text fig. 11) is a much younger Maastrichtian species from the Navesink Formation of New Jersey. Like *N.* (*N.*) *rugosum*, it is bituberculate, but the tubercle rows are much closer together, the upper part of the outer whorl face is much lower, the lower whorl face has some ribs looping from the lower row of tubercles, the apical angle seems to be much lower, and there are no constrictions of the type developed by the present species. *Nostoceras* (*N.*) *pauper* (Whitfield, 1892, p. 268, pl. 45, figs. 1–5; Cobban, 1974, p. 12, pl. 9, figs. 1–22, text fig. 10) has an even lower apical angle to the spire than *N.* (*N.*) *rugosum* does, but it has basically the same pattern of ribs and tubercles. The two differ in that the whorls of *N.* (*N.*) *rugosum* are much lower, the ribs are weaker, and the tubercles are fewer.

Occurrence.—Abundant in the middle of the Nacatoch Sand along its belt of outcrop a few kilometers northwest, north, and northeast of Washington in Hempstead County, Arkansas. The species has not been found outside Hempstead County.

Family DIPLOMOCERATIDAE Spath, 1926
Subfamily DIPLOMOCERATINAE Spath, 1926

Genus *Solenoceras* Conrad, 1860

Type species.—*Hamites annulifera* Morton, 1842, by original designation.

***Solenoceras texanum* (Shumard, 1861)**

Plate 1, figures 1–6

1861. *Ptychoceras texanus* Shumard, p. 189.
1894. *Ptychoceras texanum* Shumard. Hyatt, p. 580.
1928. *Oxybeloceras texanum* (Shumard). Adkins, p. 213.
1941. *Solenoceras texanum* (Shumard). Stephenson, p. 399, pl. 77, figs. 4, 5; pl. 79, figs. 1–4.
1969. *Solenoceras* cf. *S. texanum* (Shumard). Lewy, p. 127, pl. 3, fig. 8.

Types.—Neotype, designated by Stephenson (1941, p. 399) is USNM 21092a, from the Nacatoch Sand near Chatfield in Navarro County, Texas. Hypotypes USNM 442104 and 442105 are from Hempstead County, Arkansas.

Description.—Two specimens are referred to Shumard's species. They both consist of two closely adpressed shafts having maximum whorl heights of 6.2 and 4.9 mm. The whorl section is compressed oval. The first shaft expands slowly and is ornamented by coarse, crowded, feebly concave prorsiradiate ribs; the rib index is 4 to 5, and all ribs bear blunt ventral tubercles linked across the venter by a strong, transverse rib. The ribs change direction from prorsiradiate to rursiradiate around the curve joining the two limbs, and the whorl height increases markedly. The dorsum of the larger shaft is concave to accommodate the dorsum of the smaller shaft. There are strong, crowded, straight to slightly convex rursiradiate ribs; the rib index is 5 to 6. All ribs bear blunt ventral tubercles connected over the venter by a strong transverse rib. Sutures were not seen.

Discussion.—These two specimens differ in no significant respects from the specimen figured by Stephenson (1941, pl. 77, figs. 4, 5), and we take them all to be macroconchs, whereas the neotype (Stephenson, 1941, pl. 79, figs. 1–4) is a microconch. The compressed whorl section and coarse ribbing immediately distinguish *Solenoceras texanum* from *S. annulifera* (Morton, 1841, p. 109; 1842, p. 213, pl. 11, fig. 4; Reeside, 1962, p. 121, pl. 70, figs. 8–10), *S. bembense* Haas (1943, p. 11, figs. 4, 14), *S. humei* Douvillé (1928, p. 37, pl. 6, figs. 9, 10; Lewy 1967, p. 170, pl. 3, figs. 1–4), *S. minimum* (Basse, 1931, p. 17, pl. 1, figs. 20, 22), *S. multicostatum* Stephenson (1941, p. 402, pl. 76, figs. 12–14), and *S. reesidei* Stephenson (1941, p. 401, pl. 77, figs. 1–3). *Solenoceras nitidum* Cobban (1974, p. 83, figs. 1a–k, 2) is a much smaller species that lacks tubercles.

Occurrence.—Nacatoch Sand at USGS Mesozoic locality D7861, 4.8 km northeast of Washington on the old Confederate military road; Nacatoch Sand near Chatfield in Navarro County, Texas. Lewy (1967) recorded a fragment that may belong to this species from the upper Campanian Mishash Formation of Israel.

***Solenoceras nitidum* Cobban, 1974**

Plate 1, figures 10–12

1974. *Solenoceras nitidum* Cobban, p. 83, figs. 1a–k, 2.

Types.—Holotype is USNM 187711, paratypes USNM 187712 to 187714, from USGS Mesozoic locality 18078, a scraped area north of the dam of Union County Lake, 1.8 km northeast of Pleasant Ridge, in NW ¼NE¼NE¼ sec. 11, T. 6 S., R. 4 E., Union County, Mississippi. Hypotype is USNM 442102 from Hempstead County, Arkansas.

Description.—USNM 442102 is 16 mm long and consists of two shafts in close contact, the dorsum of the larger shaft being grooved to accommodate the dorsum of the smaller. The whorl section is subcircular. Ornament consists of crowded ribs, prorsiradiate on the smaller shaft and rursiradiate on the larger, having a rib index of 7. The

ribs pass straight across the venter without developing tubercles. Sutures were not seen.

Discussion. — Lack of tubercles distinguishes *Solenoceras nitidum* from all other species referred to the genus.

Occurrence.—Nacatoch Sand at USGS Mesozoic locality D7861, 4.8 km northeast of Washington in Hempstead County, Arkansas; Coon Creek Tongue of Ripley Formation in Mississippi.

Genus *Parasolenoceras* Collignon, 1969

Type species.—*Parasolenoceras splendens* Collignon, 1969, p. 44, pl. 530, figs. 2087, 2088.

***Parasolenoceras pulcher* n.sp.**

Plate 1, figures 7–9

Derivation of name.—Pulcher is Latin for "beautiful."

Types.—Holotype USNM 442107, four unfigured paratypes USNM 442108, all from USGS Mesozoic locality D7861, Nacatoch Sand, 4.8 km northeast of Washington on the old Confederate military road in Hempstead County, Arkansas.

Diagnosis.—Small, having compressed whorl section; ribs delicate and crowded; rib index 7 to 8.

Description.—The holotype consists of two subparallel shafts, the smaller preserved to a length of 34 mm and the larger to a length of 25 mm, joined by a curved section that defines an umbilicus having a narrow separation between the shafts. The smaller shaft expands slowly and is compressed, the whorl breadth to height ratio being 0.78; the whorl section is compressed oval. Ornament consists of delicate, convex, prorsiradiate flank ribs; the rib index is 5. All ribs bear small ventral tubercles linked over the venter by a strong transverse rib. The larger shaft, which has a much higher expansion rate than the smaller one, has a whorl breadth to height ratio of 0.64. The rib index is 7; the ribs are slightly convex and rursiradiate and are of variable strength. Most bear small ventral tubercles linked over the venter by a coarse rib that in some cases shows signs of incipient subdivision. A few weaker, nontuberculate ribs intercalate. Sutures were not seen.

Discussion.—Compression, delicate ribs, and the presence of some specimens that lack tubercles readily distinguish the new species from *Parasolenoceras interruptum* (Schlüter, 1872, p. 102, pl. 32, figs. 8, 9). The type species, *P. splendens* (Collignon, 1969, p. 44, pl. 530, figs. 2087, 2088), is much larger than our material but differs equally in its less compressed whorl section and even tuberculation.

Occurrence.—Known only from Hempstead County, Arkansas.

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PLATE 1

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

PLATE 1

Solenoceras, *Parasolenoceras*, and *Nostoceras*

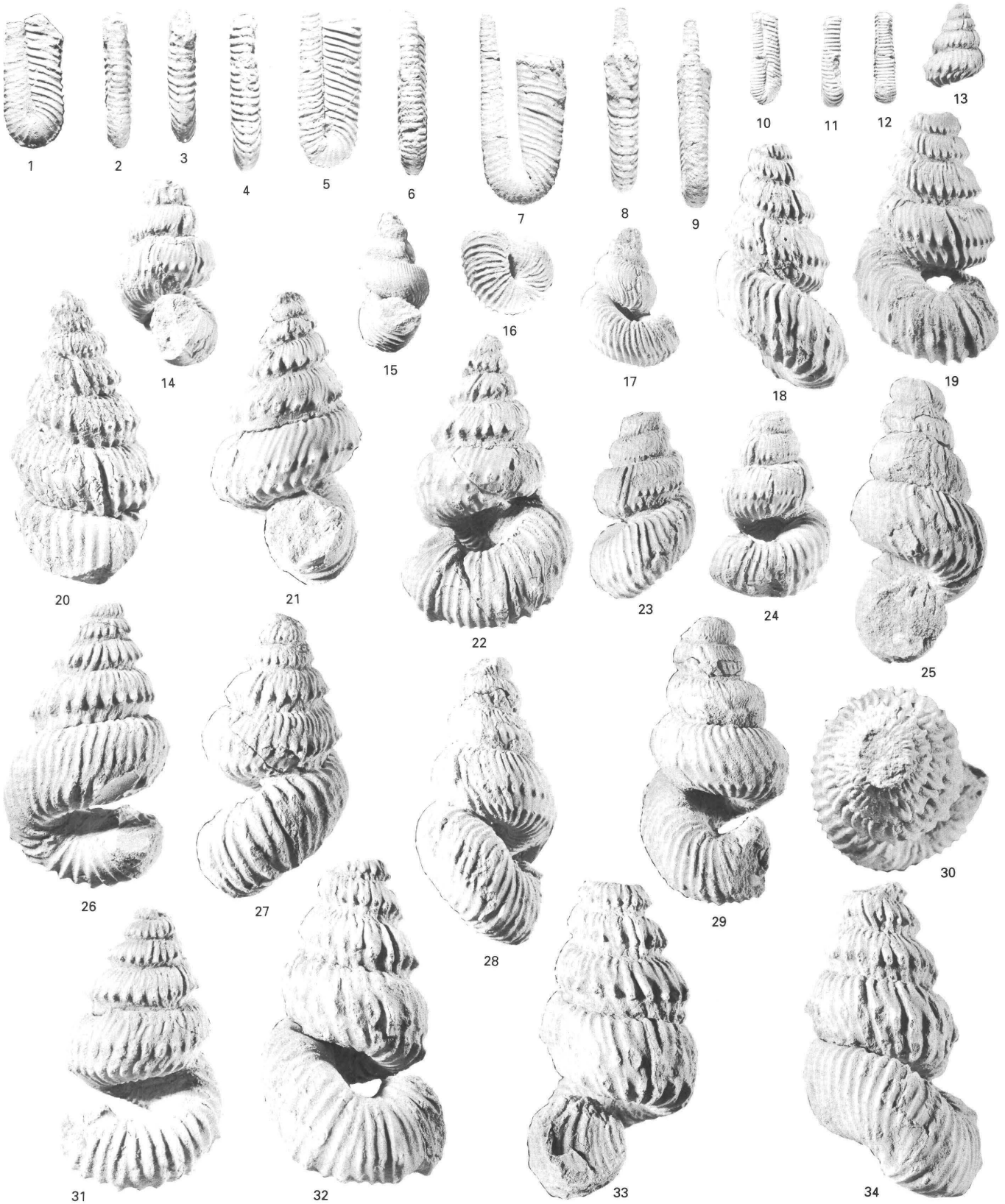
[All figures natural size]

Figures 1–6. *Solenoceras texanum* (Shumard) (p. C3)
- 1–3. Hypotype USNM 442104, from the Nacatoch Sand at USGS Mesozoic locality D7861, 4.8 km northeast of Washington, Hempstead County, Arkansas.
- 4–6. Hypotype USNM 442105, from the same locality.

7–9. *Parasolenoceras pulcher* n.sp. (p. C4). Holotype USNM 442107, from the same locality.

10–12. *Solenoceras nitidum* Cobban (p. C2). Hypotype USNM 442102, from the same locality.

13–34. *Nostoceras* (*Nostoceras*) *rugosum* n.sp. (p. C2). From the same locality.
- 13. Paratype USNM 442107.
- 14, 23, 24. Paratype USNM 442094.
- 15–17. Paratype USNM 442095.
- 18, 19. Paratype USNM 442096.
- 20. Paratype USNM 442097.
- 21, 22. Paratype USNM 442098.
- 25, 28, 29. Paratype USNM 442099.
- 26, 27, 31. Holotype USNM 442093.
- 30, 32–34. Paratype USNM 442100.



SOLENOCERAS, *PARASOLENOCERAS*, AND *NOSTOCERAS*

Chapter D

Occurrence of the Rudistid *Durania cornupastoris* (Des Moulins, 1826) in the Upper Cretaceous Greenhorn Limestone in Colorado

By WILLIAM A. COBBAN, PETER W. SKELTON, and W. JAMES KENNEDY

Description of a bivalve previously unrecorded in North America

U.S. GEOLOGICAL SURVEY BULLETIN 1985

SHORTER CONTRIBUTIONS TO PALEONTOLOGY AND STRATIGRAPHY

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Occurrence of the Rudistid *Durania cornupastoris* (Des Moulins, 1826) in the Upper Cretaceous Greenhorn Limestone in Colorado

By William A. Cobban,[1] Peter W. Skelton,[2] *and* W. James Kennedy[3]

Abstract

A group of at least 28 conjoined individuals of *Durania cornupastoris* (Des Moulins, 1826) is described from the uppermost part of the Greenhorn Limestone near La Junta in southeastern Colorado. This description is the first report of this species in the Western Interior. The specimens are from a bed of limestone concretions that contain the ammonite *Collignoniceras woollgari* (Mantell) of early middle Turonian age. A younger rudist, *Durania maxima* (Logan, 1898), is fairly abundant in the Santonian and lower Campanian part of the Niobrara Chalk in Kansas, but other rudists are scarce in the Western Interior. Occasional rudistid fragments have been found in the middle and upper Cenomanian, Turonian, Coniacian, Santonian, Campanian, and middle Maastrichtian.

