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Heteromorph ammonites from the middle Campanian *Baculites scotti* Zone in the U.S. Western Interior

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ABSTRACT:

KENNEDY, W.J., COBBAN, W.A. & SCOTT, G.R. 2000. Heteromorph ammonites from the middle Campanian *Baculites scotti* Zone in the U. S. Western Interior. *Acta Geologica Polonica*, **50** (2), 223-241. Warszawa.

Heteromorph ammonites are common in the middle Campanian *Baculites scotti* Zone of the United States Western Interior; the following species are described: *Didymoceras binodosum* (KENNEDY & COBBAN, 1993a), *D. wrighti* sp. nov., *D. jorgenseni* sp. nov., *Anaklinoceras incertum* sp. nov., *Lewyites sulcatus* sp. nov., *Solenoceras mortoni* (MEEK & HAYDEN, 1857), and *Spiroxybeloceras kimbroense* KENNEDY & COBBAN, 1999. They provide the basis for the subdivision of the *scotti* Zone into a lower *Didymoceras binodosum* Subzone, and an upper *Didymoceras jorgenseni* Subzone.

Key words: Cretaceous, Campanian, U.S. Western Interior, Ammonites, Biostratigraphy.

INTRODUCTION

Baculites scotti is the index fossil of a widely recognized middle Campanian zone between that of *Baculites reduncus* below and *Didymoceras nebrascense* above (Table 1). Heteromorph ammonites, notably helicoid members of the family Nostoceratidae, are locally common in the zone, and the following are described below: *Didymoceras binodosum* (KENNEDY & COBBAN, 1993a), *D. wrighti* sp. nov., *D. jorgenseni* sp. nov., *Anaklinoceras incertum* sp. nov., *Lewyites sulcatus* sp. nov., *Solenoceras mortoni* (MEEK & HAYDEN, 1857), and *Spiroxybeloceras kimbroense* KENNEDY & COBBAN, 1999. The material, although frequently fragmentary, provides the basis for reconstructions of five of the species described.

SCOTT (1964; *see also* SCOTT & COBBAN, 1986) recognized a number of subdivisions of the *scotti* Zone; on the basis of the present study we recognize two subzones, of *Didymoceras binodosum* below, and *Didymoceras jorgenseni* above. The distribution of the ammonites known from the subzones of the *scotti* Zone are shown in Table 2.

Localities where fossils were collected have, for the most part, been assigned U.S. Geological Survey numbers, and are shown in Text-fig. 1, and set out in Table 3. The prefix D indicates a Denver locality number, those without a letter prefix are Washington, D.C. localities.

THE *BACULITES SCOTTI* ZONE

Baculites scotti COBBAN, 1958, is a heteromorph ammonite that is straight or nearly so except for a minute initial coil. The species is of moderate size for the genus and has a fairly complex suture characterized by the lateral lobe having a constriction just above its lateral branches. The suture with its distinctive lateral lobe has been illustrated in numerous publications

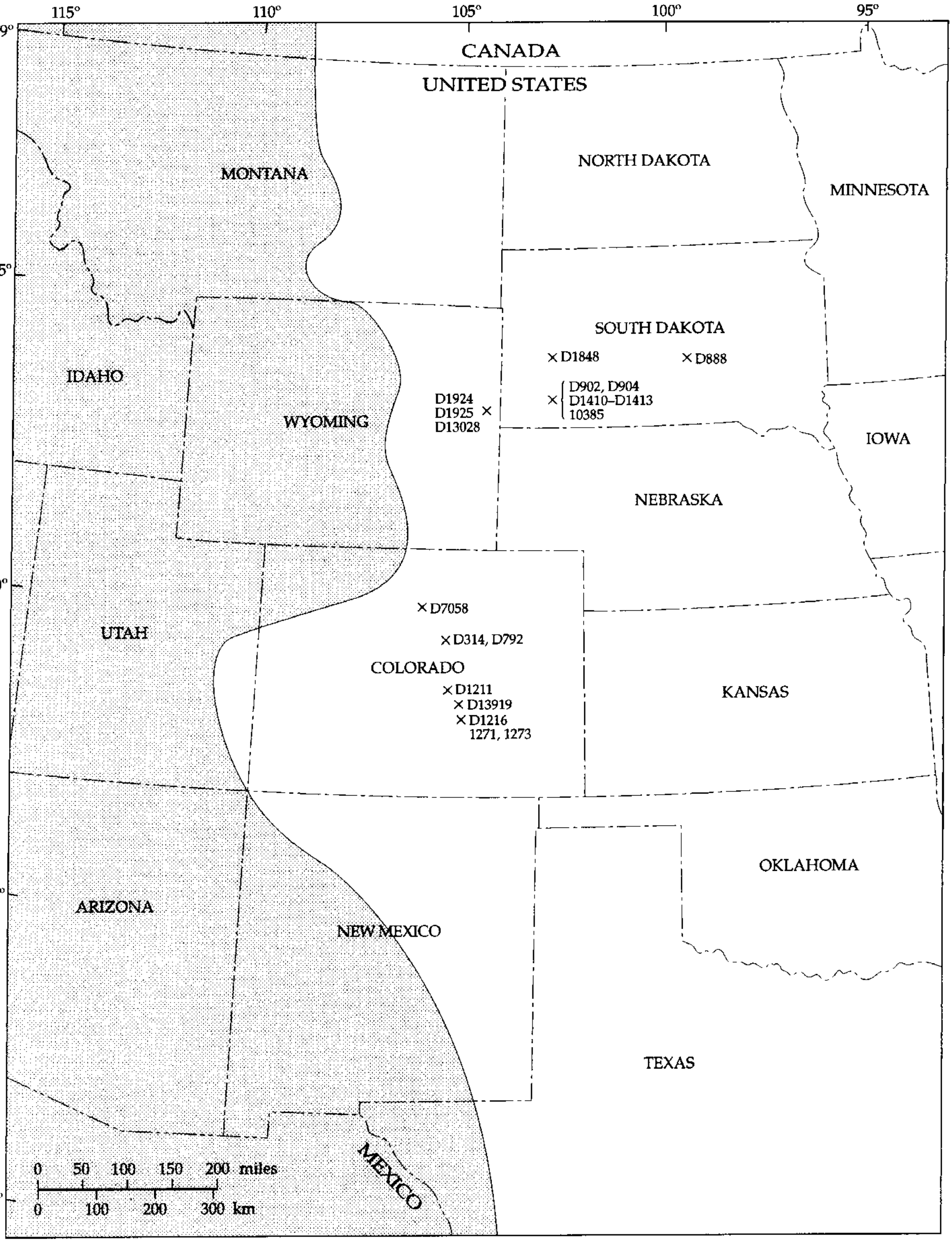

Fig. 1. Fossil localities mentioned in the text (see also Table 1); the position of the western shoreline of the Western Interior seaway during *Baculites scotti* Zone time is indicated; presumed land areas are shown stippled (*from* COBBAN & *al.* 1994)

(COBBAN 1958, fig. 1h; SCOTT & COBBAN 1965, 1975, 1986a, 1986b; GILL & COBBAN 1973; LARSON & *al.*, 1997). *Baculites scotti* was described from the "tepee zone" of GILBERT (1897) in the Pierre Shale at Baculite Mesa near Pueblo in south-central Colorado (COBBAN 1958). The species was made index species of a zone between that of *Baculites gregoryensis* COBBAN, 1951, below, and *Baculites pseudovatus* above. *B. pseudovatus* was replaced as an index species by the more readily identified heteromorph *Didymoceras nebrascense*

Cretaceous Stages and Western Interior informal substages		Western Interior ammonite zones
Maastrichtian (part)	Upper (part)	*Jeletzkytes nebrascensis*
		Hoploscaphites nicolletii
	Lower	*Hoploscaphites birkelundi*
		Baculites clinolobatus
		Baculites grandis
		Baculites baculus
		Baculites eliasi
Campanian	Upper	*Baculites jenseni*
		Baculites reesidei
		Baculites cuneatus
		Baculites compressus
		Didymoceras cheyennense
		Exiteloceras jenneyi
		Didymoceras stevensoni
		Didymoceras nebrascense
	Middle	*Baculites scotti*
		Baculites reduncus
		Baculites gregoryensis
		Baculites perplexus
		Baculites sp. (smooth)
		Baculites asperiformis
		Baculites maclearni
		Baculites obtusus
	Lower	*Baculites* sp. (weak flank ribs)
		Baculites sp. (smooth)
		Scaphites hippocrepis III
		Scaphites hippocrepis II
		Scaphites hippocrepis I
		Scaphites leei III

Table 1. Campanian and Maastrichtian ammonite zones in the United States Western Interior; the position of the *Baculites scotti* Zone is indicated

(MEEK & HAYDEN, 1856) (SCOTT & COBBAN 1959, fig. 3). A zone of *Baculites reduncus* COBBAN, 1977, was subsequently recognized between the zones of *B. scotti* and *B. gregoryensis* in Wyoming and Colorado (Table 1).

The *Baculites scotti* Zone is well developed in the Pueblo area of Colorado, where it attains a thickness of 132 m (435 ft) (SCOTT 1969). In the course of mapping the Pierre Shale in the Pueblo area, SCOTT (1964) subdivided the *scotti* Zone into the following subzones, from oldest to youngest: (1) *Anapachydiscus*? *complexus* and *Menuites*? n.sp. with *Didymoceras* n.sp. at the base, (2) *Didymoceras* n.sp. (loosely coiled), (3) *Didymoceras* n.sp. (tightly coiled), and (4) an unnamed upper and greater part of the zone. These subzones were mapped by SCOTT (1964, 1969). Their presence northwards beyond Denver was noted by SCOTT & COBBAN (1965).

A recent investigation by COBBAN & KENNEDY (1993) revealed that *Anapachydiscus*? *complexus* and *Menuites*? n.sp. of SCOTT's lowest subzone are really macroconch and microconch of *Menuites oralensis* COBBAN & KENNEDY, 1993. About that time the heteromorph marking the overlying subzone of *Didymoceras* n.sp. (loosely coiled) was described as the new genus and species *Didymoceratoides binodosum* KENNEDY & COBBAN, 1993a. The types were based on loosely coiled planispiral whorls with complete body chambers. A subsequent re-examination of the Geological Survey collections revealed that the type specimens were mostly juvenile whorls of a species of *Didymoceras* that had loosely coiled planispiral early whorls followed by several helicoid whorls that were barely in contact. Overlooked was a drawing made back in the 1960's by John R. STACY, a gifted U.S. Geological Survey illustrator, that showed a reconstruction of the complete shell (Text-fig. 2). *Didymoceras binodosum* has been found with *Menuites oralensis* at several localities in South Dakota, Wyoming, and Colorado, and, accordingly, the original subzone of *Anapachydiscus* complex-*Menuites* n.sp. and the subzone of *Didymoceras* n.sp. (loosely coiled) of SCOTT are combined in the present report as the *Didymoceras binodosum* Subzone. The guide fossil to the overlying subzone that was listed as *Didymoceras* n.sp. (tightly coiled) is herein described as *Didymoceras jorgenseni* sp. nov. (Table 2).