INTRODUCTION
By William A. Cobban and W. James Kennedy

Aside from fairly abundant occurrences in the Niobrara Formation of Kansas, rudists are rare fossils in the Upper Cretaceous rocks of the Western Interior. Isolated fragments, however, have been found in Cenomanian-Maastrichtian rocks from northwestern New Mexico as far north as southern Saskatchewan, Canada. The discovery of a cluster of rudists in the Greenhorn Limestone in southeastern Colorado is an unusual find of a species that was originally described from France. The cluster is from the uppermost part of the Bridge Creek Member of the Greenhorn Limestone in a roadcut along U.S. Highway 50 about 8 km northeast of La Junta at U.S. Geological Survey (USGS) Mesozoic locality D11226 in the center of sec. 33, T. 23 S., R. 54 W., Otero County (Hadley 7½-min quadrangle). The cluster, found by Cobban in 1980, was later taken to Oxford, England, by Kennedy, who photographed it and turned it over to Skelton for identification and description. The specimen now is housed in the National Museum of Natural History (USNM), Washington, D.C, and has USNM catalog number 442109.

Published records of rudists in the Western Interior are few. Hall and Meek (1856, p. 380, pl. 1, fig. 3a–f) described the new species *Caprinella coraloidea* from the Pierre Shale at "Sage Creek, Nebraska." At that time, Nebraska Territory included what is now South Dakota, and Sage Creek is in present-day Pennington County in southwestern South Dakota. Mudge (1876, p. 216) early noted the occurrence of rudists in the chalk of Kansas, and Williston (1897, p. 239) referred to the beds that contained them as the "Rudistes Beds." Soon after, Logan (1898, p. 494, pl. 115; pl. 119, fig. 1) described the rudist as the new species *Radiolites maximus*. The rudist was further described and illustrated by Miller (1968, p. 37, 38, pl. 4, figs. 6–8; 1970, pl. 1, fig. 2), and excellent illustrations have been given recently by Hattin (1982, pl. 7, figs. 2–5; 1986, text figs. 35, 36). Reeside (1924, p. 11) recorded a specimen assigned to *Sauvagesia* cf. *S. austinensis* Roemer from the Mancos Shale in New Mexico. Griffitts (1949) described the new species *Durania niobrarensis* from the Niobrara Formation in north-central Colorado. A fragment, identified as *C. coraloidea* by Cobban, was listed from the Cody Shale of south-central Montana by Richards (1955, p. 61) and by Knechtel and Patterson (1956, p. 31). Caldwell and Evans (1963) reported on a specimen from Saskatchewan, redescribed Hall and Meek's holotype of *C. coraloidea*, and assigned it to *Ichthyosarcolites*. Scott and others (1986, p. 31) recorded *Durania* aff. *austinensis* (Roemer) from the Niobrara Formation in northeastern New Mexico.

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OCCURRENCES OF RUDISTS IN THE WESTERN INTERIOR

By William A. Cobban and W. James Kennedy

Rudists have been found in rocks of the following ages: middle and late Cenomanian in Arizona and New Mexico; late Cenomanian or early Turonian in Colorado; middle Turonian in Colorado; early Coniacian in Colorado and Wyoming; late Coniacian–early Campanian in Kansas; early, middle, and late Campanian in Montana; late Campanian in Saskatchewan, Canada; and middle Maastrichtian in South Dakota. Occurrences in the upper Cenomanian, lower Turonian, lower, middle, and upper Campanian, and middle Maastrichtian are all based on isolated fragments.

Cenomanian

The presence of radiolitid rudists was recorded from the Thatcher Limestone Member of the Graneros Shale near Pueblo in southeastern Colorado (Kauffman, 1985, p. 95). Rudists were also observed in the Thatcher Member farther south in New Mexico by Kennedy. The Thatcher Member lies in the middle Cenomanian zone of *Conlinoceras tarrantense*.

A sandstone concretion in the Paguate Tongue of the Dakota Sandstone in northwestern New Mexico yielded a fragment of a rudist that has "affinities to the genus *Ichthyosarcolites*" (N.F. Sohl, written commun., 1970). The specimen is from USGS Mesozoic locality D7333 in the center of sec. 5, T. 14 N., R. 12 W., McKinley County. Other fossils from this locality include *Inoceramus rutherfordi* Warren, *Ostrea beloiti* Logan, *Acanthoceras amphibolum* Morrow, and *Turrilites acutus* Passy, which reveal the middle Cenomanian zone of *A. amphibolum*.

A fragment of a rudist was collected by Cobban 4.9 m above the base of the Mancos Shale in northeastern Arizona at USGS Mesozoic locality D9019 about 6 km north of Black Mountain Trading Post in Apache County, Arizona. N.F. Sohl (written commun., 1971) identified it as a "radiolitid rudist...suggesting an affinity to *Sauvagesia*." The specimen was associated with *Calycoceras naviculare* (Mantell), an ammonite from the upper Cenomanian zone of *Sciponoceras gracile*.

Kauffman (1984, p. 291) mentioned the presence of radiolitid rudists just below the Cenomanian-Turonian boundary as far north as southern Colorado (Kauffman, 1984, fig. 9), but further details were not provided.

Dane and others (1937, p. 214) mentioned the presence of a specimen of *Sauvagesia*? sp. in the Greenhorn Limestone in southeastern Colorado, but the position in the Greenhorn was not given. At the date of their publication, the Greenhorn was restricted to the sequence of alternating limestone and calcareous shale now referred to the Bridge Creek Member. Most of the member is of early Turonian age, but the lowest part is late Cenomanian.

Turonian

The cluster of rudists (*Durania cornupastoris*) reported on in this paper is from the middle Turonian zone of *Collignoniceras woollgari*. Two fragments of this species were collected by D.E. Hattin and D. Hirt in the upper part of the Bridge Creek Member of the Greenhorn Limestone in south-central Colorado in the NE¼ sec. 10, T. 17 S., R. 70 W., Fremont County (D.E. Hattin, written commun., 1988).

Part of a rudist was found by G.R. Scott in the second bed above the base of the Fort Hays Limestone Member of the Niobrara Formation at USGS Mesozoic locality D3467 near Pueblo in the NE¼ sec. 26, T. 20 S., R. 66 W., Pueblo County, Colorado. Inoceramid bivalves from the basal few beds of the Fort Hays Member in this area indicate a very late Turonian age (Scott and Cobban, 1964, table 2).

Coniacian

Specimens of *Durania* are present in USGS collections from the lower Coniacian zone of *Inoceramus deformis* in the Fort Hays Limestone Member of the Niobrara Formation in southeastern Colorado and northeastern New Mexico. Griffitts (1949) described the new species *D. niobrarensis* from rocks now assigned to the Fort Hays Limestone Member in the Boulder area of northern Colorado. In that area, the Fort Hays Member is of early Coniacian age. Hattin (1982, fig. 31) has shown the presence of the radiolitid rudist *Durania maxima* (Logan) in the middle and upper Coniacian parts of the Smoky Hill Member of the Niobrara Formation in Kansas. Reeside (1955, p. 87) recorded *Sauvagesia* cf. *S. austinensis* (Roemer) from the Mancos Shale in northwestern Colorado; the specimen was found about 15 m above the ammonite *Scaphites binneyi* Reeside, a guide to upper Coniacian rocks. Kauffman (1984, p. 293–294) reported sparse radiolitid rudists (*Durania*) in the middle to upper Coniacian zone of *Scaphites ventricosus–Magadiceramus subquadratus* as far north as Wyoming, but further documentation is lacking. However, there is a specimen of *Durania* from 61 m above the base of the Cody Shale from USGS Mesozoic locality 13098 about 15 km southeast of Cody in northwestern Wyoming; it is probably from the lower Coniacian. Scott and others (1986, p. 31) reported a specimen of *D.* aff. *austinensis* (Roemer), identified by N.F. Sohl, from the lower shale unit of the Smoky Hill Shale Member of the Niobrara Formation at USGS Mesozoic locality D11432 about 11 km southwest of Springer in northeastern New Mexico.

Santonian

Hattin (1982, p. 103, fig. 31) has shown the presence in Kansas of *D. maxima* (Logan) with *Inoceramus* (*Clado-*

ceramus) *undulatoplicatus* Roemer, a bivalve recommended as a guide to the base of the Santonian Stage (Seitz, 1959, p. 121, table 1; Birkelund and others, 1984, p. 14). Reeside (1924, p. 11) recorded *Sauvagesia* cf. *S. austinensis* Roemer from the Mancos Shale in northwestern New Mexico. *Scaphites vermiformis* Meek and Hayden is shown above and below the rudist occurrence (Reeside, 1924, pl. 3), and, accordingly, the rudist is from the middle Santonian zone of *Clioscaphites vermiformis*. Kauffman (1984, p. 295) mentioned the occurrence of *Durania* in the Santonian zones of *Clioscaphites saxitonianus*, *C. vermiformis*, *C. choteauensis*, *Desmoscaphites erdmanni*, and *D. bassleri* in Colorado, Kansas, and Wyoming, but details are not given.

Campanian

There are good records of rudists from the Campanian rocks of the Western Interior. Hattin (1982, fig. 31) has shown that *Durania maxima* persists through most of the Smoky Hill Member of the Niobrara Chalk in Kansas and that the youngest occurrences are well up into the lower Campanian.

A fragment of *Ichthyosarcolites*? *coraloidea* (Hall and Meek) was collected by Cobban from the lower Campanian zone of *Scaphites hippocrepis* III about 15 m below the Groat Sandstone Bed in the Gammon Member of the Pierre Shale at USGS Mesozoic locality 23641 in the SE¼ sec. 12, T. 9 S., R. 61 E., Carter County, Montana. Another fragment was collected by Cobban slightly higher in the zone of *Baculites* sp. (weak flank ribs) in the upper part of the Gammon Member at USGS Mesozoic locality 22177 in the N½ sec. 10, T. 9 S., R. 62 E., Carter County, Montana.

A fragment of *I.*? *coraloidea* was found by Cobban in the middle Campanian zone of *Baculites asperiformis* in the Claggett Member of the Cody Shale at USGS Mesozoic locality 21214 east of Hardin in the NW¼ sec. 18, T. 1 S., R. 35 E., Big Horn County, Montana (Richards, 1955, p. 61; Knechtel and Patterson, 1956, p. 31).

Kauffman (1984, p. 295) reported *Durania* from the *Scaphites hippocrepis* zone in southern Colorado and indicated that "rudists remained in the southern and central part of the seaway" through the *Baculites gilberti–Baculites scotti* zones. Documentation is lacking, however.

A few fragments of rudists referable to *I.*? *coraloidea* are present in the USGS's collections of fossils from the upper Campanian part of the Bearpaw Shale in east-central Montana. Two collections are from the zone of *Didymoceras stevensoni* about 52 m above the base of the Bearpaw. USGS Mesozoic locality D2630 is in the NW¼ sec. 31, T. 10 N., R. 36 E., Rosebud County, and USGS D3567 is in the S½ sec. 25, T. 7 N., R. 39 E., Rosebud County. Another specimen was found higher in the Bearpaw Shale, 114 m above the base, in the zone of *Baculites compressus* at USGS Mesozoic locality D3576 in the NE¼ sec. 36, T. 7 N., R. 39 E., Rosebud County. This zone farther south also yielded a specimen of *I.*? *coraloidea* in the Pierre Shale at USGS Mesozoic locality D1349 in the NE¼ sec. 18, T. 3 N., R. 80 W., Grand County, Colorado. The specimen of *I.*? *coraloidea* described by Caldwell and Evans (1963) from southern Saskatchewan came from the upper Campanian zone of *Exiteloceras jenneyi* in the Matador Sand Member of the Bearpaw Shale (Caldwell, 1968, p. 17, 71). A fragment of *I.*? *coraloidea* was also found in this zone near the base of the Monument Hill Member of the Pierre Shale at USGS Mesozoic locality 23054 in the SE¼ sec. 14, T. 3 S., R. 56 E., Carter County, Montana.

Maastrichtian

The youngest rudist recorded from the Western Interior is a specimen referred to as *Ichthyosarcolites*? sp. A from the middle Maastrichtian Trail City Member of the Fox Hills Sandstone of west-central South Dakota (Speden, 1970, p. 157). The specimen is from the zone of *Hoploscaphites nicolleti* of Cobban and Reeside (1952).

SYSTEMATIC PALEONTOLOGY
By Peter W. Skelton

Family RADIOLITIDAE Gray, 1847
Subfamily SAUVAGESIINAE Douvillé, 1908

Genus *Durania* Douvillé, 1908

Type species.—*Hippurites cornupastoris* Des Moulins, 1826

***Durania cornupastoris* (Des Moulins)**

Plates 1–3; text figure 1

1826. *Hippurites cornupastoris* Des Moulins, p. 141, pl. 10, figs. 1, 2.
1908. *Sauvagesia cornupastoris* Des Moulins sp. Toucas, p. 94, text figs. 61–63, pl. 18, figs. 8–10.

Material.—A bouquet of conjoined individuals (pls. 1, 2; text fig. 1) having overall dimensions of 160×235 mm. At least 28 individuals are present, represented only by their attached right valves; a fragment of the left valve of one individual is also preserved (pl. 3, fig. 2). Their inner, originally aragonitic shell layers have been leached away; only their calcitic outer shell layers, filled with matrix sediment (a pale-gray, fine bioclastic packstone) remain. The fact that no cavities remain from the loss of the aragonitic shell implies early dissolution, a conclusion supported by the presence of small oysters apparently encrusting the inner surface of the outer shell layer of some of the specimens. The bouquet is specimen USNM 442109.

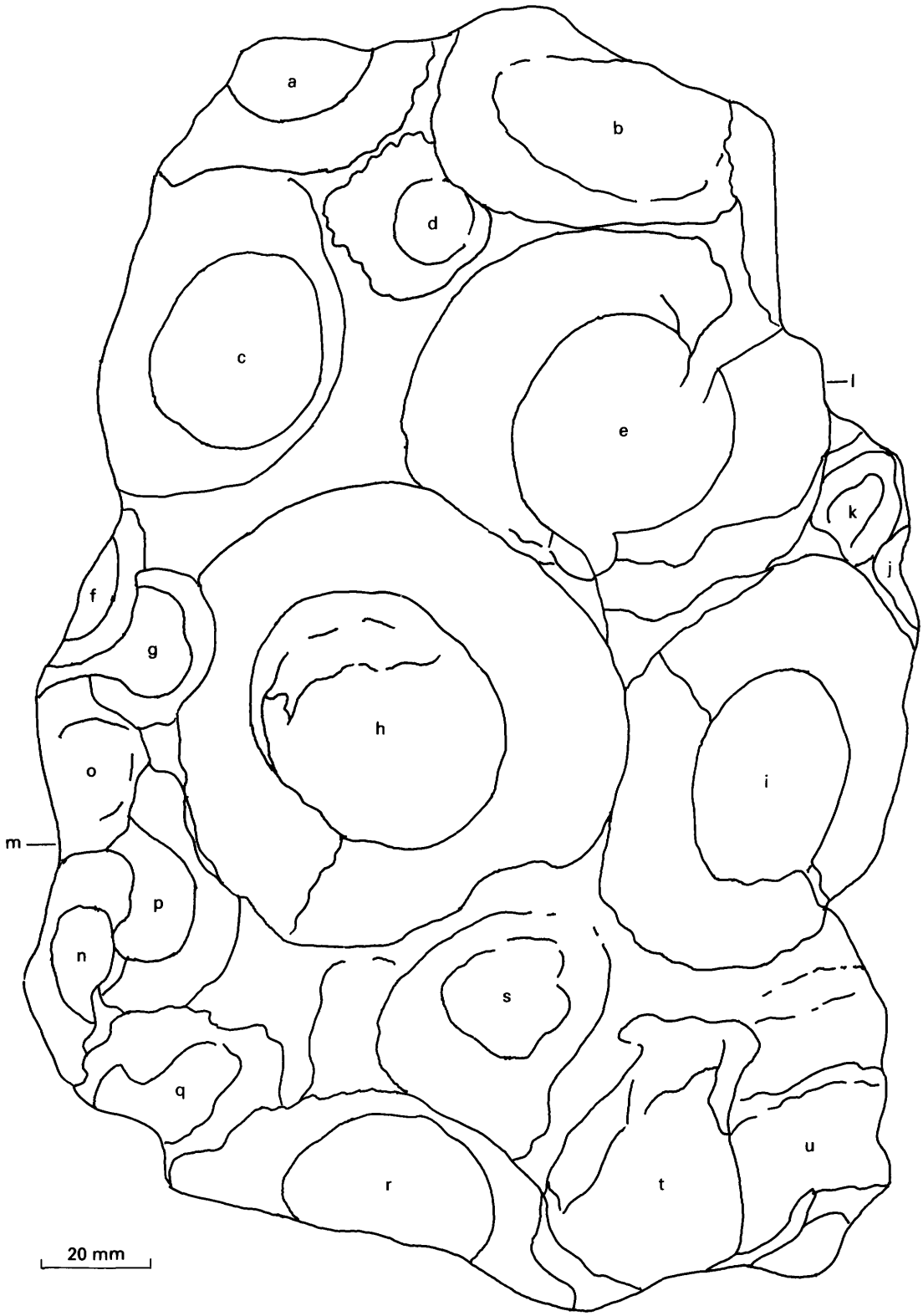

Figure 1. Individuals (a–u) in the upper surface of the cluster of *Durania cornupastoris* (Des Moulins, 1826). See plate 1 for photograph.

Description.—Right valves conical to subcylindrical, reaching over 80 mm in length in the larger specimens, and having commissural diameters of up to nearly 80 mm (table 1). External ornament consists of regular, salient radial ribs of 1.5 to 2.0 mm width, although those in the two radial bands situated on the postero-ventral flank of the valve are finer (1.0–1.5 mm width) (pl. 3, fig. 1). Broadly spaced, prominent commarginal growth rugae cut across the ribbing.

The radial bands are slightly indented and more or less flat, although the ventral one is distinctly concave in a few specimens. The ventral band is invariably the broader, reaching just over 20 mm in width, in contrast to the maximum of nearly 12 mm in the posterior band (table 1). Correspondingly, the former may have as many as 13 fine ribs, to the latter's 8 or less (table 1). The interband area projects somewhat, bearing three to four coarser ribs (pl. 3, fig. 1), similar to those around the rest of the valve wall. Its width is slightly less than that of the posterior band in all but one specimen, reaching some 10 mm (table 1).

The gently inward sloping inner rim (growth surface) of the right valve shows the characteristic sauvagesiine polygonal cell network. The cells are mostly between 0.5 and 1.0 mm in diameter (pl. 3, fig. 2). The bifurcating, radiating "vascular" impressions frequently noted on the inner valve rims of *Durania* are not detectable in these specimens. However, all the better preserved specimens in this cluster show a distinct retreat of the outer margins of the last few cell layers from the commissural periphery of the valve (pl. 3, fig. 2).

The inner margin of the outer shell layer (that is, where the junction with the lost aragonitic inner shell was situated) is elliptically subcircular, its narrowest diameter being approximately anteroposterior in most specimens. The diameters of this inner margin are approximately one-half to two-thirds those of the commissural margin (table 1). There is no vestige of an *arête cardinale*, the inner face of the outer shell layer being quite smooth (apart from fine growth lines).

The small fragment of the left valve preserved in one of the specimens (pl. 3, fig. 2, center) consists of a thin (<1 mm) sheet of dark-brown, compact, fibrous prismatic calcite, covering a part of the posterior inner rim of the right valve. It is smooth externally.

The specimens are conjoined to form a low, domed "bouquet," radiating upward and outward from an initial attachment area of less than 7×10 cm (pl. 2). The peripheral individuals were thus inclined at a low angle to the sediment surface, whereas those in the center were more or less upright in life. Several generations are represented, small individuals being attached to the flanks of the larger individuals, both in the interstitial spaces between the latter and on the raised undersides of some of the peripheral individuals.

Discussion.—The regular ribbing and the more finely ribbed radial bands of these specimens, together with their clear polygonal cell structure, immediately identify them as sauvagesiine radiolitids (Toucas, 1907–09; Douvillé, 1910). The absence of any ligamentary invagination places them in the genus *Durania* (see Douvillé, 1910). Thusfar, their classification presents no problems. Species assignment is problematical, however, because the species-level taxonomy of the genus is in serious need of revision. At present, the literature is cluttered with typologically (and commonly also stratigraphically) defined "species," most of which deserve the oblivion of synonymy; far too many are based on small numbers of specimens, little allowance being made for the extent of intraspecific variability that might reasonably be expected in such sessile epifaunal forms by analogy with, for example, oysters.

The two current "species" that invite the closest comparison with the specimens described here are the type species of the genus, *Durania cornupastoris* (Des Moulins) and *Durania arnaudi* (Choffat), originally described from France and Portugal, respectively. Both show similar adult sizes and shapes and possess the salient regular ribbing and flattish to gently concave radial bands shown by our specimens. The only categorical morphological distinction drawn between them by Toucas (1907–09) is that the interband of *D. arnaudi* is relatively protruding and narrow and has only one, two, or, rarely, three costae, whereas that of *D. cornupastoris* is broader and has "un plus grand nombre de côtes saillantes" (Toucas, 1907–09, p. 94) (Toucas's figures of the species show the number of ribs on the interband varying from three to seven, although a part of this variability is clearly ontogenetic). Polsak (1967), in an extensive study of Istrian specimens, tried to regularize this distinction by stating that the interband is always narrower than the posterior radial band in *D. arnaudi* and relatively broader than it is in *D. cornupastoris* (with three to four ribs). Moreover, the posterior band of the latter should have only half the width of its ventral band. Toucas believed *D. cornupastoris* to be an upper Turonian evolutionary modification of the reputedly middle Turonian *D. arnaudi*, although both Douvillé (1910, p. 54) and Polsak (1967, p. 194) recognized their stratigraphical co-occurrence in the upper Turonian. The Egyptian specimens described by Douvillé as *D. arnaudi* were stated to have an interband width almost equal to that of the posterior ("S") band. It thus seems that a continuum of fairly variable specimens has been arbitrarily divided between two typological "species" concepts and that the two could well be synonymized under *D. cornupastoris*. Inspection of the type and associated material will be necessary, however, for formal confirmation of this conclusion. Meanwhile, it is of interest in this context to note Douvillé's (1910, p. 54) own thoughts on the matter: "Du reste, le *D. arnaudi* se recontre également dans le Turonien supérieur et je serais porté à le

Table 1. Measurements of specimens in cluster of *Durania cornupastoris* (Des Moulins), hypotype USNM 442109

[All measurements are in millimeters. —, no measurement. See text fig. 1 for identification of individuals]

Specimen	Commissural diameter		Inner diameter of outer shell		Ventral radial band		Interband		Posterior radial band		Height of right valve
	Maximum	Minimum	Maximum	Minimum	Width	No. of ribs	Width	No. of ribs	Width	No. of ribs	
a	—	—	—	—	—	—	—	—	—	—	—
b	64.8	58.7	40.5	34.9	20.5	13	8.2	4	11.5	—	80
c	62.5	55.2	39.0	33.7	15.8	11	10.1	—	8.6	5	—
d	—	—	—	—	—	—	—	—	—	—	—
e	69.5	59.7	38.3	32.3	>17	>10	7.2	3–4	11.9	8	—
f	~38	~23	22.0	17.4	—	—	—	—	—	—	—
g	~28	20.5	19.0	—	—	—	—	—	—	—	—
h	79.0	68.8	43.2	35.3	—	—	—	—	—	—	—
i	75.6	63.7	36.6	31.8	>18	>8	7.2	3–4	10.4	7	>48
j	—	—	—	—	—	—	—	—	—	—	—
k	26.0	23.9	15.8	13.8	—	—	—	—	—	—	—
l	—	—	—	—	—	—	—	—	—	—	—
m	65.8	—	33.6	—	—	—	—	—	—	—	>75
n	—	—	—	—	—	—	—	—	—	—	—
o	—	—	—	—	—	—	—	—	—	—	—
p	—	—	—	—	—	—	—	—	—	—	—
q	—	—	—	—	—	—	—	—	—	—	—
r	68.7	—	37.6	34.5	11.1	9	8.0	3	—	—	>80
s	49.8	35.4	15.6	15.1	—	—	—	—	—	—	—
t	—	—	—	—	—	—	—	—	—	—	—
u	>64	—	—	—	—	—	—	—	—	—	>85

considerer comme une simple variété au race du *D. cornupastoris*."

The specimens considered here fall comfortably in the middle of this range of variability. The interband, which shows three to four ribs, is slightly narrower than the posterior band, except in one specimen (table 1). The posterior band in the measured specimens is just over half the width of the ventral band. In some respects, then, they are like "*D. arnaudi*" (relatively narrow, projecting interband), although they are closer to "*D. cornupastoris*" (as typologically conceived) in the relative widths of the radial bands and in having three to four interband ribs (incidentally, thus comparing very closely with the specimen refigured by Toucas (1907–09, pl. 18, fig. 8), from d'Orbigny (1847)). In view of the earlier discussion, it would thus seem sensible to assign them to *D. cornupastoris*, the older species name.

Stratigraphical and paleogeographical distribution.—*Durania cornupastoris* is a widespread species, already recognized from the upper Turonian of both the northern and the southern components of the Mediterranean Tethyan Realm—France and Algeria (Toucas, 1907–09), Egypt (Douvillé, 1910), and Istria (Polsak, 1967) as well as Portugal, Italy, Tunisia, and Mexico (reported by Sanchez, 1981). Inclusion of *D. arnaudi* would both consolidate this geographic range and extend the stratigraphic range of the species into the middle Turonian. Work in preparation by Skelton, with G.M.A. El-Asa'ad, on Campanian material from central Saudi Arabia, will lead to yet further broadening of the geographic and stratigraphic ranges of the species. This report, from the Western Interior, falls within the conventionally recognized Turonian range of the species but extends its geographic range.

Paleobiology.—The bouquet of *Durania* described here shows certain features of paleobiological interest. With respect to paleoecology, the low, domed form of the bouquet, consisting of upwardly and outwardly radiating cylindroconical shells, suggests lateral overgrowth of a relatively stable sediment surface from some rather small focal point of initial attachment. Sedimentation was evidently negligible, allowing peripheral individuals to grow to adult size despite growing subhorizontally. The bouquet thus, in aggregate, conforms to the "clinger" paradigm of Skelton and Gili (in press), although some of the (central) individuals in it would, in isolation, be classified as "elevators." We thus envisage a low- to moderate-energy environment, marked by only occasional influxes of sediment, which suffered little or no subsequent current reworking. The fine bioclastic packstone matrix of the bouquet is consistent with such an interpretation.

The monospecific makeup of the aggregation is a common feature of rudist bouquets, clusters, and thickets (Skelton and Gili, in press). The precise reasons for this makeup are unclear, although it is of interest to note the several generations present here; evidently, (viable) recruitment was limited to the one species for a period of several years. Absence or exclusion of other rudist larvae or simply attraction only of conspecific larvae for settlement in the

bouquet are all possible explanations. On present information, one cannot choose among these alternatives.