Southwest of the Black Hills uplift near the former Red Bird store in eastern Wyoming, a bed of closely spaced, silty, calcareous concretions at the top of the Red Bird Silty Member of the Pierre Shale contains several species of ammonites. These were reported as *Baculites scotti* COBBAN, 1958, *Didymoceras* n.sp., *Exiteloceras* n.sp., *Anaklinoceras mortoni* (HALL & MEEK, 1856), and *Anapachydiscus complexus* (HALL & MEEK, 1856) (GILL & COBBAN 1966, p. A56). The

SUBZONE	*D. binodosum*	*D. jorgenseni*
Menuites oralensis (COBBAN & KENNEDY, 1993)	X	X
Anaklinoceras incertum sp. nov.	X	
Didymoceras binodosum (KENNEDY & COBBAN, 1993a)	X	
Didymoceras wrighti sp. nov.	X	
Didymoceras jorgenseni sp. nov.		X
Lewyites sulcatus sp. nov.		?
Spiroxybelocerus kimbroense (KENNEDY & COBBAN, 1999)	X	X
Solenoceras mortoni (MEEK & HAYDEN, 1859)	X	X
Baculites scotti (COBBAN, 1958)	X	X
Baculites texanus (KENNEDY & COBBAN, 1999)	X	X
Trachyscaphites pulcherrimus (ROEMER, 1841)	X	

Table 2. Subzonal distribution of ammonites in the *Baculites scotti* Zone

USGS Locality No.		Collector(s) and year
1271	South of Baculite Mesa [NE1/4 sec. 9, T. 20 S., R. 64 W., Pueblo County, Colorado]. Pierre Shale.	G.K. Gilbert, 1893
1273	South of Baculite Mesa [SW1/4 SW1/4 sec. 10, T. 20 S., R. 64 W., Pueblo County, Colorado]. Pierre Shale.	G.K. Gilbert, 1893
10385	Mouth of Beaver Creek on Cheyenne River, S. of Buffalo Gap, South Dakota. Pierre Shale 30 m (100 feet) above river.	T.W. Stanton, 1920
D314	SW1/4 SE1/4 sec. 6, T. 5 S., R. 69 W., Jefferson County, Colorado. Pierre Shale, about 527 m (1,730 ft) above base.	G.R. Scott, 1955
D888	SE1/4 NW1/4 sec. 17, T. 104 N., R. 71 W., Lyman County, South Dakota. Pierre Shale, from Gregory Member.	W.A. Cobban, 1956
D902	Buff and grey concretions in Pierre Shale, S. side of Beaver Creek, 7.3 km (4.5 mi) SSE of Buffalo Gap, in NE1/4 sec. 22, T. 7 S., R. 7 E., Fall River County, South Dakota.	W.A. Cobban, 1956
D904	Pierre Shale, N. side of Cheyenne River, 7.8 km (4.7 mi) SE of Buffalo Gap, in NW1/4 NW1/4 sec. 23, T. 7 S., R. 7 E., Fall River County, South Dakota.	W.A. Cobban, 1956
D927	Hygiene Member of Pierre Shale, in NW1/4 SE1/4 sec. 19, T. 7 S., R. 68 W., Douglas County, Colorado.	G.R. Scott, R.Van Horn, W.A. Cobban, 1956
D1058	Pierre Shale, 5 km (3 mi) NW of Granby in sec. 23, T. 2 N., R. 77 W., Grand County, Colorado.	W.A. Cobban, G.R. Scott 1956
D1211	NW1/4 SE1/4 sec. 30, T. 15, S., R. 66 W., El Paso County, Colorado. Pierre Shale	G.R. Scott, 1957
D1216	Pierre Shale, in C S1/2 N1/2 sec. 15, T. 20 S., R. 64 W., Pueblo County, Colorado.	G.R. Scott, W.A. Cobban 1956
D1410	Same locality as D904, from grey calcareous concretions in SE1/4 NW1/4 NW1/4 sec. 23, T. 7 S., R. 7 E., Fall River County, South Dakota. Pierre Shale.	G.R. Scott, W.A. Cobban 1957
D1411	Pierre Shale. W. facing bluff 1.7 km (1 mi) NNE of Oral in NW1/4 NW1/4 sec. 26, T.7 S., R.7 E., Fall River County, South Dakota.	G.R. Scott, W.A. Cobban 1957
D1412	Same locality as D1411. Pierre Shale. 1957	G.R. Scott, W.A. Cobban
D1413	Same locality as D1411. Pierre Shale, from higher than D1411.	G.R. Scott, W.A. Cobban 1957
D1848	Pierre Shale, in SE1/4 sec. 9, T. 4 N., R. 8 E., Meade County, South Dakota.	J.R. Gill, 1958
D1924	Ridge-forming tan concretionary limestone and grey limestone nodules 220.4-221.3 m (723-726 ft.) above base of Red Bird Silty Member of Pierre Shale in NE1/4 sec. 23, T. 38 N., R. 62 W., Niobrara County, Wyoming.	H.A. Tourtelot, J.R. Gill, W.J. Mapel, C.S. Robinson, W.A. Cobban, G.R. Scott, 1957
D1925	Same horizon as D1924, in E1/2 E1/2 sec. 1, and W1/2 NW1/4 sec. 13, T.38 N., R.62 W., Niobrara County, Wyoming.	H.A. Tourtelot, J.R. Gill, W.J. Mapel, C.S. Robinson, W.A. Cobban, G.R. Scott, 1957
D5298	Tepee-butte limestone in Pierre Shale in the NE1/4 NE1/4 sec. 15, T. 20 S., R. 64 W., Pueblo County, Colorado.	H. Mendryk, 1972
D13027	Top of Red Bird Silty Member of Pierre Shale (Bed 54 of section), Red Bird section, in W1/2 SW1/4 sec. 12, T. 38 N., R. 62 W., Niobrara County, Wyoming.	H. Mendryk, 1972
D13028	Top of Red Bird Silty Member of Pierre Shale, probably in sec. 32, T. 39 N., R. 61 W., Niobrara County, Wyoming.	H. Mendryk, 1972
D13939	Pierre Shale, SE1/4 SE1/4 sec. 32, T. 18 S., R. 64 W., Pueblo County, Colorado.	K. Hirsch, 1974

Table 3. U.S. Geological Survey fossil localities mentioned in the text (*see also* Text-fig. 1)

Didymoceras n.sp. is described below as *D. wrighti* sp.nov. The *Exiteloceras* n.sp. was figured by KENNEDY & COBBAN (1993a, figs 9.4-9.5) as *Didymoceratoides binodosum*; the *Anaklinoceras mortoni* is described below as *A. incertum* sp. nov.; and the *Anapachydiscus complexus* was reassigned to *Menuites oralensis* COBBAN & KENNEDY, 1993 (p. 10). The new species *D. wrighti* comes from the *D. binodosum* Subzone, possibly low in the subzone.

REPOSITORIES OF SPECIMENS

BHI: Black Hills Institute of Geological Research, Hill City, South Dakota.
SDJ: S.D. JORGENSEN Collection, Omaha, Nebraska.
UND: University of North Dakota, Grand Forks.
USNM: U.S. National Museum of Natural History, Washington, D.C.

CONVENTIONS

All dimensions are given in millimeters. The suture terminology is that of WEDEKIND (1916), as reviewed by KULLMANN & WIEDMANN (1970); E = external lobe, L = lateral lobe, U = umbilical lobe, I = internal lobe.

Rib index is the number of ribs in a distance equal to the whorl height at the mid-point of the interval counted.

SYSTEMATIC PALAEONTOLOGY

Suborder Ancyloceratina WIEDMANN, 1966
Superfamily Turrilitaceae GILL, 1871
Family Nostoceratidae HYATT, 1894

Genus *Didymoceras* HYATT, 1894
(= *Emperoceras* HYATT, 1894 p. 575; *Didymoceratoides* KENNEDY & COBBAN, 1993a, p. 90)

TYPE SPECIES: *Ancyloceras nebrascense* MEEK & HAYDEN, 1856, p. 71, by original designation by HYATT (1894 p. 573). The holotype, USNM 469, is from a limestone concretion from rocks now assigned to the Pierre Shale in South Dakota.

Didymoceras binodosum
(KENNEDY & COBBAN, 1993a)
(Pls 1, 2; Pl. 3, Figs 4-7; Pls 4, 5; Pl. 10, Figs 2-4; Pl. 12, Figs 14, 15; Text-figs 2, 3)

1963. *Bostrychoceras secoense* YOUNG, p. 42 (*pars*), Pl. 4, Fig. 8 only.
1980. *Didymoceras* cf. *secoenes* [*sic*] (YOUNG); BLASZKIEWICZ, p. 24, Pl. 5, Figs 4, 6; Pl. 7, Figs 16, 19.
1993a. *Didymoceratoides binodosum* KENNEDY & COBBAN, p. 92, Figs 8.1, 8.2, 8.5, 8.6, 8.13-8.15, 8.22-8.24, 8.28, 8.29, 8.32, 8.33, 8.35-8.39, 9.1-9.5, 12.1.
1994. *Didymoceratoides binodosum* KENNEDY & COBBAN; EMERSON & *al*., p. 314, unnumbered figures.
1997. *Didymoceras binodosum*; LARSON & *al*., frontispiece on p. vi; p. 53, upper two unnumbered figures.
1999. *Didymoceras binodosum* (KENNEDY & COBBAN, 1993a); KENNEDY & COBBAN, p. 72, Pl. 2, Pl. 3, Figs 2-5, 7-11; Pl. 4, Figs 2-5, 8-11; Pl. 5, Figs 11-20; Text-figs 3, 4.

TYPES: Holotype is USNM 441521, from the *Baculites scotti* Zone in the Pierre Shale at USGS Mesozoic locality D1412 about 1.6 km. north-northeast of Oral in the NW1/4NW1/4 sec. 26, T. 7S., R. 7E, Fall River County, South Dakota (Pl. 1, Figs 4-6).

DESCRIPTION: A reconstruction of the species is shown in Text-fig. 2. The earliest growth stage is an open planispire with the whorls in contact that extends from the protoconch for nearly two whorls (Pl. 1, Figs 3-6; Pl. 4, Fig. 6). There follows a more open coil that is in the form of a low helix or planispire and extends for a further two whorls, and is generally elliptical, the ellipse varying greatly in its maximum diameter; the range is 65 to 120 mm (Pl. 1, Figs 1, 2, 5, 6; Pl. 2, Figs 1-7; Pl. 3, Fig. 6, Pl. 4, Fig. 6; Pl. 12, Figs 14, 15). The third growth stage is marked by a decrease in the translation rate, producing a regular helix of up to 3.5 whorls, the whorls barely in contact, with traces of an impressed zone on the upper whorl surface to accommodate the ribs and tubercles on the base of the preceding whorl (Pl. 3, Figs 4-6; Pl. 4, Figs 1-5, 7). The final sector of the body chamber uncoils, as a result of a further marked increase in the translation rate (Pl. 5, Figs 1-4).

The first half whorl of the first growth stage following the protoconch is smooth, after which ribbing develops (Pl. 1, Figs 3, 4). The whorl section is circular, the ribs weak on the dorsum, but strong, coarse, rursiradiate and feebly convex on the flanks, with a rib index of 3. All ribs bear septate ventral spines, represented by flat-topped tubercles when damaged, or on moulds. The spines are linked across the venter by a broad transverse rib, which shows a tendency to break down into a pair of riblets.

On the second, elliptical and feebly helical growth stage, the same basic pattern of coarse bituberculate ribs persists, with a rib index of 3-4. The rib direction varies from rursiradiate, straight to feebly convex, to

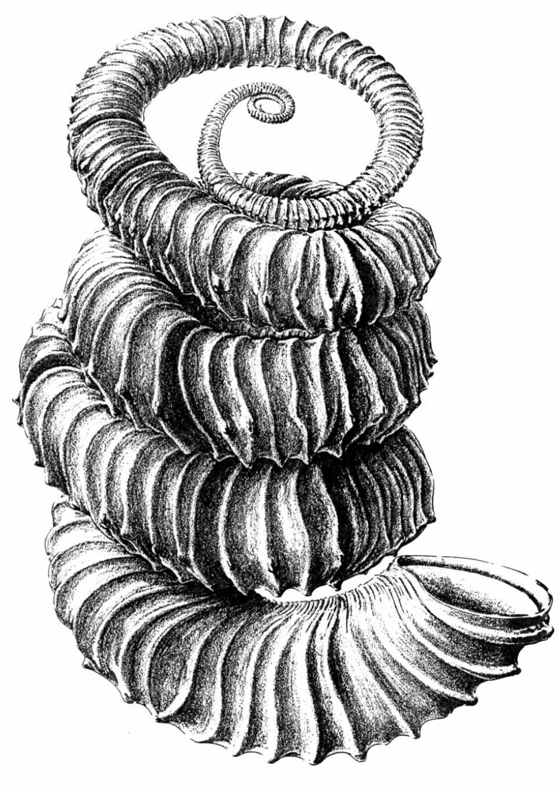

Fig. 2. Reconstruction of *Didymoceras binodosum* (KENNEDY & COBBAN, 1993a), by John R. STACY; reduced × 0.7

rectiradiate, to prorsiradiate, while the helical element in the coiling introduces irregularities. Nontuberculate ribs develop at this growth stage, with from one to four tuberculate ribs between. The spines are slender and recurved where preserved. Strong distant constrictions may become prominent towards the end of this growth stage with associated flared collar ribs (Text-fig. 2). The transition to the third, helicoid stage is abrupt (Pl. 3, Fig. 6). Ribs are narrow, weak and transverse on the inner whorl face, but strengthen and increase by branching and intercalation across the upper whorl face, where they are strongly rursiradiate. They strengthen markedly and are convex across the junction of upper and outer whorl faces. There are both fine and coarse-ribbed variants at this stage: all show sharp prorsiradiate straight ribs on the upper part of the outer whorl face. Two of these ribs may link into a single rib on the upper part of the outer whorl face, but this is a rare condition. In most cases a single rib, less commonly a pair of ribs, join to a transversely elongated subspinose tubercle at or below mid-flank with single nontuberculate ribs between. These may alternate regularly with the tuberculate ribs or be sparsely and irregularly developed. A single rib or a pair of strong rursiradiate ribs link the tubercles in this row to a subspinose lower row, offset adaperturally, and lying at the junction of outer and lower whorl faces; ribs commonly zigzag between the tubercles in upper and lower rows. The lower row of tubercles give rise to coarse, feebly concave, markedly rursiradiate ribs on the lower whorl surface that in some cases join together in pairs towards the umbilical margin. Broad, deep constrictions, up to 5 per whorl, are present throughout the helical stage, and have associated flared, bituberculate ribs. The body chamber occupies one and a half whorls of the helix, and a further loosely coiled half whorl. Body chambers fall into two size classes, suggesting the species to be dimorphic.