A particular feature of interest in these specimens is the retreat of the last few cell layers from the commissural margin (pl. 3, fig. 2). Whatever the cause was, it seems to have affected all the specimens in which the state of preservation allows detection. In places, the polygonal cell pattern of the right-valve inner rim (growth surface) has become radially flattened (pl. 3, fig. 2), implying shrinkage of the overlying generative mantle margin and thus of whatever microanatomical features of the latter were responsible for creating the network of polygonal cell walls on the valve rim. This polygonal cell pattern might reflect either some pathological condition or, more likely, some inimical environmental change, which eventually probably killed off the bouquet (since the shrinkage affected the last few cell layers). The time period represented by radiolitid cell layers has yet to be comprehensively analyzed, but preliminary studies by Skelton (1976) and Amico (1978) as well as ongoing work by Skelton suggest that the cell layers were produced in semilunar (spring-neap tidal) cycles. The few cell layers involved in the terminal mantle shrinkage of the specimens considered here thus indicate that the effect took place over a period of between one and a few months. The bouquet was recovered from the top of a limestone unit, overlain by marl; thus, a distinct possibility is that the effect reflects a rather rapid sustained increase in water turbidity. Such a reaction would certainly be consistent with the hypothesis that *Durania* possessed symbiotic zooxanthellae in its expanded mantle margins (for example, Kauffman and Sohl, 1979); a sustained increase in water turbidity would have had deleterious effects on such a symbiosis, as it does on living hermatypic corals. However, the case for symbiotic algae in most rudists is weak, since only a few taxa show specific adaptations for exposure of mantle tissue to the light. Other more plausible explanations based on mode of feeding are available for the elaboration of the mantle margins in advanced rudists (see Skelton and Wright, 1987, for discussion). Kauffmann's repeated assertions (for example, Kauffmann, 1969; Kauffmann and Sohl, 1979) that the left-valve rim of *Durania* did not cover the right-valve rim, such that its mantle tissue would have been openly exposed, are incorrect; many well-preserved specimens (for example, some of those illustrated by Toucas, 1907–09, such as his fig. 62 and pl. 18, fig. 8a) testify that the calcitic left-valve rim, albeit thin, entirely covered the inner rim of the right valve. Its apparent absence in some specimens is merely preservational failure. Since the left-valve rim could reach 2 to 3 mm of thickness in parts (Campanian *Durania* from central Saudi Arabia), it remains to be shown that this rim would have been sufficiently translucent for Kauffmann's symbiosis hypothesis to remain tenable. An alternative explanation for the demise of the *Durania* bouquet discussed here, then, is that the increasing turbidity (or other environmental change) inhibited effective feeding by mantle marginal particle entrapment (Skelton, 1979).

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PLATES 1–3

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

PLATE 1

Durania cornupastoris (Des Moulins, 1826) (p. D3)

[Figure about eight-tenths natural size]

Top view of hypotype USNM 442109, from U.S. Geological Survey Mesozoic locality D11226 in the center of sec. 33, T. 23 S., R. 54 W., Otero County, Colorado. See plate 2 for bottom view.

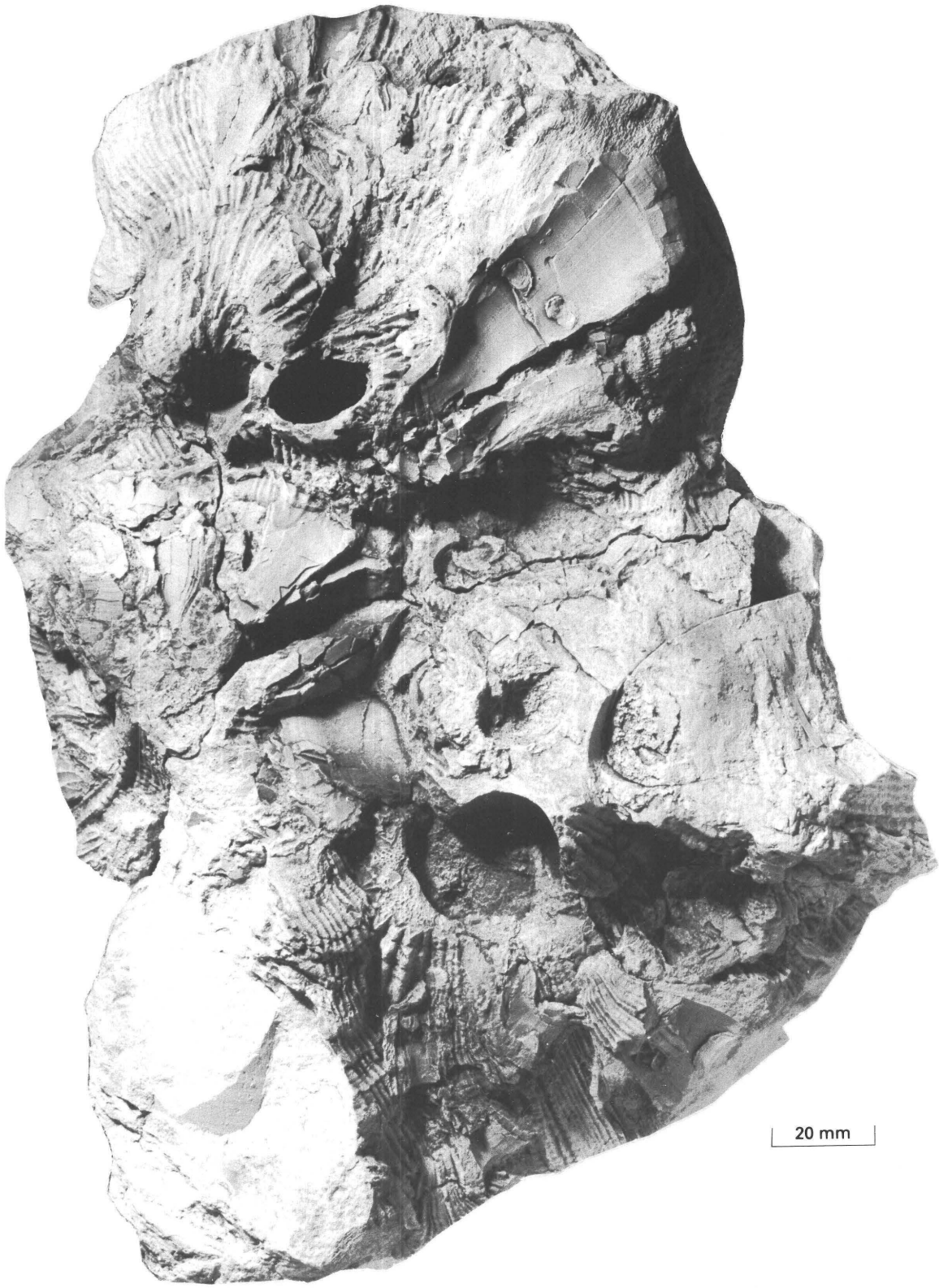
DURANIA CORNUPASTORIS

PLATE 2

Durania cornupastoris (Des Moulins, 1826) (p. D3)

[Figure about eight-tenths natural size]

Bottom view of hypotype USNM 442109, from U.S. Geological Survey Mesozoic locality D11226 in the center of sec. 33, T. 23 S., R. 54 W., Otero County, Colorado. See plate 1 for top view.



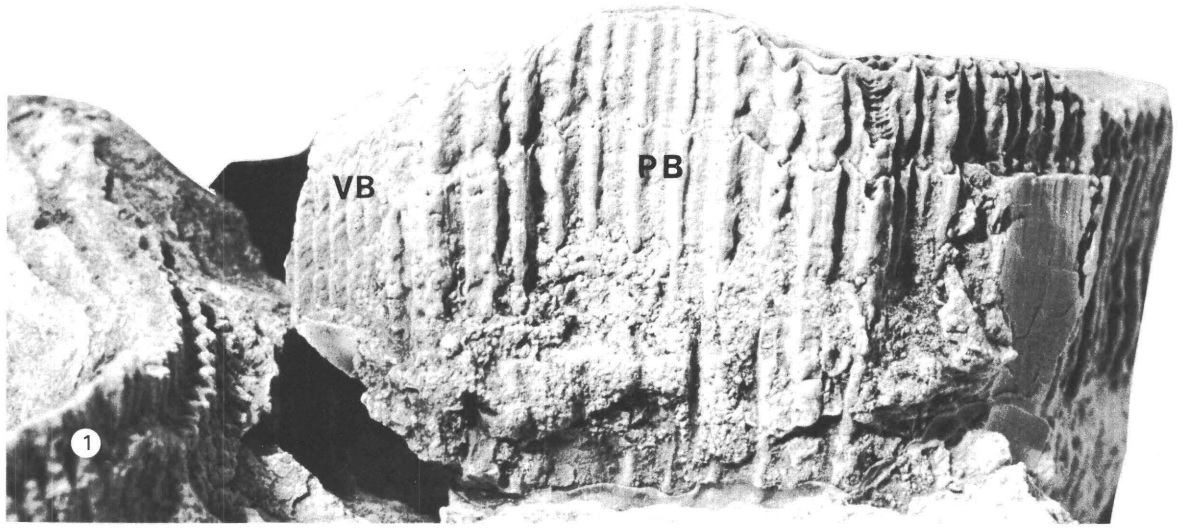
DURANIA CORNUPASTORIS

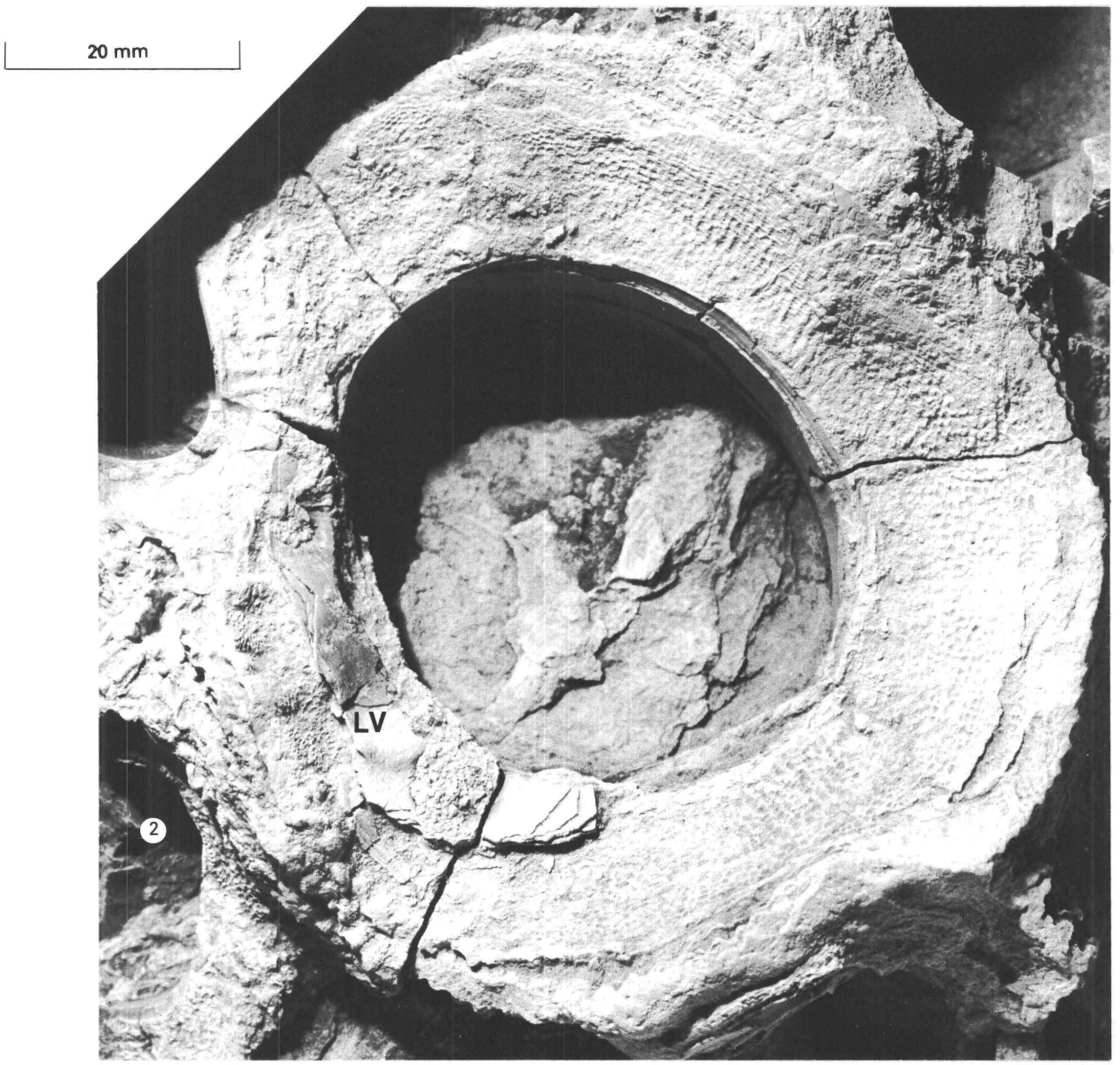
PLATE 3

Durania cornupastoris (Des Moulins, 1826) (p. D3)

[Figures enlarged]

Figure 1. Side view near top of one of the specimens. VB, ventral band; PB, posterior band.
2. Top view of another of the specimens. LV, left valve.





DURANIA CORNUPASTORIS

Chapter E

Upper Cretaceous (Maastrichtian) Ammonites from the *Nostoceras alternatum* Zone in Southwestern Arkansas

By WILLIAM A. COBBAN and W. JAMES KENNEDY

Descriptions and illustrations of early Maastrichtian ammonites from southwestern Arkansas

U.S. GEOLOGICAL SURVEY BULLETIN 1985

SHORTER CONTRIBUTIONS TO PALEONTOLOGY AND STRATIGRAPHY

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Upper Cretaceous (Maastrichtian) Ammonites from the *Nostoceras alternatum* Zone in Southwestern Arkansas

By William A. Cobban[1] *and* W. James Kennedy[2]

Abstract

Calcareous concretions in the Nacatoch Sand in Hempstead County, Arkansas, yield abundant fossils of the lower Maastrichtian *Nostoceras alternatum* zone, previously recognized in Mississippi, Alabama, and Georgia. The fossils include *Inoceramus regularis* d'Orbigny, 1842, *Pseudophyllites indra* (Forbes, 1846), *Brahmaites* sp., *Sphenodiscus* sp., *Nostoceras* (*Nostoceras*) *alternatum* (Tuomey, 1854), *Solenoceras nitidum* Cobban, 1974, *Baculites claviformis* Stephenson, 1941, and *Jeletzkytes* sp. A and sp. B. The *N. alternatum* zone may correlate with the *Baculites clinolobatus* zone in the Western Interior.

INTRODUCTION

The *Nostoceras* (*Nostoceras*) *alternatum* zone was introduced by Cobban (1974) as a biostratigraphic unit characterized by the index fossil and an associated assemblage of *Solenoceras nitidum* Cobban, 1974, *Exiteloceras* sp., *Axonoceras sohli* Cobban, 1974, *Baculites* cf. *B. undatus* Stephenson, 1941, and *Hoploscaphites* sp. It was assigned a Maastrichtian age and recognized in a part of the Coon Creek Tongue of the Ripley Formation in northeastern Mississippi and in age-equivalent parts of the Ripley Formation along the Chatahoochie River separating Alabama and Georgia.

We have recorded the presence of the zonal fauna, together with previously unrecorded forms, from the Nacatoch Sand in southwestern Arkansas. The Nacatoch Sand is a complex suite of terrigenous clastic rocks that rests unconformably on the Ozan Formation, Marlbrook Marl, or Saratoga Chalk and is overlain conformably by the Arkadelphia Marl. Dane (1929) provided the best account of the stratigraphy of these units.

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The lower member of the Saratoga Chalk contains a rich ammonite fauna that we refer to the *Nostoceras* (*Nostoceras*) *hyatti* zone of late Campanian age. The middle glauconitic member of the Nacatoch Sand (Dane, 1929, p. 116, 117) contains a distinctive ammonite fauna of the *Nostoceras* (*Nostoceras*) *rugosum* zone (Cobban and Kennedy, this volume, Chap. C) that we regard as lowest Maastrichtian in ammonite terms, although the exact level of the Campanian-Maastrichtian boundary is disputed. The *N.* (*N.*) *alternatum* zone overlies the *N.* (*N.*) *rugosum* zone and is regarded as lower Maastrichtian. The *N.* (*N.*) *alternatum* zone is overlain by the Arkadelphia Marl, which contains *Discoscaphites*, the only ammonite known to us at the present time from that formation.

The fauna described hereins consists of *Pseudophyllites indra* (Forbes, 1846), *Brahmaites* sp., *Sphenodiscus* sp., *N.* (*N.*) *alternatum* (Tuomey, 1854), *S. nitidum* Cobban (1974), *Baculites claviformis* Stephenson (1941), *Jeletzkytes* sp. A, and *Jeletzkytes* sp. B, associated with numerous *Inoceramus regularis* d'Orbigny (1842) (USNM 449226–449229, pl. 1, figs. 16–18, 22). This assemblage can be correlated with the detailed ammonite sequence in the Western Interior of the United States with a fair degree of certainty. The underlying *N.* (*N.*) *rugosum* zone appears to be coeval with the *B. baculus* zone of the Western Interior inasmuch as both are characterized by abundant *Inoceramus* (*Endocostea*) *typicus* Whitfield (1880). The succeeding Arkadelphia Marl that contains *Discoscaphites* can be no older than the zone containing *Discoscaphites roanensis* and *Hoploscaphites nicolleti* in the Western Interior, at which level true *Discoscaphites* first appears. *Inoceramus regularis* d'Orbigny (1842) (pl. 1, figs. 16–18, 22), although long ranging elsewhere in the world, is abundant in the United States only in the *N.* (*N.*) *alternatum* zone of the Gulf Coast and the *B. clinolobatus* zone of the Western Interior. More important, the multinodose *Jeletzkytes* sp. B is of a type, albeit undescribed, that first appears in the *B. clinolobatus* zone with which we therefore correlate the Gulf Coast *N.* (*N.*) *alternatum* zone.

Some of the specimens figured here were photographed by R.E. Burkholder, recently retired from the U.S. Geological Survey (USGS), Denver, Colo. Specimens described and illustrated here are kept in the National Museum of Natural History (USNM), Washington, D.C., and have USNM catalog numbers. Plaster casts of some are kept at the Federal Center in Denver.

Kennedy acknowledges the financial support of the Natural Environment Council (U.K.), the Royal Society, and the Astor Fund (Oxford) and the technical assistance of the staff of the Geological Collections, University Museum, Oxford, and the Department of Earth Sciences, Oxford.

LOCALITY OF FOSSILS

The fossils described herein are from greenish-gray, fine-grained, hard, calcareous concretions in the Nacatoch Sand at USGS Mesozoic locality D8839 in the SW¼SW¼ sec. 17, T. 12 S., R. 27 W., Hempstead County, Arkansas, and were collected by B.F. Clardy, R.E. Burkholder, and W.A. Cobban in 1973.

SYSTEMATIC PALEONTOLOGY

Order AMMONOIDEA Zittel, 1884
Suborder AMMONITINA Hyatt, 1889

Superfamily TETRAGONITACEAE Hyatt, 1900

Family TETRAGONITIDAE Hyatt, 1900

Genus *Pseudophyllites* Kossmat, 1895

Type species.—By original designation *Ammonites indra* Forbes, 1846, p. 105, pl. 11, fig. 7.

***Pseudophyllites indra* (Forbes, 1846)**

Plate 1, figures 1–5

1846. *Ammonites indra* Forbes, p. 105, pl. 11, fig. 7.
1977. *Pseudophyllites indra* (Forbes, 1846). Kennedy and Klinger, p. 182, figs. 19a–f, 20–22 (with full synonymy).
1986. *Pseudophyllites indra* (Forbes, 1846). Kennedy, p. 19, pl. 1, figs. 1–5; text figs. 4e, 5a, 6a–e.

Lectotype.—British Museum (Natural History) C51068, the original of Forbes (1846, pl. 11, fig. 7) from the Valudayur Group near Pondicherry, southern India; by subsequent designation by Kennedy and Klinger (1977, p. 182).

Description.—USNM 449204 (pl. 1, figs. 1, 2) consists of nearly half a whorl 53 mm in diameter. Coiling is involute; the umbilicus is small and deep. The whorl section has a broadly rounded umbilical shoulder, convergent flanks, and a broadly rounded venter. Ornament consists of delicate growth lines and lirae that are convex and prorsiradiate on the flanks and then curve back over the ventrolateral shoulder and cross the venter in a shallow convexity. Periodic striae separate this ornament into broad bands. Suture was not seen.

Discussion.—A smaller specimen (USNM 449205, pl. 1, figs. 3–5), from the Nacatoch Sand near Chatfield in Navarro County, Texas, also belongs to this species and compares closely with topotypes in the British Museum (Natural History). The ornament of the Arkansas specimen recalls that of the syntype of *Gaudryceras colloti* de Grossouvre, 1894 (pl. 37, fig. 8), which is a synonym. Kennedy and Klinger (1977) and Kennedy (1986) have discussed differences from other species.

Occurrence.—Upper Santonian(?), lower Campanian to upper Maastrichtian. Southern India, Zululand (South Africa), Pondoland (South Africa), Madagascar, western Australia, Japan, Sakhalin, Alaska, British Columbia, California, Brazil, Chile, the U.S. Gulf Coast, New Jersey, northern Ireland, Poland, Austria, and southwestern France.

Superfamily DESMOCERATACEAE Zittel, 1895
Family KOSSMATICERATIDAE Spath, 1922

Subfamily KOSSMATICERATINAE Spath, 1922

Genus *Brahmaites* Kossmat, 1897

Type species.—*Ammonites Brahma* Forbes, 1846, p. 100, pl. 8, fig. 1, by original designation by Kossmat (1897, p. 44 (151)).

***Brahmaites* sp.**

Plate 1, figures 6–8, 14, 15

Description.—Two fragments (USNM 449206 and 449207) are referred to *Brahmaites*. The smaller is a half-whorl that had an estimated original diameter of 28 mm; the larger is a short sector that has a whorl height of 13 mm. Coiling is very evolute, and the broad umbilicus has moderate depth. The whorl section appears to have been as wide as it was high; it has a rounded, subvertical wall, a broadly rounded umbilical shoulder, flattened convergent flanks, and a broadly rounded venter. There are distant, deep, prorsiradiate constrictions and collar ribs. On the smaller specimen, the ribs are separated by an undetermined number of primary ribs that are restricted to the umbilical region and inner flanks. Constrictions and associated ribs are convex on the umbilical shoulder and then bend forward across the flanks, curve slightly forward on the ventrolateral shoulder, and become broadly convex over the venter. The adapical collar rib is weak at the smallest diameter seen but strong at the larger end (pl. 1, figs. 6, 15). A strong umbilical bulla is present on USNM 449207 (pl. 1, fig. 7). The adapertural rib is of comparable strength but lacks a bulla. Suture was not seen.

Discussion.—Coiling, ornament, and constrictions reveal these fragments to be *Brahmaites* (for example, compare Henderson and McNamara, 1985, pl. 6, figs.

11–14; pl. 7, fig. 1; Kennedy, 1986, text fig. 10a–k). The genus has not been previously recognized from North America.

Superfamily ACANTHOCERATACEAE de Grossouvre, 1893 [1894]
Family SPHENODISCIDAE Hyatt, 1900

Subfamily SPHENODISCINAE Hyatt, 1900

Genus *Sphenodiscus* Meek, 1871

Type species.—*Ammonites lenticularis* Owen, 1852, p. 579 (*non* Phillips, 1829, pl. 6, fig. 5)=*Ammonites lobata* Tuomey, 1854, p. 168.

***Sphenodiscus* sp.**

Plate 1, figure 9; text figure 1

Description.—USNM 449208 (pl. 1, fig. 9) is a crushed, smooth juvenile 37 mm in diameter that has a small, shallow umbilicus. Traces of the suture line are preserved (text fig. 1) and have typical narrow-stemmed lobes and undivided saddles.

Discussion.—This specimen is specifically indeterminate but represents the earliest record of the genus in the northern part of the Gulf Coast.

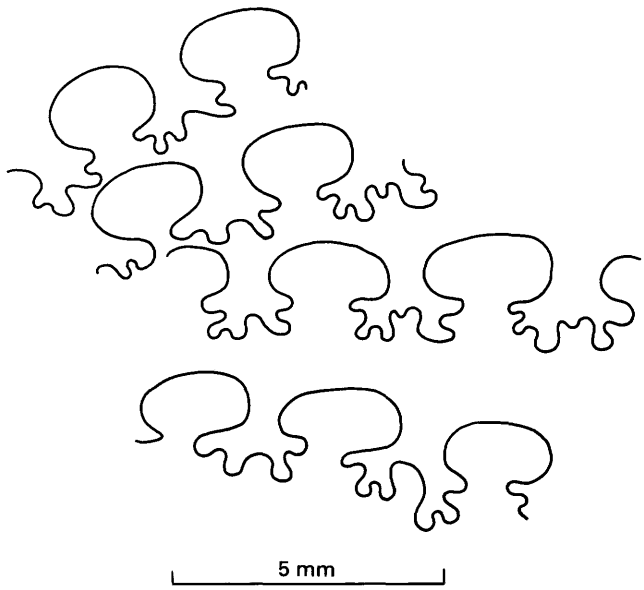

Figure 1. Partial suture of *Sphenodiscus* sp.

Suborder ANCYLOCERATINA Wiedmann, 1966
Superfamily TURRILITACEAE Gill, 1871

Family NOSTOCERATIDAE Hyatt, 1894

Genus and Subgenus *Nostoceras* Hyatt, 1894

Type species.—*Nostoceras stantoni* Hyatt, 1894, p. 569, by original designation (=*Ancyloceras? approximans* Conrad, 1855, p. 266).

***Nostoceras* (*Nostoceras*) *alternatum* (Tuomey, 1854)**

Plate 2, figures 5–27

1854. *Turrilites alternatns* [sic] Tuomey. p. 168.
1860. *Turrilites spinifera* Conrad. p. 284.
1861. *Turrilites alternatus* Tuomey. Gabb, p. 91.
1861. *Turrilites spinifera* Conrad. Gabb, p. 92.
1974. *Nostoceras alternatum* (Tuomey). Cobban, p. 86, figs. 1w–rr, 5.

Type.—The holotype, from Noxubee County, Mississippi, is apparently lost.

Description.—The species is markedly dimorphic, and adults fall into two size classes (Cobban, 1974, p. 86). Coiling is both dextral and sinistral. Most specimens have a high spire (apical angle as much as 50°). Whorls are in contact for most of ontogeny, but the last half-whorl of body chamber uncoils and recurves slightly. Most of the upper whorl face lies in an impressed zone that accommodated the base of the preceding whorl; it is usually pitted to accommodate tubercles. The outer whorl face is flattened above and broadly rounded below. Contact of the outer and lower whorl faces is narrowly rounded, and the base of the whorls is flattened. Coarse, single, straight prorsiradiate ribs, 40 to 50 per whorl, arise at the upper whorl contact and extend down to the lower whorl contact, where they join in pairs at prominent spines that are accommodated in the interspaces between ribs of the succeeding whorl; occasional nontuberculate ribs are present. On the base of the spire, a strong, straight prorsiradiate rib or a pair of weak ribs is linked to strong tubercles at the contact of the lower and inner whorl faces. In some cases, ribs on the lower face zigzag between tubercles. A straight rursiradiate rib extends from these tubercles onto the inner surface of the whorl. Interspaces are periodically deepened into constrictions, and the associated ribs may be flared. On the uncoiled part of the body chamber, ribs become irregular in strength, and flared ribs and constrictions become prominent toward the adult aperture. The aperture is preceded by two high, flared ribs separated by a deep constriction (pl. 2, figs. 17, 27). Sutures are very simple for the genus. The E/L saddle (between the external and lateral lobes) is broad, rectangular, little incised, and asymmetrically bifid; the L/U saddle (between the lateral and umbilical lobes), the lateral lobe (L), and the umbilical lobe (U) are narrower and symmetrically bifid.