Suture (Text-fig. 3) with small E, asymmetrically bifid moderately incised E/L, very broad, deeply splayed bifid L, small, bifid, narrow-stemmed L/U, deeply incised U with large median element, and narrow I.

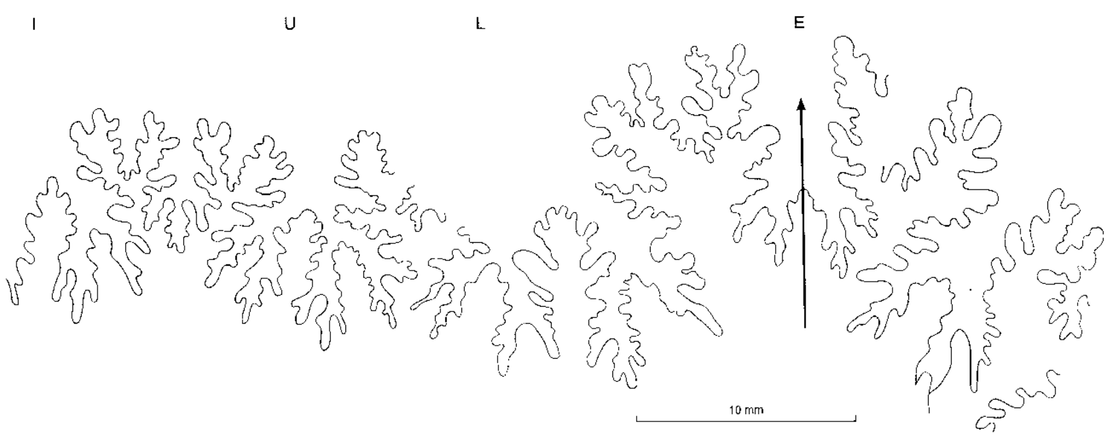

Fig. 3. Suture line of *Didymoceras binodosum* (KENNEDY & COBBAN, 1993a), from USNM 501724, from USGS Mesozoic locality D1848

DISCUSSION: The early growth stages of *D. binodosum* are highly distinctive, as is the presence of strong constrictions throughout ontogeny; together these features distinguishing the species from the generally larger *D. nebrascense* (MEEK & HAYDEN, 1856) (p. 71; see reconstruction *in* GILL & COBBAN 1973, p. 7, Text-fig. 5a; SCOTT & COBBAN 1975, Map I-937; KENNEDY & COBBAN 1976, Text-fig. 7, left; KENNEDY & *al*. in press) and *Didymoceras cheyennenese* (MEEK & HAYDEN, 1856) (p. 71; see reconstruction *in* GILL & COBBAN 1973, p. 10, Text-fig. 5c; SCOTT & COBBAN 1975; KENNEDY & COBBAN 1976, Text-fig. 7, right; KENNEDY & *al*. in press), both of which also have the whorls widely separated, and a final long U shaped section to the body chamber. *Didymoceras stevensoni* (WHITFIELD, 1877) (*see* WHITFIELD 1880, p. 477, Pl. 14, Figs 5-8, and reconstruction *in* SCOTT & COBBAN 1965; GILL & COBBAN 1973, p. 7, Text-fig. 5b; SCOTT & COBBAN 1975; KENNEDY & *al*. in press) has the whorls in contact in middle growth as in the present species, but utterly different early whorls, no constrictions and a recurved U-shaped final sector to the body chamber that is widely separated from the base of the spire. *Didymoceras puebloense* COBBAN & *al*., 1997 (p. 225, Figs 2-5) has the whorls widely separated in the helical growth stage, and a much longer and larger U-shaped body chamber than *D. binodosum*, more prominent looping of ribs and tubercles, and poorly defined constrictions. *Didymoceras wrighti* sp. nov., and *D. jorgenseni* sp. nov., both have quite different coiling styles in early growth.

OCCURRENCE: In the United States Western Interior this species is known from the *Baculites scotti* zone, *D. binodosum* Subzone, in the Pierre Shale at many localities in South Dakota and Colorado. It also occurs in the Sego Sandstone and the Anchor Mine Tongue of the Mancos Shale in Utah. It is abundant in the Kimbro nodule zone in the Bergstrom Formation in Travis County, Texas, and may be present in the Wenonah Formation in New Jersey (KENNEDY & COBBAN, 1994a). The species is also found in the upper Campanian of the Vistula Valley, Poland, and the Gschliefgraben, Austria.

Didymoceras wrighti sp. nov.
(Pls 6-7; Text-figs 4-5)

DERIVATION OF NAME: The species is named for C.W. WRIGHT, principal author of the Treatise volume on Cretaceous Ammonoidea.

TYPES: The holotype is USNM 501725 (Pl. 7, Figs 1, 2), paratypes USNM 501726-501732 (Pl. 6, Figs 2-11; Pl. 7, Figs 3, 4) from the Pierre Shale, *Baculites scotti* Zone, *D. binodosum* Subzone, at USGS Mesozoic locality D1925, ridge-forming concretionary limestone and grey limestone nodules 220.4-221.3 m (723-726 feet) above the base of the Red Bird Silty Member, E1/2, E1/2 sec. 14, and W1/2, NW1/4 sec. 13, T. 38 N., R. 62 W., Niobrara County, Wyoming. A further paratype, USNM 401726 (Pl. 6, Fig. 1) is from USGS Mesozoic locality D13028.

DESCRIPTION: The earliest growth stage that can be recognized in this species (see reconstruction in Text-fig. 4) takes the form of a helix with very high translation rate (Pl. 6, Figs 1-5, 8, 9, 12; Pl. 7, Figs 1, 2). The second growth stage is a much tighter helix, the whorls not in contact (Pl. 6, Figs 6, 7; Pl. 7, Figs 1-4), while the final part of the adult body chamber is marked by an increase in translation rate and is helical, with the aperture slightly upturned (Pl. 6, Figs 10, 11). The whorl sec-

Fig. 4. Reconstruction of *Didymoceras wrighti* sp. nov., by John R. STACY; reduced × 0.88

tion is circular in the early growth stage, with a rib index of 6. The ribs are weakest on the dorsum, feebly convex, and slightly oblique. They strengthen across the junction of upper and outer whorl faces and are straight and prorsiradiate on the upper whorl surface. They are straight and rursiradiate on the outer whorl face, where there are two rows of subequal tubercles on most of the ribs, their position varying depending on the degree of torsion, with nontuberculate, sometimes weaker ribs separated by one or more tuberculate ribs. The ribs occasionally link in pairs at tubercles. Ribs on the lower whorl face arise singly, rarely in pairs, from the lower row of tubercles and are strong, coarse, straight to feebly convex, and rursiradiate. One distinctive pathological example of this growth stage has only a single row of tubercles (Pl. 6, Figs 4, 5). There is an abrupt transition to the middle, more tightly helical growth stage of up to three regularly coiled but clearly separated helical whorls. Ribs are weak and feebly convex on the inside of the whorl, strengthening markedly over the junction of inner and outer whorl faces. They are markedly prorsiradiate on the inner part of the upper whorl face, strengthening across the face, increasing by branching and intercalation, and are markedly convex across the junction of upper and outer whorl faces. The ribs are strong, straight, and rursiradiate on the outer whorl face; most link, either singly or in pairs, at short mid-lateral spines, represented by flat-topped tubercles when damaged, and on internal moulds. Occasional nontuberculate ribs are also present. One or two ribs link the spines/tubercles in the upper row to a lower row of spines/tubercles, displaced adaperturally of the upper row, and at the junction of outer and lower whorl faces, the link is either simple, or in the form of a zigzag; looping of ribs between tubercles is rare. The lower row of tubercles give rise to single ribs that are coarse, rursiradiate, and feebly convex on the lower whorl face, fading out before reaching the umbilicus in some cases, and linking in pairs close to the umbilical margin in others. Ribs and tubercles coarsen markedly on the last sector of adult body chamber. Both helical whorls and body chambers bear weak, broad constrictions, with associated flared collar ribs. Body chambers fall into two size groups, showing the species to be dimorphic.

The suture (Text-fig. 5) is deeply incised. E is narrow, E/L narrow-stemmed and bifid, L broad, bifid with a large median element. L/U is narrow-stemmed, bifid, U small with narrow neck and large median element, U/I bifid, and I narrow.

DISCUSSION: The coiling of the early whorls immediately distinguishes *Didymoceras wrighti* sp. nov. from species such as *D. cheyennense*, *D. nebrascense* and *D. stevensoni*, as discussed above, as does the presence of constrictions, and absence of a long U shaped final sector to the body chamber. It is closest to *Didymoceras binodosum* described above, from which it differs in its narrower helix, coarser ribbed body chamber, in the form of the early whorls (compare Figures 2 and 4), and in having the middle helical stage with whorls well-separated rather than just in contact, with consequent impressed zone on the upper whorl face in *D. binodosum*. The constrictions of *D. binodosum* are much more pronounced, and the relationship between ribs and tubercles much simpler than in *D. wrighti*.

OCCURRENCE: *Baculites scotti* Zone, *D. binodosum* Subzone, Pierre Shale in Wyoming, South Dakota and Colorado.

Didymoceras jorgenseni sp. nov.
(Pl. 3, Figs 1-3; Pls 8, 9; Pl. 10, Fig. 1; Pl. 11, Figs 1, 2; Text-figs 6, 7)

1975. *Didymoceras* n.sp. HIRSCH, Fig. 6A.

1997. *Didymoceras* cf. *archiacianum* LARSON & *al*., p. 53, lower two figures.

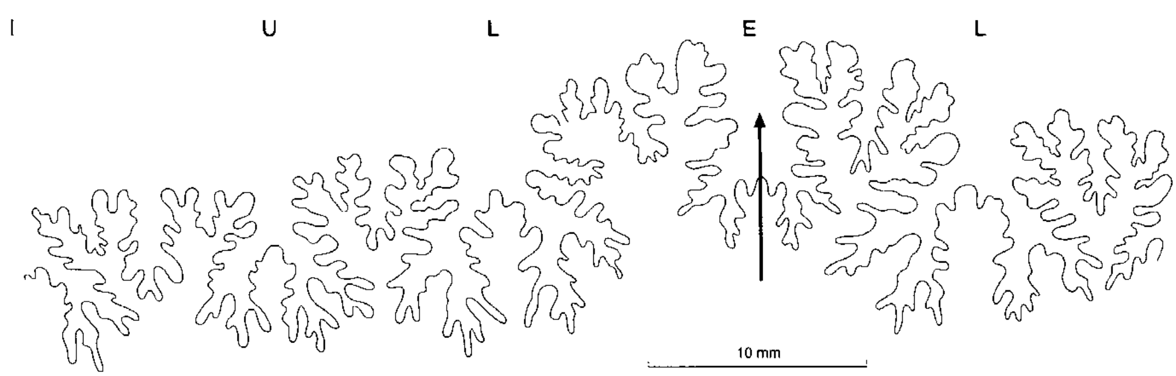

Fig. 5. Suture line of *Didymoceras wrighti* sp. nov., paratype USNM 501728 (*see also* Pl. 6, Figs 4, 5), from USGS Mesozoic locality D1925

DERIVATION OF NAME: For Steven D. JORGENSEN of Omaha, Nebraska, who provided a series of fine specimens for our account of this species.

TYPES: The holotype is USNM 501733 (Pl. 8, Fig. 7), paratypes USNM 501737, 501739, 501741, 501743, 501744 (Pl. 8, Figs 2, 4, 6, 9; Pl. 9, Figs 1, 2), from USGS Mesozoic locality D1413, in the *B. scotti* Zone, *D. jorgenseni* Subzone Pierre Shale, west facing bluff 1.65 km (1 mile) NNE of Oral, in NW1/4, NW1/4 sec. 28, T. 7 S., R. 7 E., Fall River County, South Dakota.

Additional paralectotypes are USNM 501736 and 501746 (Pl. 8, Fig. 1; Pl. 9, Fig. 4), from locality D1401; USNM 501738 and 401745 (Pl. 8, Fig. 3, Pl. 9, Fig. 3), from locality 1273; USNM 501740, 501742, 501747 (Pl. 8, Figs 5, 8; Pl. 9, Fig. 5), from locality 1271; USNM 501748 (Pl. 9, Figs 6, 7) from locality D792, and USNM 501749 (Pl. 9, Fig. 8), from locality D1058.

DESCRIPTION: This is a medium sized species of *Didymoceras*. A reconstruction is shown in Text-fig. 6. The earliest growth stage is in the form of a small incomplete (through damage) elliptical coil, with a very high translation rate and a major diameter of 18 mm, seen in USNM 501745 (Pl. 9, Fig. 3), USNM 501746 (Pl. 9, Fig. 4) and USNM 501737 (Pl. 8, Fig. 2). This is succeeded by a helical stage with a much lower translation rate, the whorls clearly to barely separated, that extends for at least five and a half whorls (Pl. 8, Figs 1-9; Pl. 9, Figs 5, 8; Pl. 10, Fig. 1; Pl. 11), after which the translation rate increases, the final sector of body chamber rotating so that the dorsum faces the base of the spire, with the adult aperture directed upwards and away from the base of the spire (Pl. 8, Fig. 9; Pl. 9, Figs 1, 2, 6, 7; Pl. 10, Fig. 1; Pl. 11). Body chambers fall into two classes, showing the species to be dimorphic.

The initial elliptical whorl has a depressed oval whorl section. Ornament is of coarse ribs, weak and transverse on the dorsum, but strengthening across the dorsolateral region, and coarse, strong, feebly concave and feebly prorsiradiate to rursiradiate, each bearing a ventral tubercle, the tubercles linked across the venter by coarse rib. On the initial whorls of the second, helical growth stage ribs are coarse, rursiradiate and convex at the junction of upper and outer whorl faces. Single straight, prorsiradiate ribs sweep across the outer whorl face, with a short spine in the middle of the outer whorl face (represented by flat-topped tubercles when damaged, and on internal moulds), linked by a single rib to a second row of short spines/tubercles at the junction of outer and lower whorl faces, from which single coarse, convex, prorsiradiate ribs sweep across the lower whorl face. As size increases, this simple pattern of ribbing

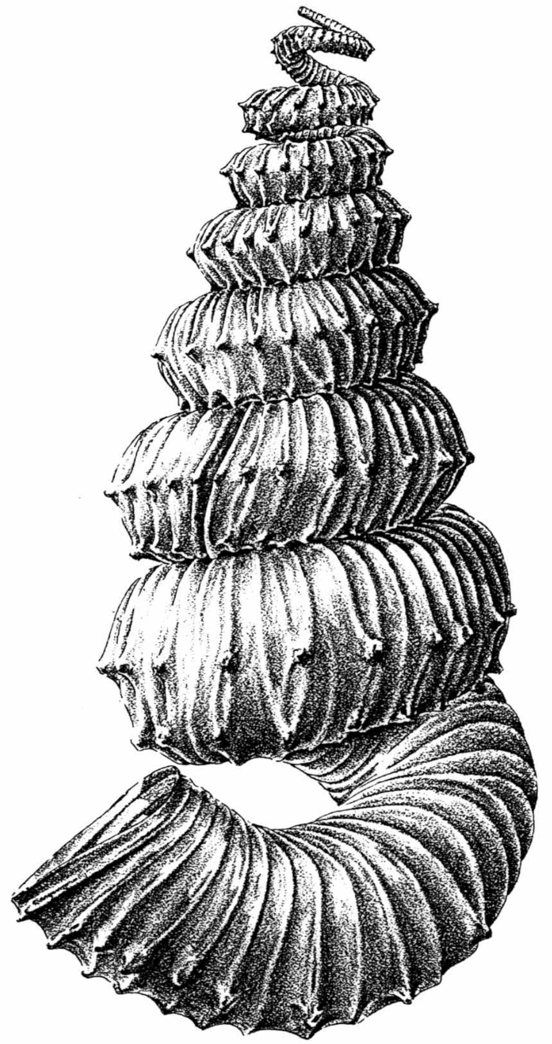

Fig. 6. Reconstruction of *Didymoceras jorgenseni* sp. nov., by John R. STACY; natural size

and tuberculation becomes more complex. Ribs are very weak and convex on the inner whorl surface, but strengthen across the junction of inner and upper whorl surfaces and are concave, coarse and rursiradiate on the upper whorl surface, where the ribs may increase by branching and intercalation. Ribs sweep forwards across the upper part of the outer whorl face, linking singly or in pairs to the spines/tubercles in the upper row, which become progressively coarser as size increases; there are a few nontuberculate ribs. The zone between the upper and lower rows of spines/tubercles becomes markedly flattened, and a complex rib pattern links the rows, with pairs of ribs looping between tubercles; ribs that lack an upper tubercle may link to the lower row, or ribs may zigzag between the tubercles in upper and lower rows. Coarsely ornamented specimens

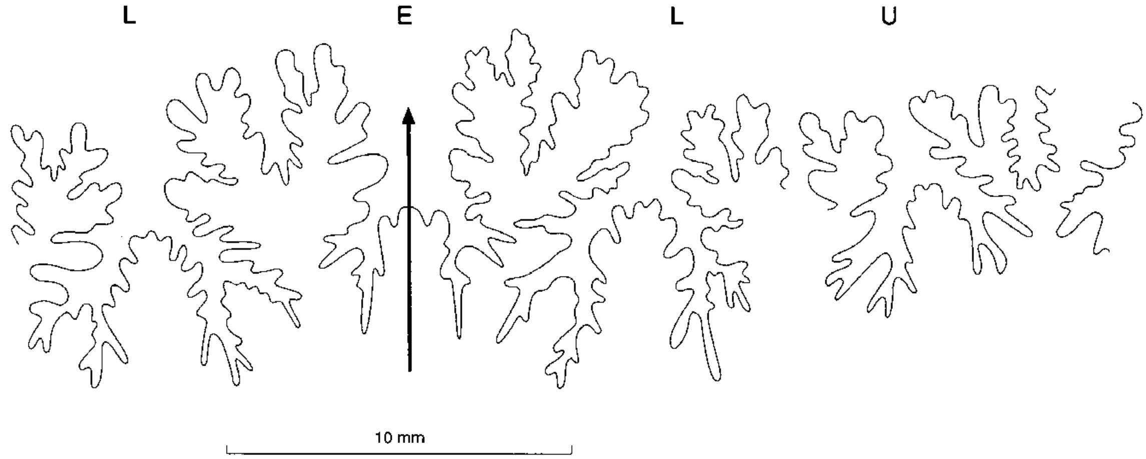

Fig. 7. Suture line of *Didymoceras jorgenseni* sp. nov., USNM 501750, from USGS Mesozoic locality D1410

generally have the simplest ribbing pattern, the weaker, denser ribbed specimens the most complex (Pl. 11). The tubercles in the lower row give rise to coarse, feebly convex prorsiradiate ribs on the lower whorl surface, while some nontuberculate ribs also extend across the lower whorl surface. The final half whorl of body chamber uncoils and twists, so that the plane of median symmetry of the body chamber is parallel to the plane of median symmetry of the helical whorls. Ornament simplifies markedly on this part of the shell. The outer face of the whorl is ornamented by coarse, narrow, prorsiradiate ribs that link either singly or, less commonly, in pairs at strong thorn-like ventral spines. These are linked across the venter by a broad coarse rib that may show incipient splitting into a pair of looped ribs. There are rare nontuberculate ribs. Widely separated constrictions, with associated collar ribs, are present on the helical whorls and body chamber. Suture (Text-fig. 7) deeply incised, with narrow-stemmed, bifid E/L, deeply cut, narrow-necked L with large median element, broad-stemmed, bifid L/U, small, deeply splayed bifid U, small U/I and I.

DISCUSSION: The presence of occasional constrictions sets *Didymoceras jorgenseni* sp. nov. apart from species such as *Didymoceras nebrascense* (Meek & Hayden, 1856), *D. cheyennense* (Meek & Hayden, 1856) and *D. stevensoni* (Whitfield, 1877), discussed above, all of which are much larger and have long, recurved, U shaped sectors to the body chamber. *Didymoceras binodosum*, described above, is more constricted than the present species, is much larger, with quite different, loosely coiled early growth stages, and whorls that are in contact rather than free. It has far fewer whorls in the helical stage and a much larger apical angle with consequent squat, rather than narrow spire. *Didymoceras wrighti* sp. nov., described above, is much larger, with loosely coiled helical early whorls that have a very high translation rate, and fewer whorls to the spire, which has a larger apical angle.

OCCURRENCE: Pierre Shale, *B. scotti* Zone, *D. jorgenseni* Subzone in South Dakota and Colorado.

Genus *Anaklinoceras* Stephenson, 1941

TYPE SPECIES: *Anaklinoceras reflexum* Stephenson 1941, p. 414, Pl. 83, Figs 1-5, by original designation.

Anaklinoceras incertum sp. nov
(Pl. 12, Figs 1-13; Pl. 13, Figs 7-9; Text-figs 8-9)

1997. *Anaklinoceras* n.sp. Larson & *al*., unnumbered figure on p. x.

DERIVATION OF NAME: Incertus (Latin), doubtful.

TYPES: Holotype is USNM 501751, (Pl. 12, Figs 1-4), paratypes USNM 501752-501755 (Pl. 12, Figs 5-13) from USGS Mesozoic localities D1925, Pierre Shale, *Baculites scotti* Zone, *D. jorgenseni* Subzone, ridge-forming tan concretionary limestone nodules 220.4-221.3 m (723-726 ft) above base of Red Bird Silty Member, E1/2 E1/2 sec.1, W1/2 SW1/4 sec.12, and W1/2 NW1/4 sec.13, T.38 N., R.62 W., Niobrara County, Wyoming. A further paratype, USNM 401752 (Pl. 12, Figs 5, 6) is from USGS Mesozoic locality D13027. Paratype BHI 2092 (Pl. 13, Figs 7-9) is from the Pierre Shale of Lyman County, South Dakota.

DESCRIPTION: The shell consists of an initial 25 mm high helix of six whorls, followed by a loose recurved hook, widely separated from the spire, the aperture above the top of the spire and directed inwards towards its axis; a reconstruction is shown in Text-fig. 8. The whorls of the spire expand slowly, the translation rate is moderate, the whorls not in contact, or barely in contact. The whorl section is depressed. Coarse, widely spaced prorsiradiate ribs extend from the upper whorl suture to strong conical to transversely elongated tubercles in the middle of the outer whorl face. A coarse rursiradiate rib sweeps forwards and connects to a weaker, transversely elongate tubercle at the junction of outer and lower whorl faces. These in turn give rise to coarse, rursiradiate convex ribs on the lower whorl face that weaken across the umbilical margin and are weak and concave on the inner whorl surface. The great majority of the ribs are single, but an occasional pair of ribs link at the upper tubercle. Ribbing is weak on the inner whorl face of the hook, but strong, narrow and prorsiradiate on the flanks, separated by wider interspaces. The hook is not symmetrical, as a result of which the tubercles are displaced to one side, being linked by a strong rib (Pl. 12, Fig. 2; Pl. 13, Figs 7, 9). Tubercles decline, and ribs zigzag between them immediately prior to the aperture in the holotype, but not the paratypes; this may be a pathological condition. Part of the suture of paratype BHI 2092 is shown in Text-fig. 9.