Discussion.—The position of the tubercles at the contact of the outer and lower whorl faces and close to the umbilicus on the base of the whorl, as well as the prominent spines between the ribs of the succeeding whorl, differentiate *N.* (*N.*) *alternatum* from other North American species of the genus. *Nostoceras* (*N.*) *alternatum* most closely resembles *N.* (*N.*) *obtusum* Howarth (1965, p. 384, pl. 10, fig. 2; text fig. 17) from the Campanian of Angola, which

has a much lower spire, a lower whorl, finer ribs, and a much wider umbilicus. The second row of tubercles is in the middle of the lower whorl face and gives rise to pairs of ribs that extend over the inner whorl face.

Occurrence.—*Nostoceras* (*N.*) *alternatum* zone in the Coon Creek Tongue of the Ripley Formation in Mississippi, Alabama, and Georgia. Nacatoch Sand in Arkansas.

Family DIPLOMOCERATIDAE Spath, 1926
Subfamily DIPLOMOCERATINAE Spath, 1926

Genus *Solenoceras* Conrad, 1860

Type species.—*Hamites annulifer* Morton, 1841, p. 109.

***Solenoceras nitidum* Cobban, 1974**

Plate 2, figures 1–4

Types.—Holotype is USNM 187711, and paratypes are USNM 187712 to 187714, all from USGS Mesozoic locality 18078, a scraped area north of the dam of Union County Lake, 1.8 km northeast of Pleasant Ridge, in the NW¼NE¼NE¼ sec. 11, T. 6 S., R. 4 E., Union County, Mississippi.

Description.—Shell is small; fragments are up to 15 mm long and consist of two parallel shafts that are not in contact but joined by a curved sector. All specimens are crushed to varying degrees. Ornament on the smaller shafts is of sharp, narrow, prorsiradiate flank ribs that are narrower than the interspaces and pass straight across the venter. The ribs become markedly prorsiradiate and slightly convex at the beginning of the curved sector and swing round to become straight and rursiradiate on the larger shaft, where the rib index is 7 to 8. There are neither tubercles nor constrictions. The degree of separation between the two shafts is variable.

Discussion.—Absence of tubercles distinguishes *S. nitidum* from all other species referred to the genus.

Occurrence.—*Nostoceras* (*N.*) *alternatum* zone of the Coon Creek Tongue of the Ripley Formation in Mississippi, Alabama, and Georgia as well as in the *N.* (*N.*) *rugosum* zone in the Nacatoch Sand in Arkansas.

Family BACULITIDAE Gill, 1871

Genus *Baculites* Lamarck, 1799

Type species.—*Baculites vertebralis* Lamarck, 1801, p. 103, by subsequent designation by Meek (1876, p. 391).

Baculites claviformis Stephenson, 1941

Plate 3, figures 1–9

1892. *Baculites asper* Morton. Whitfield, p. 278, pl. 46, figs. 10, 11.
1907. *Baculites asper* Morton? Weller, p. 823, pl. 109, figs. 6, 7.
1926. *Baculites grandis* Hall and Meek. Wade, p. 182, pl. 60, figs. 8, 12.
1941. *Baculites claviformis* Stephenson, p. 403, pl. 1; pl. 77, figs. 6–8; pl. 78, figs. 1–6.
1962. *Baculites* sp. Reeside, p. 117, pl. 68, figs. 8, 9.
1974. *Baculites claviformis* Stephenson. Cobban, p. 5, pl. 3, figs. 7, 8, 12–14.

Types.—Holotype is USNM 77241, and paratypes are USNM 77242 to 77244, all from the Nacatoch Sand of northeastern Texas.

Description.—The approximately 30 specimens present in the collection of fossils from USGS Mesozoic locality D8839 have whorl heights ranging from 6.5 to 43.5 mm. Whorl sections are ovate and moderately stout to moderately compressed (whorl breadth to whorl height ratio, 0.76 in large specimens). Growth angles are large (6°-8°) in most of the smaller specimens (pl. 3, figs. 2, 5) and much smaller in the larger specimens (pl. 3, figs. 7, 8). The venter is broadly rounded, the dorsolateral area is narrowly rounded, the dorsal flanks are flattened, and the ventral part of the flanks converges to the rounded venter, which is much narrower than the dorsum. The weak ornament consists of narrow ribs that are weak on the dorsum, which they cross in a broad convexity. The ribs then curve back across the dorsolateral area and are concave across the dorsal two-thirds of the flank. The ribs project forward and strengthen on the outer flank to intersect the line of the venter at an angle of 20.5° and cross the venter in a narrow convexity. Growth lines and striae develop on the outermost flank and venter, which bears a dense irregular ornament. A few specimens have low folds on the flank in addition to the ribs. One specimen preserves the aperture, which has a short dorsal rostrum and a long ventral rostrum (pl. 3, fig. 2). Sutures were not seen.

Discussion.—This species is characterized by large size, an ovate whorl section, a flattened dorsum in adults, and flank ornament of closely spaced lateroventral and ventral ribs and distant crescentic dorsolateral ribs. It most closely resembles *Baculites undatus* Stephenson (1941, p. 405, pl. 79, figs. 5–10), which has a similar whorl section but quite distinct ornament of strong crescentic flank ribs that extend out onto the lateroventral region.

Occurrence.—This species first occurs in the Gulf Coast region associated with *N.* (*N.*) *hyatti* in the Coon Creek Tongue at the base of the Ripley Formation and ranges as high as the Owl Creek Formation, which overlies the Ripley where it is associated with *Eubaculites carinatus* (Morton, 1834) and *Sphenodiscus pleurisepta* (Conrad, 1857). *Baculites claviformis* is known from northeastern Texas, Arkansas, Mississippi, Alabama, Tennessee, New Jersey, and possibly Colorado.

Superfamily SCAPHITACEAE Gill, 1871
Family SCAPHITIDAE Gill, 1871

Subfamily SCAPHITINAE Gill, 1871

Genus *Jeletzkytes* Riccardi, 1983

Type species.—*Scaphites nodosus* Owen, 1852, p. 481, pl. 8, fig. 4, by original designation (Riccardi, 1983, p. 14).

***Jeletzkytes* sp. A**

Plate 1, figs. 10–13

Description.—Two fragments of adult body chambers show lateral and ventral ornament (pl. 1, figs. 10, 11) and part of the adult aperture (pl. 1, figs. 12, 13). In the former, coarse inner flank (primary) ribs branch on the outer flank, and additional fine ribs intercalate. The fine ribs link in groups of two or three at sharp ventrolateral clavi separated by nontuberculate ribs. Groups of as many as four fine ribs loop between clavi on either side of the venter, which they cross in a broad convexity. Intercalated nontuberculate ribs may branch on the ventrolateral shoulder and cross the venter parallel to the other ribs. The fragment that has the aperture shows a loss of ventral clavi; primary flank ribs give rise to groups of as many as five secondary ribs. Aperture is markedly contracted.

Discussion.—These fragments belong to an undescribed scaphite known from the *B. clinolobatus* zone in the Western Interior.

***Jeletzkytes* sp. B**

Plate 1, figs. 19–21

Description.—Crushed juveniles have coarse, irregularly branched ribs and umbilical, inner and outer lateral and ventrolateral tubercles on some ribs. Two or three fine ribs link ventral clavi over the venter. A body chamber, 74 mm long, has coarse ribs that branch and intercalate both low and high on the flank. Five rows of small bullate to nodate tubercles are present on many ribs on each flank. Delicate ribs occur between the outer tubercles. All tubercles weaken somewhat near the adult aperture.

Discussion.—This second species of *Jeletzkytes* is new also. Ornament of this type can be matched in undescribed forms from the *B. clinolobatus* zone in the Western Interior.

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PLATES 1–3

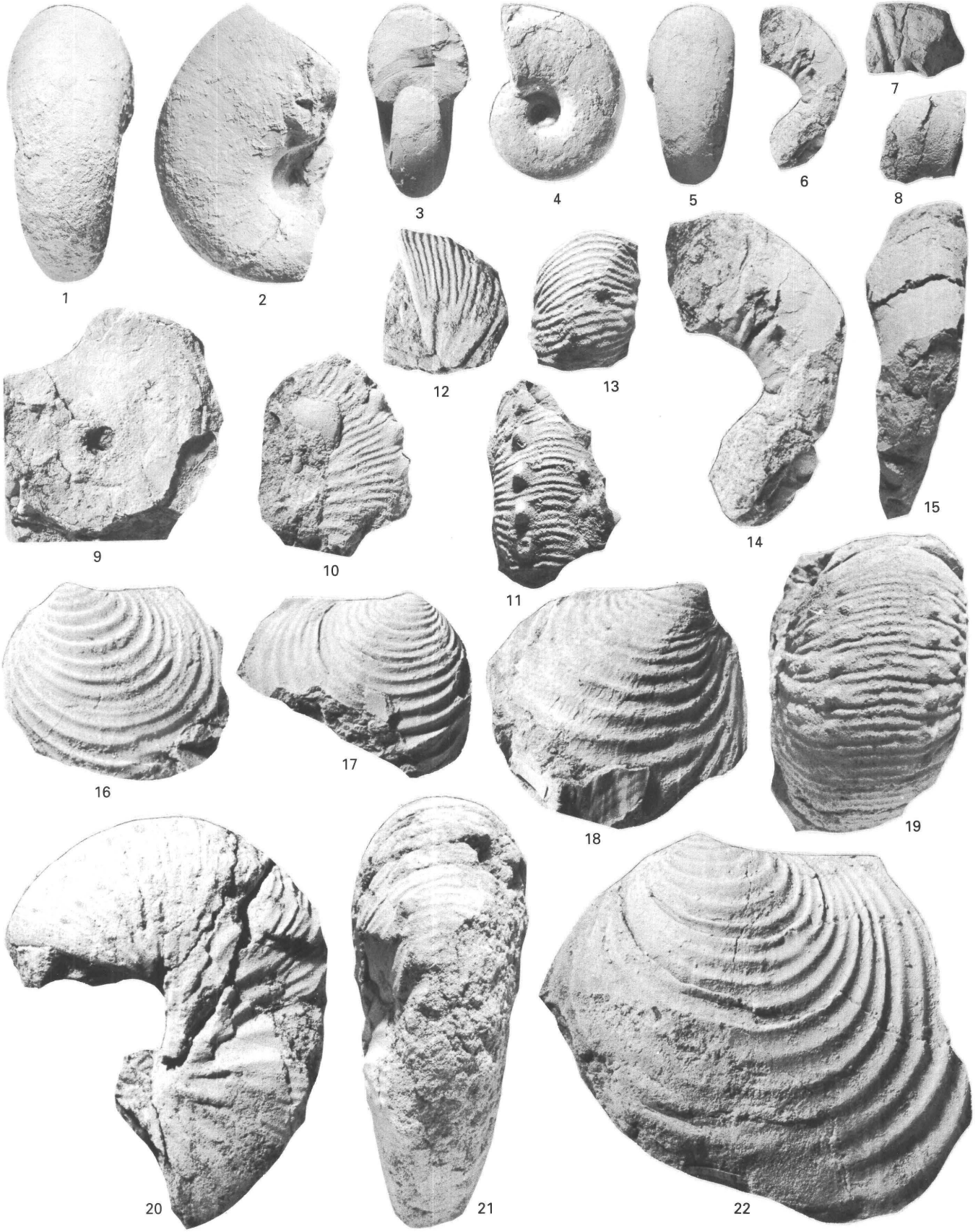
Contact photographs of the plates in this report are available, at cost, from the U.S. Geological Survey Photographic Library, Federal Center, Denver, CO 80225.

PLATE 1

Pseudophyllites indra (Forbes), *Brahmaites* sp., *Sphenodiscus* sp., *Jeletzkytes*, and *Inoceramus regularis* d'Orbigny

[All figures natural size]

Figures 1–5. *Pseudophyllites indra* (Forbes) (p. E2)
1, 2. Hypotype USNM 449204.
3–5. Hypotype USNM 449205.
6–8, 14, 15. *Brahmaites* sp. (p. E2)
6, 14, 15. Figured specimen USNM 449206.
7, 8. Figured specimen USNM 449207.
9. *Sphenodiscus* sp. (p. E3). Figured specimen USNM 449208.
10–13. *Jeletzkytes* sp. A (p. E5)
10, 11. Figured specimen USNM 449223.
12, 13. Figured specimen USNM 449224.
16–18, 22. *Inoceramus regularis* d'Orbigny (p. E1)
16. Hypotype USNM 449226.
17. Hypotype USNM 449227.
18. Hypotype USNM 449228.
22. Hypotype USNM 449229.
19–21. *Jeletzkytes* sp. B (p. E5). Figured specimen USNM 449225.