DISCUSSION: The loose coiling of the spire, with whorls not in contact or barely in contact, and the open coiling of the body chamber which is not in contact with the spire, readily distinguishes *Anaklinoceras incertum* sp. nov. from the type species, *A. reflexum* STEPHENSON, 1941 (p. 414, Pl. 83, Figs 1-5). The loose coiling and bituberculate spire ornament recalls that of certain *Didymoceras*, and the species may be a passage form between the two genera.

OCCURRENCE: As for types, plus USGS Mesozoic locality D13027, Red Bird section of the Pierre Shale, from top of Red Bird Silty Member, Niobrara County, Wyoming. The species also occurs in the Gregory Member of the Pierre Shale, in Lyman County, South Dakota.

Family Diplomoceratidae SPATH, 1926
Subfamily Polyptychoceratinae MATSUMOTO, 1938
Genus *Lewyites* MATSUMOTO & MIYAUCHI, 1984

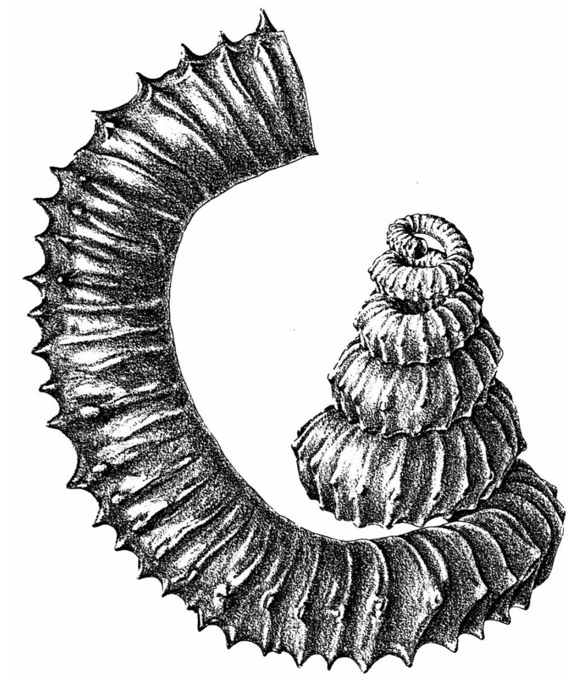

Fig. 8. Reconstruction of *Anaklinoceras incertum* sp. nov., by John R. STACY, × 2

TYPE SPECIES: *Idiohamites*(?) *oronensis* LEWY, 1969, p. 127, Pl. 3. Figs 10, 11, by original designation by MATSUMOTO & MIYAUCHI, 1984, p.64.

Lewyites sulcatus sp. nov.
(Pl. 13, Figs 5, 6, 10-13)

DERIVATION OF NAME: Sulcus (latin), furrow or groove.

TYPES: Holotype is no. 10743a in the collections of the Department of Geology and Geological Engineering of the University of North Dakota, Grand Forks (Pl. 13, Fig. 10), paratypes are nos. 10471 and 10473 b-f in the same collections (Pl. 13, Figs 5, 6, 11) from the Gregory Member of the Pierre Shale, *Baculites scotti* Zone, in a roadcut in the SW1/4, sec. 9, T.140 N., R.58 W., 1.2 km (0.7 mi) NW of North Valley City, Barnes County, North Dakota. Paratype USNM 501756 (Pl. 13, Figs 12, 13) is from the Pierre Shale of Lyman County, South Dakota.

DESCRIPTION: The type material is in the form of a series of crushed moulds with aragonitic shell adhering. Coiling was in an open ellipse, with a maximum preserved whorl height of 38 mm. At the smallest diameter seen, ornament is of delicate straight to feebly concave

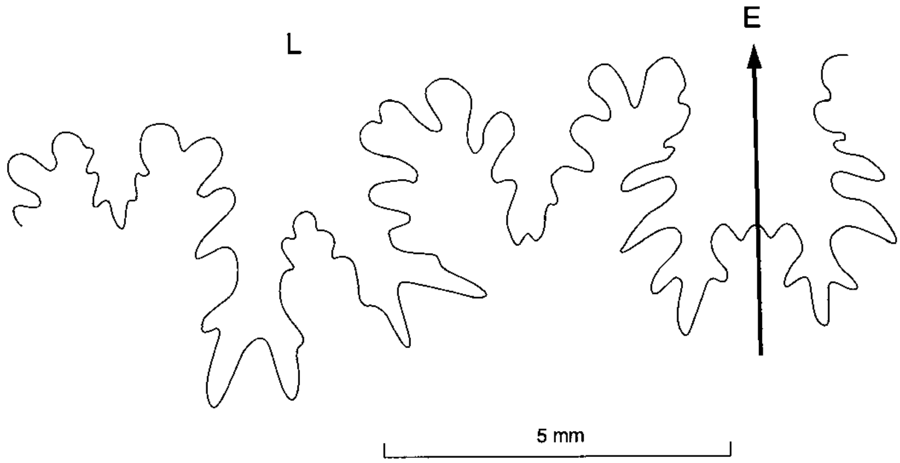

Fig. 9. Part of suture line of *Anaklinoceras incertum* sp. nov., paratype BHI 2092

ribs that vary from slightly prorsiradiate to rectiradiate to slightly rursiradiate, depending on position on the coil; the rib index is 10. The ribs strengthen across the flanks, and join in pairs at short septate ventral spines, represented by flat-topped tubercles on moulds, or where damaged. Single narrow, nontuberculate ribs intercalate between the tuberculate groups and may be annular, or link to tubercles on the opposite flank, while a narrow rib or ribs connect tubercles across the venter. There are widely separated constrictions, which are followed by a strong tuberculate collar-rib (Pl. 13, Figs 5, 6). The holotype is a much larger specimen (Pl, 13, Fig. 10), some 125 mm long, with a maximum preserved whorl height of 33 mm. The rib index is 10 to 12, the ribs straight, joining either singly or in pairs at ventral tubercles, with nontuberculate ribs between; widely separated constrictions are followed by a tuberculate collar rib, as in earlier growth stages. The largest specimen, No. 10743d (Pl. 13, Fig. 11) has a maximum preserved whorl height of 38 mm. The rib index is 8, with single tuberculate and nontuberculate ribs alternating regularly, and there is a single poorly defined constriction. Only fragmentary traces of the suture line are visible on one specimen.

DISCUSSION: The presence of constrictions and associated flared collar rib distinguishes juvenile *Lewyites sulcatus* sp. nov. from the types of *Lewyites oronensis* (LEWY, 1969) (p. 127, Pl. 3, Figs 10-11) and *L. circularis* (LEWY, 1969) (p. 128, Pl. 3, Fig. 9). Adult *Lewyites* from the Coon Creek Tongue of the Ripley Formation in Tennessee have tubercles on all ribs at a size comparable to the largest paratype of *L. sulcatus*, and lack constrictions (COBBAN & KENNEDY 1994, Pl. 3, Figs 7-8)

OCCURRENCE: As for types. The species also occurs at USGS Mesozoic locality D888, and in the Gregory Member of the Pierre Shale in Lyman County, South Dakota.

Genus *Spiroxybeloceras* KENNEDY & COBBAN, 1999

TYPE SPECIES: *Ptychoceras meekanum* WHITFIELD, 1877 (p. 44), illustrated by WHITFIELD (1880, Pl. 16, Figs 1, 2), by original designation. WHITFIELD 's type came from the Pierre Shale in the valley of Beaver Creek southwest of Newcastle, Weston County, Wyoming.

Spiroxybeloceras kimbroense
KENNEDY & COBBAN, 1999
(Pl. 13, Figs 1, 3, 4; Pl. 14, Figs 24-26; Pl. 15, Figs 1-31; Text-figs 10B, 11)

1993a. *Oxybeloceras crassum* (WHITFIELD, 1877); KENNEDY & COBBAN, p. 93, Fig. 8.7-8.12, 8.16-8.21.
1993b. *Oxybeloceras crassum* (WHITFIELD, 1877); KENNEDY & COBBAN, p. 142, Pl. 8, Figs 18-37; Text-figs 7B, 10B.
1994. *Oxybeloceras crassum* (WHITFIELD, 1877); EMERSON & *al*., p. 318, unnumbered figures.
1997. *Oxybeloceras* sp.; LARSON & *al*., Fig. on p. 5; lower figure on p. 57.
1999. *Spiroxybeloceras kimbroense* KENNEDY & COBBAN, p. 74, Pl. 1, Figs 1-18; Pl. 5, Figs 1-10; Text-fig. 5.

TYPES: Holotype USNM 475039, from the Kimbro nodule zone in the Bergstrom Formation at USGS Mesozoic locality 17386, 1.1 km southwest of Manda, Travis

County, Texas. Paratypes USNM 475040-475058 are from the same horizon at USGS Mesozoic localities 15536, 16145, 17386, and J.P. CONLIN'S locality Tr-7-Kta, in the same general area.

DESCRIPTION: Adult body chambers of this species fall into two size classes, showing it to be dimorphic (Pl. 15). A reconstruction of a complete adult of the species is shown in Text-fig. 10B. A few specimens preserve the earliest whorls, which are a planispire of two whorls in close contact (Pl. 13, Fig. 3), succeeded by a curved sector of varying length, which passes into a long, slightly curved shaft. A broadly curved sector links this to the final shaft (Pl. 13, Fig. 1). The two shafts are initially separated by a tear-shaped opening enclosed within the curve (Pl. 13, Fig. 1). Thereafter they are in contact, with the dorsum of the large shaft slightly grooved to accommodate the dorsum of the smaller shaft (Pl. 15, Figs 11, 12, 15, 29). The position of the last septum varies, but is generally towards the adapertural end of the smaller shaft, close to the curved sector.

The first part of the coiled whorls immediately succeeding the protoconch is smooth, followed by a rapid acquisition of ornament. The whorl section is circular to depressed, the ribs weak on the dorsum, coarse, blunt, feebly convex and rursiradiate on the flanks, terminating in transversely elongated flat-topped tubercles that are the bases of short, septate spines. They are connected across the venter by a coarse transverse rib. The whorl section becomes progressively more depressed on the first shaft, with whorl breadth to height ratios of up to 1.4, the whorl section depressed reniform in intercostal section and with a broad, flat venter in costal section. Ribs are weak and concave on the dorsum, strengthening across the dorsolateral margin, strong and narrower than the interspaces on the flanks, where they are prorsiradiate and straight to slightly convex. All ribs bear small, sharp septate ventral spines, represented by transversely elongated flat-topped tubercles when damaged and on internal moulds. A strong single rib, sometimes split into incipient looped riblets, links these tubercles across the venter.

Ribbing changes from prorsiradiate to rursiradiate around the curved sector, and is straight, strong, narrow and rursiradiate on the larger shaft, the ribs separated by wider interspaces. All ribs bear ventral spines, linked across the venter by a strong rib that may show incipient division into a pair of looped riblets. The adult aperture is preceded by a marked constriction succeeded by a few narrow, nontuberculate ribs.

Suture (Text-fig. 11) little incised, with broad bifid elements, the saddles with broad stems.