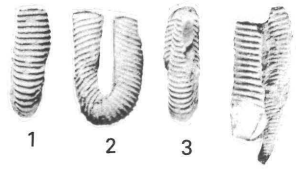
PSEUDOPHYLLITES INDRA, *BRAHMAITES* SP., *SPHENODISCUS* SP., *JELETZKYTES*, AND *INOCERAMUS REGULARIS*

PLATE 2

Solenoceras nitidum Cobban and *Nostoceras* (*N.*) *alternatum* (Tuomey)

[All figures natural size]

Figures 1–4. *Solenoceras nitidum* Cobban (p. E4)
1–3. Hypotype USNM 449218.
4. Hypotype USNM 449219.
5–27. *Nostoceras* (*N.*) *alternatum* (Tuomey) (p. E3)
5–7. Hypotype USNM 449209.
8, 9. Hypotype USNM 449210.
10. Hypotype USNM 449211.
11, 17. Hypotype USNM 449212.
12, 13. Hypotype USNM 449213.
14–16. Hypotype USNM 449214.
18–20. Hypotype USNM 449215.
21–24. Hypotype USNM 449216.
25–27. Hypotype USNM 449217.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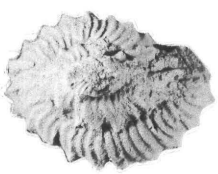
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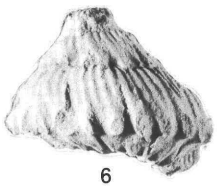
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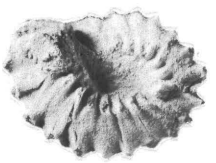
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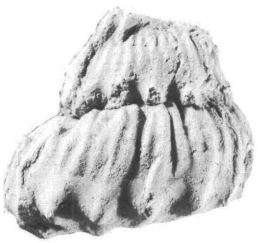
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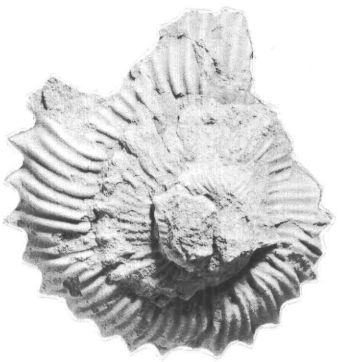
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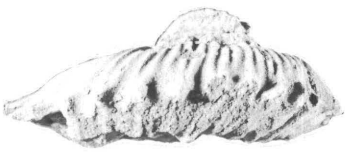
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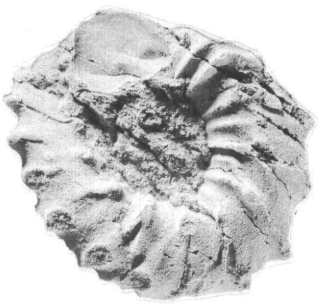
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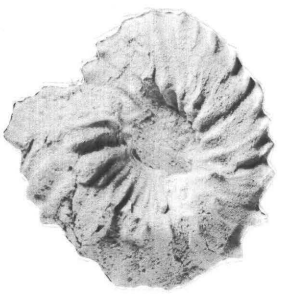
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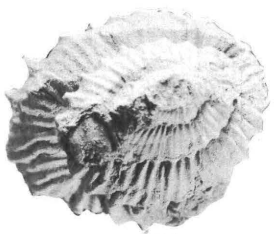
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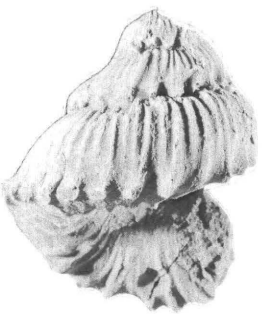
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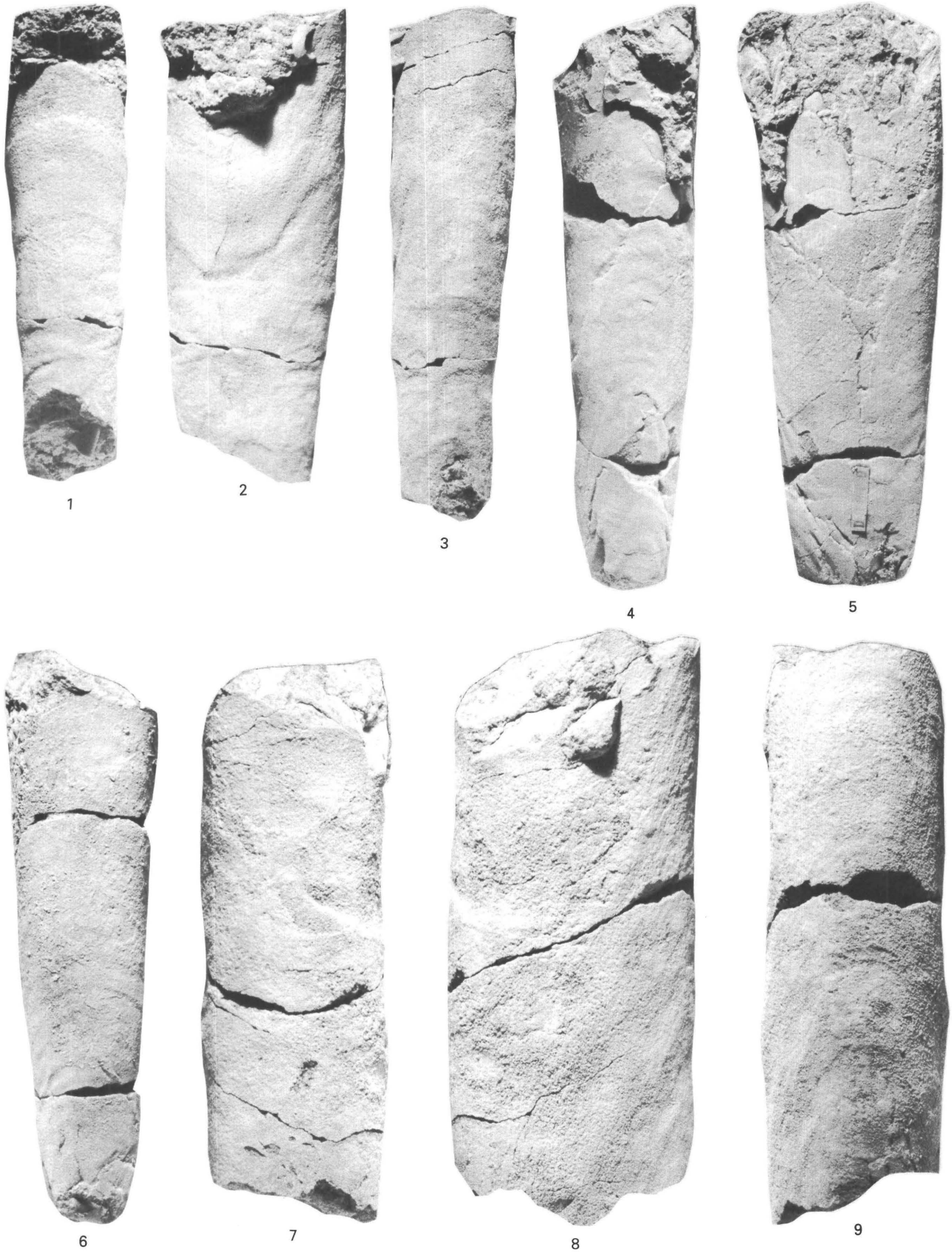
SOLENOCERAS NITIDUM AND *NOSTOCERAS* (*N.*) *ALTERNATUM*

PLATE 3

Baculites claviformis Stephenson

[All figures natural size]

Figures 1–9. *Baculites claviformis* Stephenson (p. E4)
1–3. Hypotype USNM 449220.
4–6. Hypotype USNM 449221.
7–9. Hypotype USNM 449222.



BACULITES CLAVIFORMIS

Chapter F

Pachydiscus (Ammonoidea) from Campanian (Upper Cretaceous) Rocks in the Western Interior of the United States

By WILLIAM A. COBBAN and W. JAMES KENNEDY

Description of rare occurrences of the cosmopolitan ammonite *Pachydiscus*, previously unrecorded from the Western Interior of the United States

U.S. GEOLOGICAL SURVEY BULLETIN 1985

SHORTER CONTRIBUTIONS TO PALEONTOLOGY AND STRATIGRAPHY

CONTENTS

PLATES

[Plates follow References cited]

FIGURES

Pachydiscus (Ammonoidea) from Campanian (Upper Cretaceous) Rocks in the Western Interior of the United States

By William A. Cobban[1] *and* W. James Kennedy[2]

Abstract

Examples of the Campanian-Maastrichtian ammonite genus *Pachydiscus* Zittel, 1884, occur as great rarities in the Western Interior of the United States. *Pachydiscus* (*Pachydiscus*) cf. *oldhami* (Sharpe, 1855) and *P.* (*P.*) cf. *arkansanus* (Stephenson, 1941) are recorded from the *Baculites compressus* zone of Montana, and *P.* (*P.*) *arkansanus* (Stephenson, 1941) is recorded from the *Exiteloceras jenneyi* zone of Colorado and South Dakota.

INTRODUCTION

The Upper Cretaceous ammonite *Pachydiscus* Zittel, 1884, has a nearly worldwide distribution in rocks of Campanian and Maastrichtian age, but, like many other cosmopolitan ammonite genera, unquestioned *Pachydiscus* have not been previously recorded from the Western Interior. A single specimen of *Pachydiscus* (*Pachydiscus*) cf. *oldhami* (Sharpe, 1855), first described from Ireland but known to occur widely in Europe and the U.S.S.R., has been found recently in the *Baculites compressus* zone in the Bearpaw Shale of Montana. The Montana specimen was associated with a fragment of a much stouter pachydiscid that is referred to *P.* (*P.*) cf. *arkansanus* (Stephenson, 1941), a species originally described from the Nacatoch Sand of southwestern Arkansas. A much larger specimen of Stephenson's species was collected in 1950 from the Terry Sandstone Member of the Pierre Shale in northern Colorado. The purpose of this report is to make known these rare occurrences of *Pachydiscus* in the Western Interior.

Most of the specimens described in this report were donated to the U.S. Geological Survey (USGS) by David L. Anderson of Dakota Fossils in Rapid City, S. Dak. (pl. 1, figs. 1–3; pl. 4, figs. 1–3); Thebe Hanson of Oacoma, S. Dak. (unfigured specimen USNM 449201); the late R.G. Coffin of Fort Collins, Colo. (pl. 1, fig. 4; pl. 2); and the late J.P. Conlin of Fort Worth, Tex. (pl. 3; pl. 4, fig. 4). These specimens are kept in the National Museum of Natural History (USNM), Washington, D.C., and carry USNM catalog numbers. Plaster casts of most of them are in the USGS reference collections at the Federal Center in Denver. Kennedy acknowledges the financial support of the National Environment Research Council (U.K.), the Royal Society, and the Astor Fund (Oxford) and the technical support of the staff of the Geological Collections, Oxford University Museum, Oxford, and the Department of Earth Sciences, Oxford.

CONVENTIONS

Dimensions are given in millimeters. *D* is diameter; *Wb*, whorl breadth; *Wh*, whorl height; and *U*, umbilicus. Figures in parentheses refer to dimensions as a percentage of the diameter. Suture terminology is the system of Wedekind (1916) as reviewed by Kullmann and Wiedmann (1970), where E is the external lobe, L is the lateral lobe, U is the umbilical lobe, and I is the internal lobe.

SYSTEMATIC PALEONTOLOGY

Family PACHYDISCIDAE Spath, 1922
Genus and Subgenus *Pachydiscus* Zittel, 1884.

***Pachydiscus* (*Pachydiscus*) cf. *oldhami* (Sharpe, 1855)**

Plate 1, figures 1–3; text figure 1

1855. *Ammonites oldhami* Sharpe, p. 32, pl. 14, fig. 2.
1986. *Pachydiscus* (*Pachydiscus*) *oldhami* (Sharpe, 1855). Kennedy, p. 40, pl. 3; pl. 4, figs. 4, 5; pl. 5, figs. 1–3; text figs. 4a, 15, 16, 18 (with synonymy).

Type.—Holotype, by monotypy, is no. 37244 in the collections of the British Geological Survey in Keyworth,

Manuscript approved for publication March 21, 1991.
[1]U.S. Geological Survey, Denver, CO 80225.
[2]Geological Collections, University Museum, Parks Road, University of Oxford, Oxford OX1 3PW, U.K.

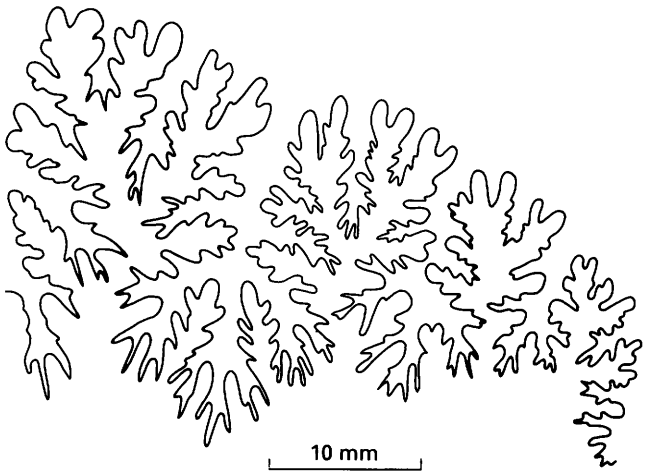


Figure 1. External suture of *Pachydiscus* (*P.*) cf. *oldhami* (Sharpe, 1855), USNM 449198.

the original of Sharpe (1855, pl. 32, pl. 14, fig. 2) from the upper Campanian White Limestone of Dungivan, Northern Ireland (see Kennedy, 1986, text fig. 16).

Description.—USNM 449198 is a crushed and corroded internal mold of a phragmocone that has the following dimensions and ratios to the diameter: *D*, 116 mm; *Wb*, 40.0 mm (34.5 percent); *Wh*, 50.5 mm (43.5 percent); *U*, 28.5 mm (24.6 percent); and *Wb*:*Wh*, 0.70.