DISCUSSION: The present material from the *Baculites scotti* Zone and older horizons has previously been referred to *Oxybeloceras crassum* (WHITFIELD, 1877) (see revision *in* KENNEDY & *al*., in press). We now know that similar as the adpressed shafts and linking curved sectors are in the two species, the earlier growth stages are so different as to justify separation at generic level. In *O. crassum* the shell consists of two tightly adpressed shafts, up to 127 mm long; the early whorls are

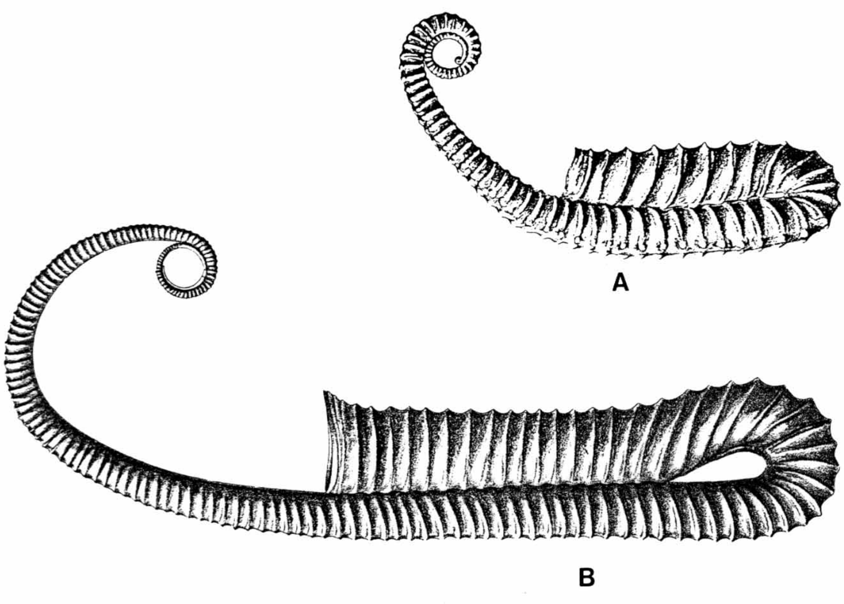

Fig. 10. A – Reconstruction of *Spiroxybeloceras meekanum* (WHITFIELD, 1877); B – Reconstruction of *Spiroxybeloceras kimbroense* KENNEDY & COBBAN, 1999, both by John R. STACY, and both natural size

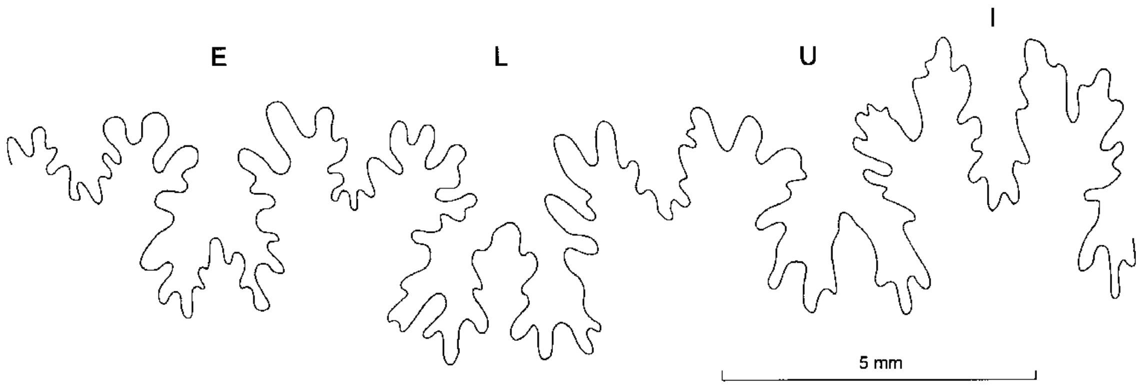

Fig. 11. Suture line of *Spiroxybeloceras kimbroense* KENNEDY & COBBAN, 1999, USNM 501768 from the Gregory Member of the Pierre Shale, Lyman County, South Dakota

unknown. In *S. kimbroense*, there is an initial spiral, at first smooth, thereafter ribbed, extending for two or more whorls, followed by a long curved sector (Text-fig. 10B). Fragmentary adult specimens here referred to *S. kimbroense* are associated with fragments of coiled early whorls at several localities in the *scotti* Zone, as well as at lower horizons in the Pierre Shale, and we place all of this material in *S. kimbroense* rather than *O. crassum*. All occurrences of *O. crassum* at higher levels in the Pierre are invariably associated with straight shafts to the smallest diameters known, diameters at which *S. kimbroense* is already coiled.

Adult fragments of *Spiroxybeloceras kimbroense* and *Oxybeloceras crassum* can generally (though not invariably) be separated by the larger opening associated with the curved section of *S. kimbroense*, which also has a depressed whorl section and less markedly impressed dorsum to the final shaft. Some specimens show the shafts parallel but not in contact for several centimeters distance from the curved section linking shafts. Others show marked irregularity associated with the adapical sections of the final shaft.

S. meekanum (WHITFIELD, 1877) (see revision *in* KENNEDY & *al*., in press; Pl. 13, Fig. 2; Text-fig. 10A herein) of the *Didymoceras cheyennense* Zone, is a smaller species than *Spiroxybeloceras kimbroense*, distinguished by the marked break in profile of the smaller shaft succeeding the initial spiral, and the distant flared ribs of the adult body chamber. *Spiroxybeloceras humei* (DOUVILLÉ, 1929), as illustrated by LEWY (1967, p. 170, Pl. 3, Figs 1-3) has a shorter body chamber and much finer ribbing.

OCCURRENCE: *Spiroxybeloceras kimbroense* first appears in the *Baculites gregoryensis* Zone, and ranges through the *B. scotti* in the Pierre Shale in Wyoming, South Dakota and Colorado. It is abundant in the Kimbro nodule zone in the Bergstrom Formation in Travis County, Texas, and also occurs in the Annona Chalk in Arkansas. The species may also be present in the Wenonah Formation in New Jersey.

Genus *Solenoceras* CONRAD, 1860

TYPE SPECIES: *Hamites annulifer* MORTON, 1841 (p. 109; 1842, p. 213, Pl. 11, Fig. 4), by the subsequent designation of CONRAD 1860, p. 284.

Solenoceras mortoni (MEEK & HAYDEN, 1857)
(Pl. 14, Figs 1-23; Text-figs 12, 13)

1857. *Ptychoceras mortoni* MEEK & HAYDEN, p. 134.
1859. *Ptychoceras mortoni* MEEK & HAYDEN, p. 685.
1860. *Ptychoceras mortoni* MEEK & HAYDEN; MEEK & HAYDEN, p. 421.
1864. *Ptychoceras mortoni* MEEK & HAYDEN; MEEK, p. 23.
1876. *Ptychoceras mortoni* MEEK & HAYDEN; MEEK, p. 412, Pl. 20, Figs 4a-c.
1910. *Ptychoceras mortoni* MEEK & HAYDEN; GRABAU & SHIMER, p. 202, Figs 1467, 1468 (copy of MEEK 1876).
1925. *Hamites* (*Ptychoceras*) *mortoni* MEEK & HAYDEN; DIENER, p. 78.
1997. *Solenoceras mortoni*; LARSON & *al*., p. 47, top figure.

TYPES: The holotype is the original of MEEK & HAYDEN 1857, p. 134, figured as 'type' by MEEK 1876, Pl. 20, Figs 4a-c, from the 'Great Bend on the Missouri River below Fort Pierre; from the lower part of the Fort Pierre group of the Upper Missouri Cretaceous series'. We have been unable to trace this specimen, and presume it to be lost; copies of MEEK's original figures are shown in Text-fig. 12.

DESCRIPTION: The most complete specimen is BHI 4109 (Pl. 14, Figs 1, 2, 12), which consists of two tightly adpressed parallel shafts linked by a narrowly rounded curved sector. The shafts are separated by a small tear-shaped opening within the curved sector, and the venter of the larger shaft is slightly distorted to accommodate the opening. The smaller shaft has a circular cross section; the larger shaft is slightly compressed. Ornament on the smaller shaft is of delicate prorsiradiate, feebly convex ribs; the rib index is 5. Ribs strengthen across the flanks, and all bear a tiny ventral tubercle, the tubercles linked across the venter by a delicate transverse rib. There is some variation in rib and tubercle strength on the venter, and some interspaces are slightly deepened. Ribbing weakens and effaces around the curved sector. It reappears at the beginning of the larger shaft, and is initially very markedly rursiradiate, becoming somewhat less so adaperturally to the curved sector; the rib index is 4-5, the ribs narrow, and all terminating in tiny conical tubercles linked across the venter by a broad, transverse rib. There is some irregularity in rib strength and interspace depth; at one point 3 ribs form a zigzag. The strong rursiradiate ribbing on the venter at the base of the larger shaft may even form chevrons on an occasional individual (for example, unfigured specimen USNM 501769).

BHI 4030 (Pl. 14, Figs 11, 18, 19) is the largest specimen seen, the final body chamber shaft of an individual 35.4 mm long. The ribbing is more irregular than in the previous example, with ribs single, joined in pairs at the ventral tubercles or looped, with one rib towards the adapertural end of the shaft flared, and preceded by a marked constriction.

BHI 4026 (Pl. 14, Figs 7, 8, 16) shows similar irregular ornament, and BHI 4021 (Pl. 14, Figs 5, 6, 15) has

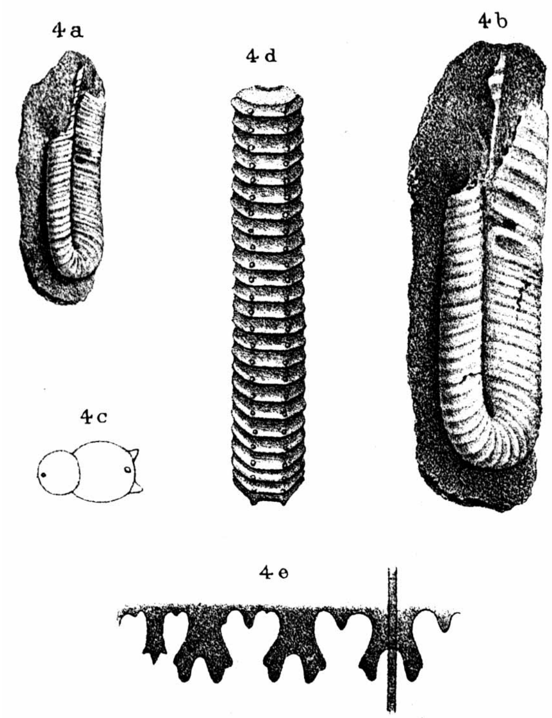

Fig. 12. *Solenoceras mortoni* (MEEK & HAYDEN, 1857). Copy of the figures of the holotype in MEEK, 1876, Pl. 20, Fig. 4a-4e; with respect to Figure 4d, MEEK notes that the Figure shows the specimen 'too flat between the rows of nodes'

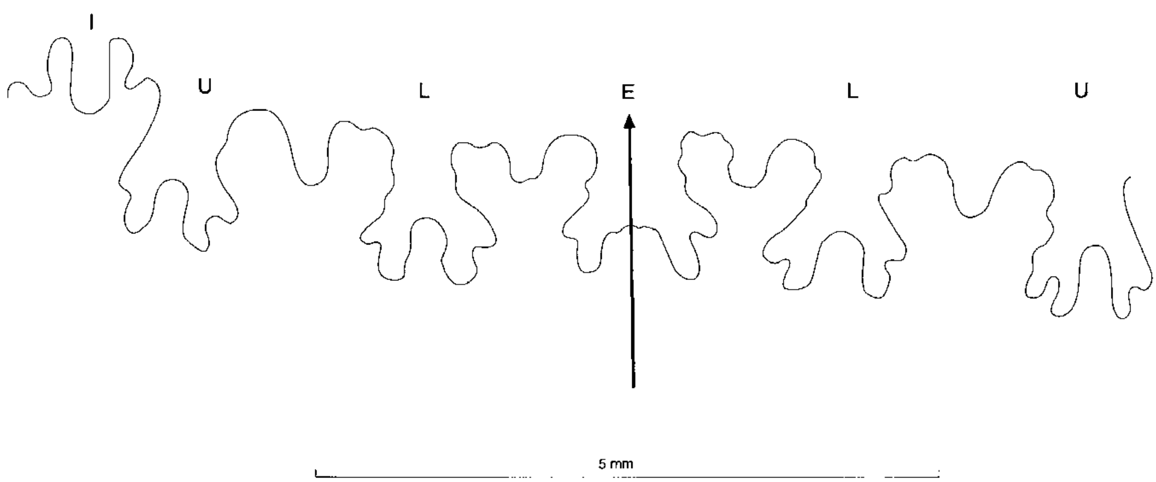

Fig. 13. *Solenoceras mortoni* (MEEK & HAYDEN, 1857), suture line, from BHI 4685, from the Gregory Member of the Pierre Shale, Lyman County, South Dakota

relatively coarse, even ribbing, with a rib index of only 3. The rib crests of this specimen show pronounced flattening in places.

Irregular ornament is at its most striking development in BHI 2147 (Pl. 14, Figs 14, 20-23), an individual with a markedly compressed whorl section. The smaller shaft shows periodic constrictions, the larger shaft constrictions and irregularly developed associated flared ribs.

The suture (Text-fig. 13) comprises little incised, symmetrically bifid and subequal E, L, and U, and E/L, and L/U. I is small and entire.

DISCUSSION: When compared with other species of the genus, the type species, *S. annulifer* (MORTON, 1841) (see revision in KENNEDY & COBBAN 1994b, p. 1295, Figs 11.1-11.10, 11.14) has a depressed, reniform whorl section, and dense, even ribs with minute to effaced ventral tubercles. *Solenoceras texanum* (SHUMARD, 1861) (p. 190; see revision in STEPHENSON 1941, Pl. 77, Figs 4, 5; Pl. 79, Figs 1-4) has compressed whorls and even ribbing. *Solenoceras reesidei* STEPHENSON, 1941 (p. 401, Pl. 77, Figs 1-3) is more finely and evenly ribbed, as is *S. multicostatum* STEPHENSON, 1941 (p. 402, Pl. 76, Figs 12-14). *Solenoceras nitidum* COBBAN, 1974 (p. 83, Text-figs 1a-k, 2) lacks tubercles. *Solenoceras humei* DOUVILLÉ, 1929 (p. 37, Pl. 6, Figs 9, 10; LEWY, 1967, p. 170, Pl. 3, Fig. 4; LÜGER & GRÖSCHKE 1989, Pl. 49, Figs 3, 4) is a *Spiroxybeloceras*. *Solenoceras bembense* HAAS, 1943 (p. 11, Text-figs 4, 14) has a depressed whorl section and blunt, prorsiradiate ribs; it may not even be a *Solenoceras*.

OCCURRENCE: Gregory Member of Pierre Shale, *Baculites gregoryensis* and *B. scotti* zones, Lyman County, South Dakota; *B. scotti* Zone, roadcut in SW1/4, sec. 9, T.140 N., R58 W., 1.2 km (0.7 mi) NW of Valley City, Barnes County, North Dakota.

Acknowledgements

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Revised version accepted: 21th September 1999

PLATE 1

Didymoceras binodosum (KENNEDY & COBBAN, 1993a)

1 – USNM 501711 from USGS Mesozoic locality D904
2 – USNM 441522, from USGS Mesozoic locality D1925
3 – SDJ Di487H, Pierre Shale in NE1/4 NW1/4 sec. 23, T.7 S., R. 7 E., Fall River County, South Dakota
4-6 – the holotype, USNM 441521, from USGS Mesozoic locality D1412

Figures 1, 2, 5, 6, are × 1; Fig. 3 is × 2; Fig. 4 is × 3

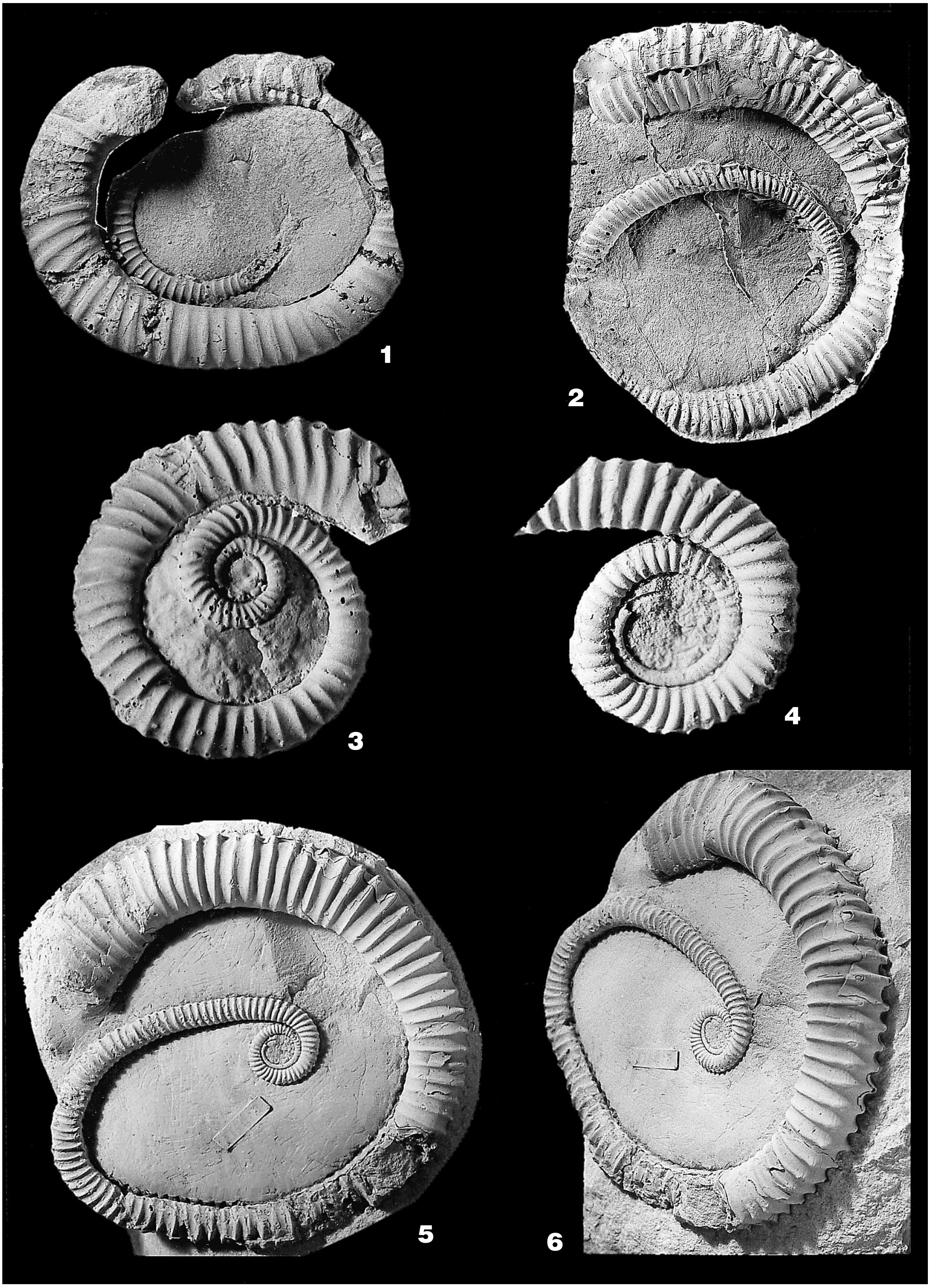
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PLATE 2

Didymoceras binodosum (KENNEDY & COBBAN, 1993a)

1 – USNM 501712, from USGS Mesozoic locality D1216
2 – USNM 441522, from USGS Mesozoic locality D1924
3 – USNM 501713, from USGS Mesozoic locality D1411
4, 5, 7 – USNM 501714, from USGS Mesozoic locality D904
6 – SDJ Di588A, from the Pierre Shale near Oral, Fall River County, South Dakota

All figures are × 1

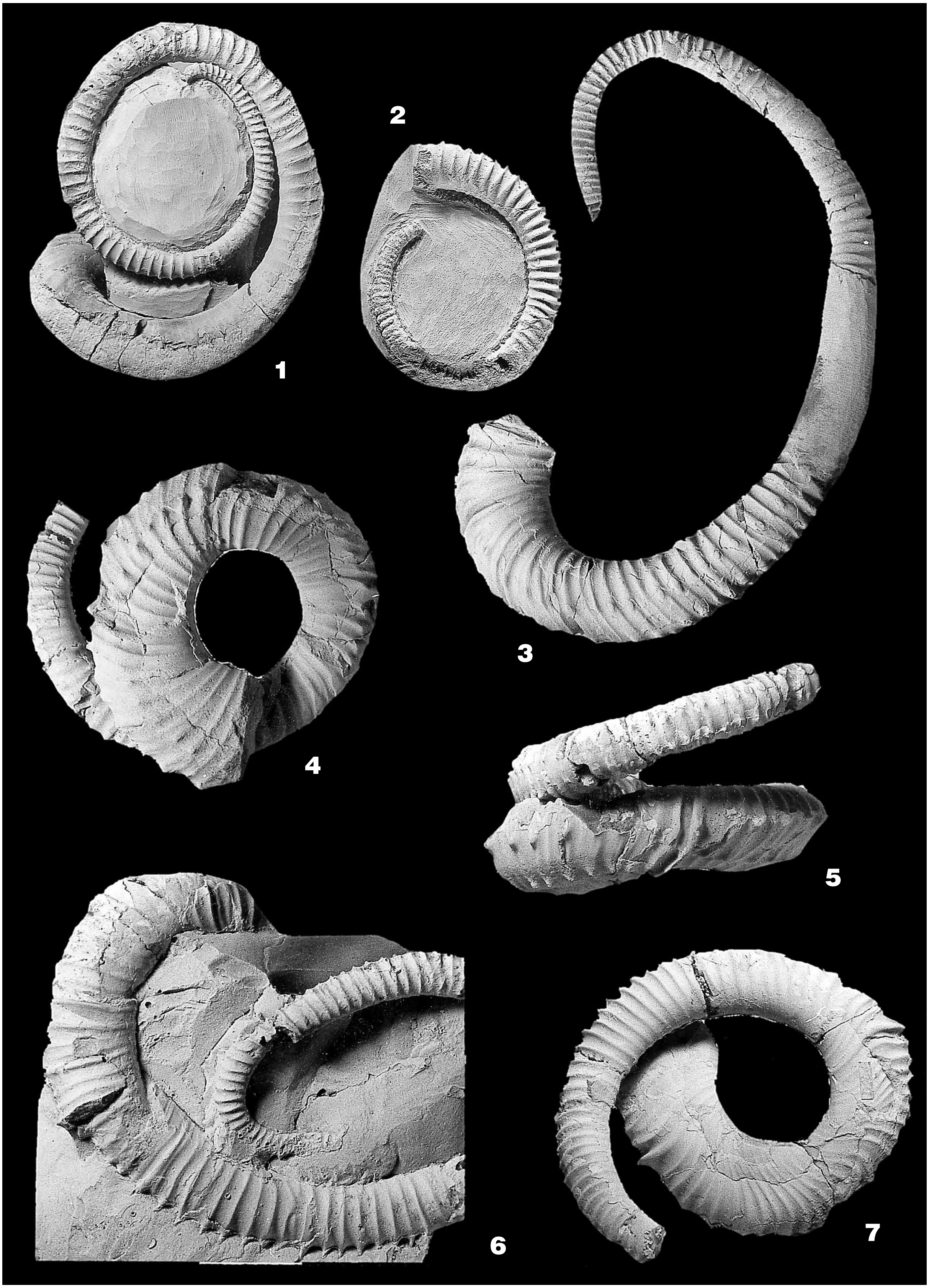
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PLATE 3

1-3 – *Didymoceras jorgenseni* sp. nov.
1 – USNM 501734, from USGS Mesozoic locality D1410
2-3 – USNM 501735, from USGS Mesozoic locality D314

4-7 – *Didymoceras binodosum* (KENNEDY & COBBAN, 1993a)
4-5 – USNM 501715, from USGS Mesozoic locality D904
6 – BHI 4051, from the Pierre Shale near Oral, Fall River County, South Dakota
7 – USNM 501716, from USGS Mesozoic locality D1412