Coiling is moderately evolute. The umbilicus, which comprises 24.6 percent of the diameter, has a low, outward-inclined umbilical wall. The whorl section is compressed; the whorl breadth to height ratio ranges between 0.79 and 0.84 depending on the degree of post-mortem crushing. The umbilicus and inner flanks are broadly rounded, the outer flanks convergent, and the venter rounded. Inner whorls within the umbilicus have distant, straight, prorsiradiate primary ribs, 10 to 12 per whorl, that arise at incipient umbilical bullae. The badly corroded outer whorl has primary ribs that arise in pairs from bullae and are separated by as many as four long and short intercalated ribs. Intercalated ribs are weaker than the primaries on the inner to middle flank, where the ribs are prorsiradiate and straight. The bullate primaries weaken somewhat, and the secondaries strengthen on the outer flank so that the ribs become equal in development. Ribs bend forward slightly on the outer flank and cross the venter in a shallow convexity, where they are interrupted over the line of the siphuncle by a narrow groove. There are an estimated 30 ribs on the penultimate whorl. Suture (text fig. 1) has deeply incised asymmetrically bifid E/L and L/U_2 marked by narrow stems. L and U_2 are subtrifid.

Discussion.—Whorl proportions and ribbing style closely resemble those of *P.* (*P.*) *oldhami* (Sharpe, 1855), but the corroded nature of the holotype and the present specimen preclude firm identification. There are also close similarities to juvenile *P.* (*P.*) *haldemsis* (Schlüter, 1867) (see revision by Kennedy and Summesberger, 1984, p. 158, pl. 4, figs. 1–5; pl. 5, fig. 1; pl. 6, fig. 2; pl. 7, figs. 1–11; pl. 13, fig. 1; Kennedy 1986, p. 45, pl. 4, figs. 1–3; pl. 5, figs. 7–14; text figs. 11a–d, 17), but this species has coarser ornament and well-developed bullae when young and retains its ornament to a large size, whereas *P.* (*P.*) *oldhami* becomes smooth.

Occurrence.—USNM 449198 is from the *B. compressus* zone in the Bearpaw Shale just above bentonite bed A (Smith, 1962; Berg, 1970), 9 km south of Ingomar in the NE¼ sec. 36, T. 9 N., R. 34 E., Rosebud County, Montana. The species occurs widely in the upper Campanian in Northern Ireland; Norfolk, England; Aquitaine, France; Poland; and European Russia. Polish occurrences are within the *Didymoceras donezianum* zone of the Vistula Valley sequence (Błaszkiewicz, 1980).

***Pachydiscus* (*Pachydiscus*) *arkansanus* (Stephenson, 1941)**

Plate 1, figure 4; plates 2–4; text figure 2

1941. *Parapachydiscus arkansanus* Stephenson, p. 418, pl. 84; pl. 85, figs. 1–3; pl. 86, figs. 1–5; pl. 87, figs. 1–3.

Types.—Holotype USNM 77286 is from the Nacatoch Sand, 3.5 km northeast of Washington in Hempstead County, Arkansas. Paratype USNM 21094 is from the Nacatoch Sand near Chatfield in Navarro County, Texas. Paratype USNM 20962 is from the Nacatoch Sand near Kaufman in Kaufman County, Texas.

Description.—What may be the early growth stages of this species are represented by USNM 449199 (pl. 4, figs. 1–3). This part of a phragmocone has a maximum preserved whorl height of 46 mm and a whorl breadth to height ratio of 1.06. Ornament consists of narrow ribs separated by wider interspaces. The ribs, which are weak on the inner flanks and strong and concave on the outer flank, cross the venter in a broad convexity. Where shell is absent, ornament is much more subdued (pl. 4, fig. 3) and nearly effaced on the inner flank. A narrow groove marks the line of the siphuncle. USNM 449200 (pl. 1, fig. 4; pl. 2) is a large, rather worn internal mold of a phragmocone 256 mm in diameter and moderately evolute. The deep umbilicus comprises 26 percent of the diameter and has a rounded umbilical wall that is undercut on the mold. The slightly depressed whorl section is reniform and has broadly rounded flanks and venter (text fig. 2).

Ornament consists of strong primary ribs that are narrower than the interspaces and arise at weak umbilical bullae on the umbilical shoulder. Ribs are generally single, but some are occasionally paired. Ribs are straight on the inner flank but flex forward and strengthen on the outer flank and then cross the venter in a broad convexity.

USNM 449201 is a huge phragmocone that has the following dimensions and proportions: *D*, 375 (100 percent); *Wb*, 180 (48 percent); *Wh*, 180 (48 percent); *Wb*:*Wh*,

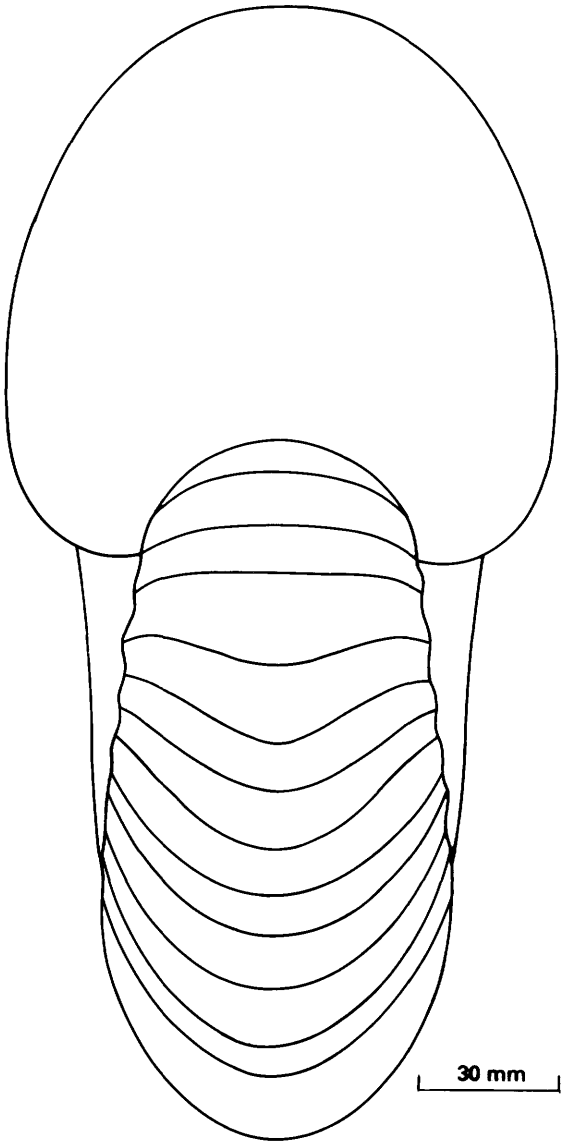


Figure 2. Restored whorl section of *Pachydiscus* (*P.*) *arkansanus* (Stephenson, 1941), based on USNM 449202.

1.00; and *U*, 84 (22 percent). The whorl section is slightly depressed and reniform, and the deep umbilicus has a rounded wall. Inner whorls have 23 ribs that arise at the umbilical seam and strengthen across the umbilical shoulder into short, blunt spines. These spines decline and disappear at the beginning of the outer whorl, where ornament consists of alternating long, slightly bullate, narrow, strong primary ribs and long secondary ribs. All ribs are straight on the inner flank but flex forward and become a little concave on the outer flank and then cross the venter in a broad convexity. The ribs decline by the middle third of the outer whorl; on the last third, ornament consists of distant, prorsiradiate ribs on the inner and middle flank that decline on the outer flank and efface on the venter.

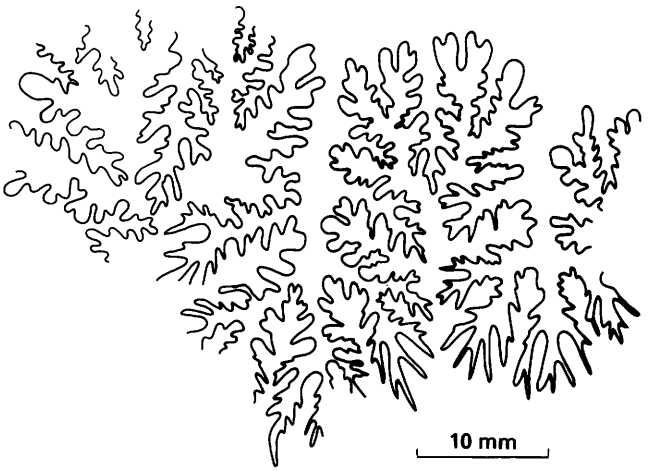


Figure 3. Partial external suture of *Pachydiscus* (*P.*) cf. *arkansanus* (Stephenson, 1941), USNM 449199.

The juvenile fragment (USNM 449199), in comparison with *P.* (*P.*) *arkansanus*, shows the suture (text fig. 3). Lobes are deeply and intricately subdivided, bifid, and narrow stemmed. Saddles are similarly incised and narrow necked (text fig. 3).

Discussion.—The ornament of these specimens differs in no significant respects from that of the holotype of *Pachydiscus* (*P.*) *arkansanus* (Stephenson, 1941, p. 418, pl. 84; pl. 85, fig. 1; pl. 86, fig. 1). A better preserved Gulf Coast specimen from the James P. Conlin collection (USNM 449202) (pl. 3; pl. 4, fig. 4) has coarse umbilical spines on the inner whorls and simplified ribbing on the outer whorl, as does the largest Western Interior specimen.

These large pachydiscids most closely resemble *P.* (*P.*) *colligatus* (Binkhorst, 1861) among other described species, but the lectotype of this European Campanian species loses most of its ornament at a stage where *P.* (*P.*) *arkansanus* is still ribbed. The small specimen of *P.* (*P.*) *colligatus* figured by de Grossouvre (1893, pl. 33 only) has coarser ribs that are much more markedly projected and concave on the ventrolateral shoulders in comparison with similarly sized *P.* (*P.*) *arkansanus*.

Occurrence.—The holotype of *P.* (*P.*) *arkansanus* is from the Nacatoch Sand on the old Confederate military road 3.5 km northeast of Washington in Hempstead County, Arkansas, a locality containing other fossils that seem correlative with the *B. baculus* zone of the Western Interior sequence. Specimens from the Nacatoch Sand in northeastern Texas come from horizons correlated with the *B. compressus* to *B. jenseni* zones. USNM 449200 is from USGS Mesozoic locality 22923, *Exiteloceras jenneyi* zone, Terry Sandstone Member of Pierre Shale, in W½ sec. 29, T. 9 N., R. 68 W., Larimer County, Colorado. USNM 449203, a juvenile fragment compared to this species, is from the *E. jenneyi* zone, DeGrey Member of the Pierre Shale, USGS Mesozoic locality 21595, 3.3 km west of

Oacoma in the S½ sec. 22, T. 104 N., R. 72 W., Lyman County, South Dakota. USNM 449201 is from the Gregory Member of the Pierre Shale in the SE¼ sec. 5, T. 103 N., R. 72 W., about 9.9 km southwest of Oacoma in Lyman County, South Dakota.

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PLATES 1–4

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PLATE 1

Pachydiscus (*Pachydiscus*) cf. *oldhami* (Sharpe, 1855) and *Pachydiscus* (*Pachydiscus*) *arkansanus* (Stephenson, 1941)

[All figures are natural size except as indicated]

Figures 1–3. *Pachydiscus* (*P.*) cf. *oldhami* (Sharpe, 1855). USNM 449198, from the *Baculites compressus* zone in the Bearpaw Shale just above bentonite bed A in the NE¼ sec. 36, T. 9 N., R. 34 E., 9.1 km south of Ingomar in Rosebud County, Montana.

4. *Pachydiscus* (*P.*) *arkansanus* (Stephenson, 1941). USNM 449200, from the Terry Sandstone Member of the Pierre Shale at U.S. Geological Survey Mesozoic locality 22923, in the W½ sec. 29, T. 9 N., R. 68 W., Larimer County, Colorado. For side view, see plate 2. Figure 9/10 natural size.

PACHYDISCUS (*PACHYDISCUS*) CF. *OLDHAMI* AND *PACHYDISCUS* (*PACHYDISCUS*) *ARKANSANUS*

PLATE 2

Pachydiscus (*Pachydiscus*) *arkansanus* (Stephenson, 1941)

[Figure is 9/10 natural size]

USNM 449200, from the Terry Sandstone Member of the Pierre Shale at U.S. Geological Survey Mesozoic locality 22923, in the W½ sec 29, T. 9 N., R. 68 W., Larimer County, Colorado. For end view, see plate 1, figure 4.

PACHYDISCUS (PACHYDISCUS) ARKANSANUS

PLATE 3

Pachydiscus (*Pachydiscus*) *arkansanus* (Stephenson, 1941)

[Figure is natural size]

USNM 449202, J.P. Conlin collection, from the Nacatoch Sand of Kaufman County, Texas. For ventral view, see plate 4, figure 4.

PACHYDISCUS (PACHYDISCUS) ARKANSANUS

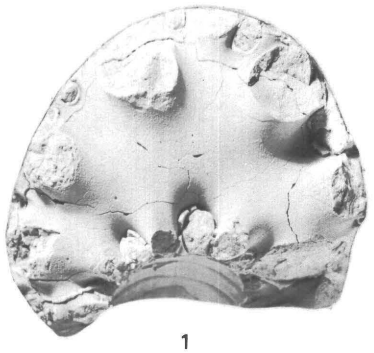
PLATE 4

Pachydiscus (*Pachydiscus*) *arkansanus* (Stephenson, 1941)

[All figures are natural size]

Figures 1–3. USNM 449199, from the Bearpaw Shale just above bentonite bed A in the NE¼NE¼ sec. 36, T. 9 N., R. 34 E., Rosebud County, Montana.

4. USNM 449202, J.P. Conlin collection, from the Nacatoch Sand of Kaufman County, Texas. For side view, see plate 3.



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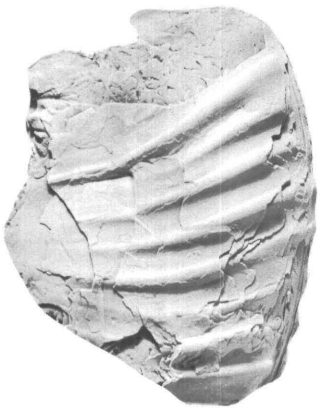

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PACHYDISCUS (PACHYDISCUS) ARKANSANUS

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