All figures are × 1

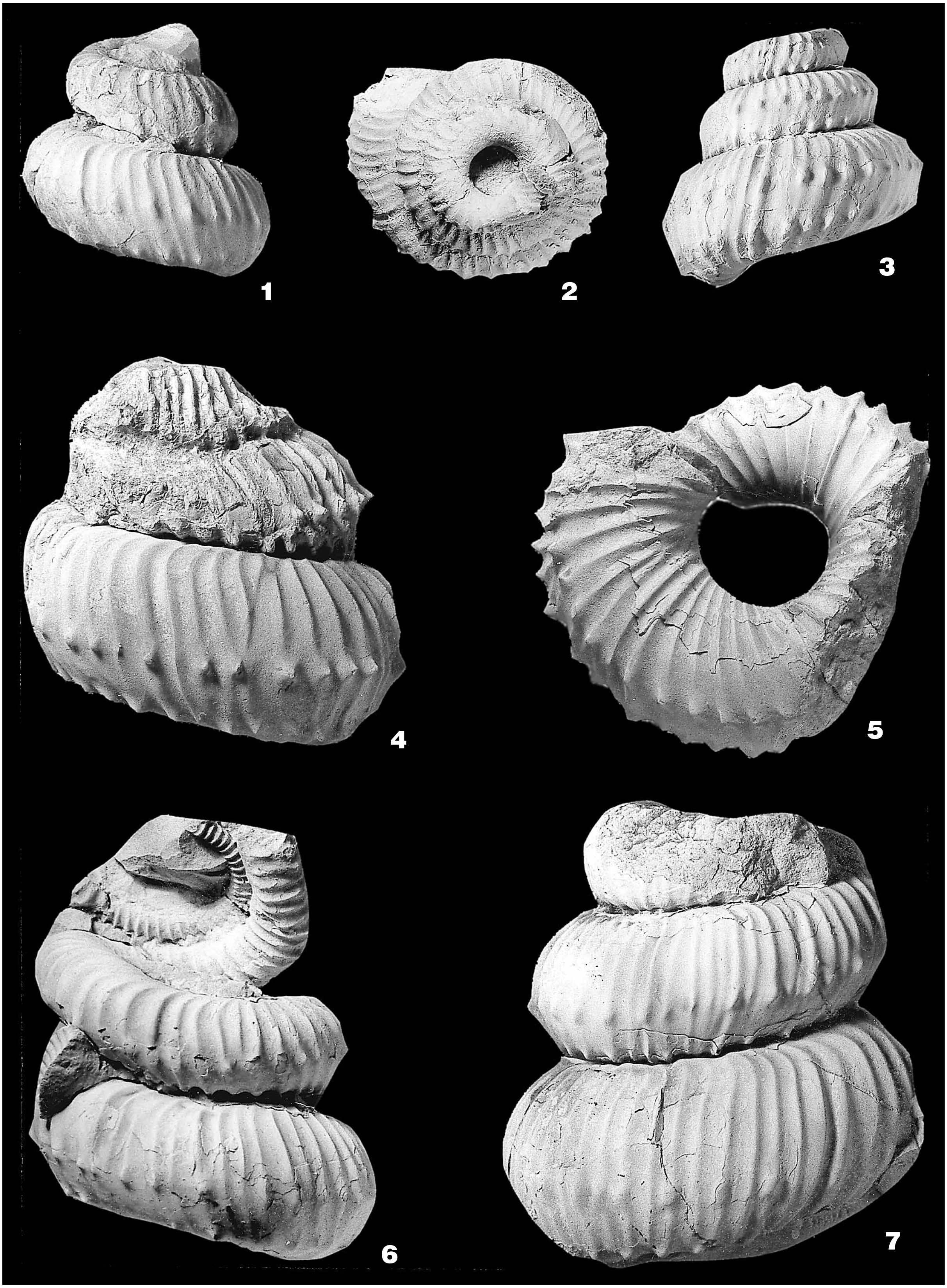
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PLATE 4

Didymoceras binodosum (KENNEDY & COBBAN, 1993a)

1-2 – USNM 501717, from USGS Mesozoic locality D904
3-4 – USNM 501718, from USGS Mesozoic locality D1925
5 – USNM 501719, from USGS Mesozoic locality D902, with nucleus of *Menuites oralensis* COBBAN & KENNEDY, 1993
6-7 – SDJ Di 1088A, from the Pierre Shale in the NW1/4 sec. 26, T.7 S., R.7 E., Fall River County, South Dakota

All figures are × 1

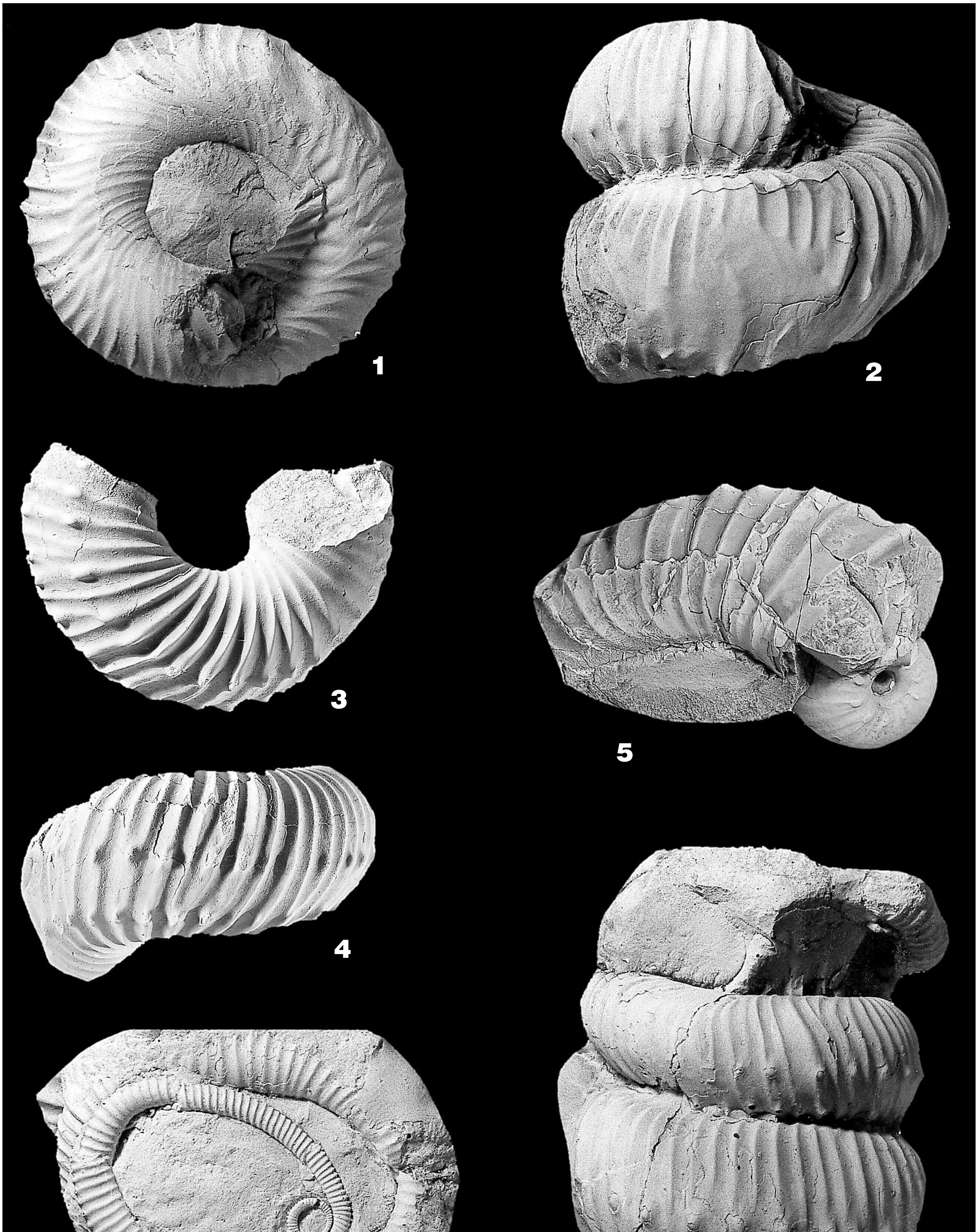
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PLATE 5

Didymoceras binodosum (KENNEDY & COBBAN, 1993a)

1 – USNM 501720, from USGS Mesozoic locality 10385
2 – USNM 501721, from USGS Mesozoic locality D904
3-4 – USNM 475020, from USGS Mesozoic locality D1412

All figures are × 1


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PLATE 6

Didymoceras wrighti sp. nov.

1, 12 – paratype USNM 501726, from USGS Mesozoic locality D13028
2-3 – paratype USNM 501727, from USGS Mesozoic locality D1925
4-5 – paratype USNM 501728, from USGS Mesozoic locality D1925
6-7 – paratype USNM 501729, from USGS Mesozoic locality D1925
8-9 – paratype USNM 501730, from USGS Mesozoic locality D1925
10-11 – paratype USNM 501731, from USGS Mesozoic locality D1925

All figures are × 1

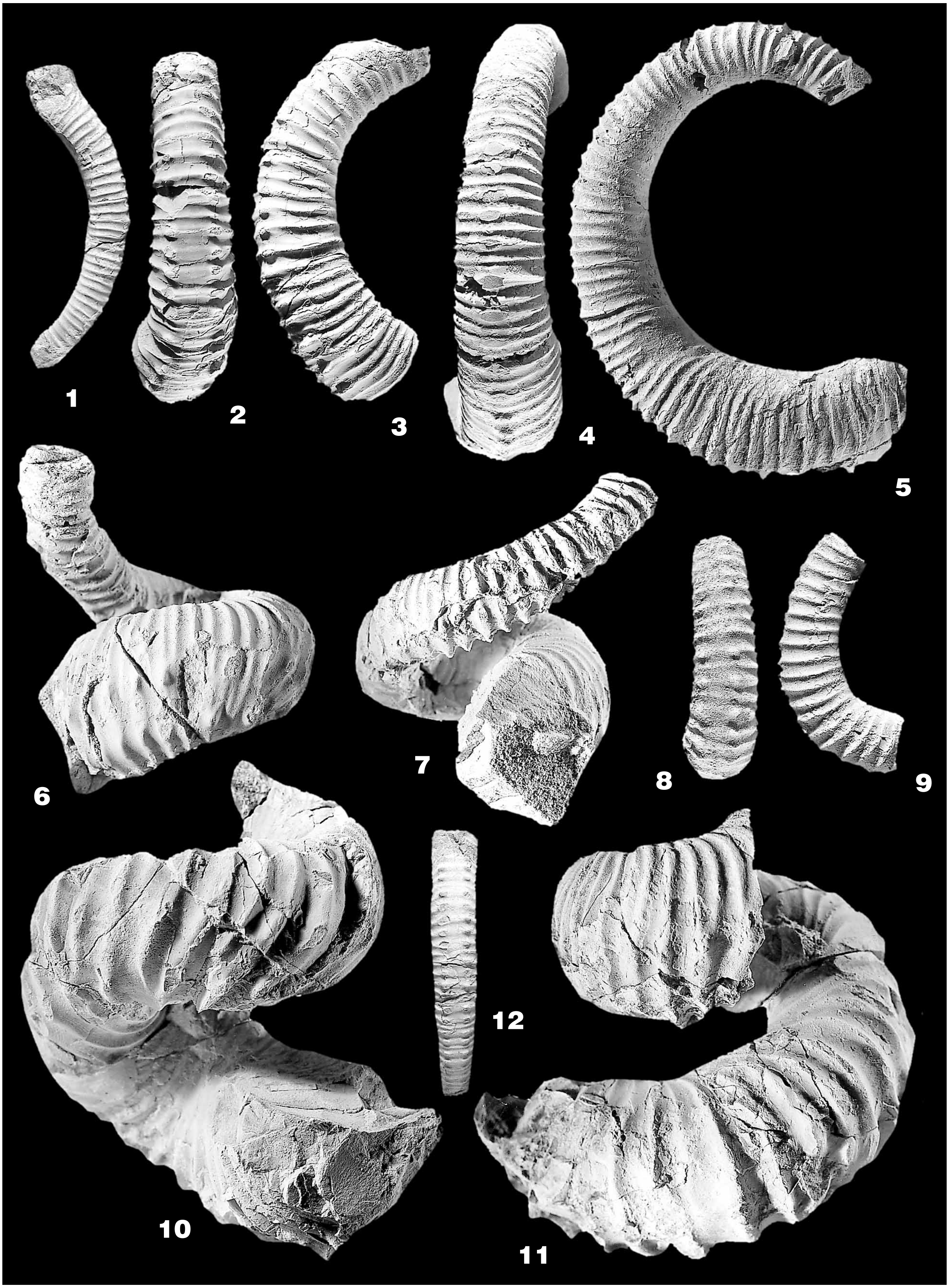
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PLATE 7

Didymoceras wrighti sp. nov.

1-2 – holotype, USNM 501725, from USGS Mesozoic locality D1925
3-4 – paratype USNM 501732, from USGS Mesozoic locality D1925

All figures are × 1

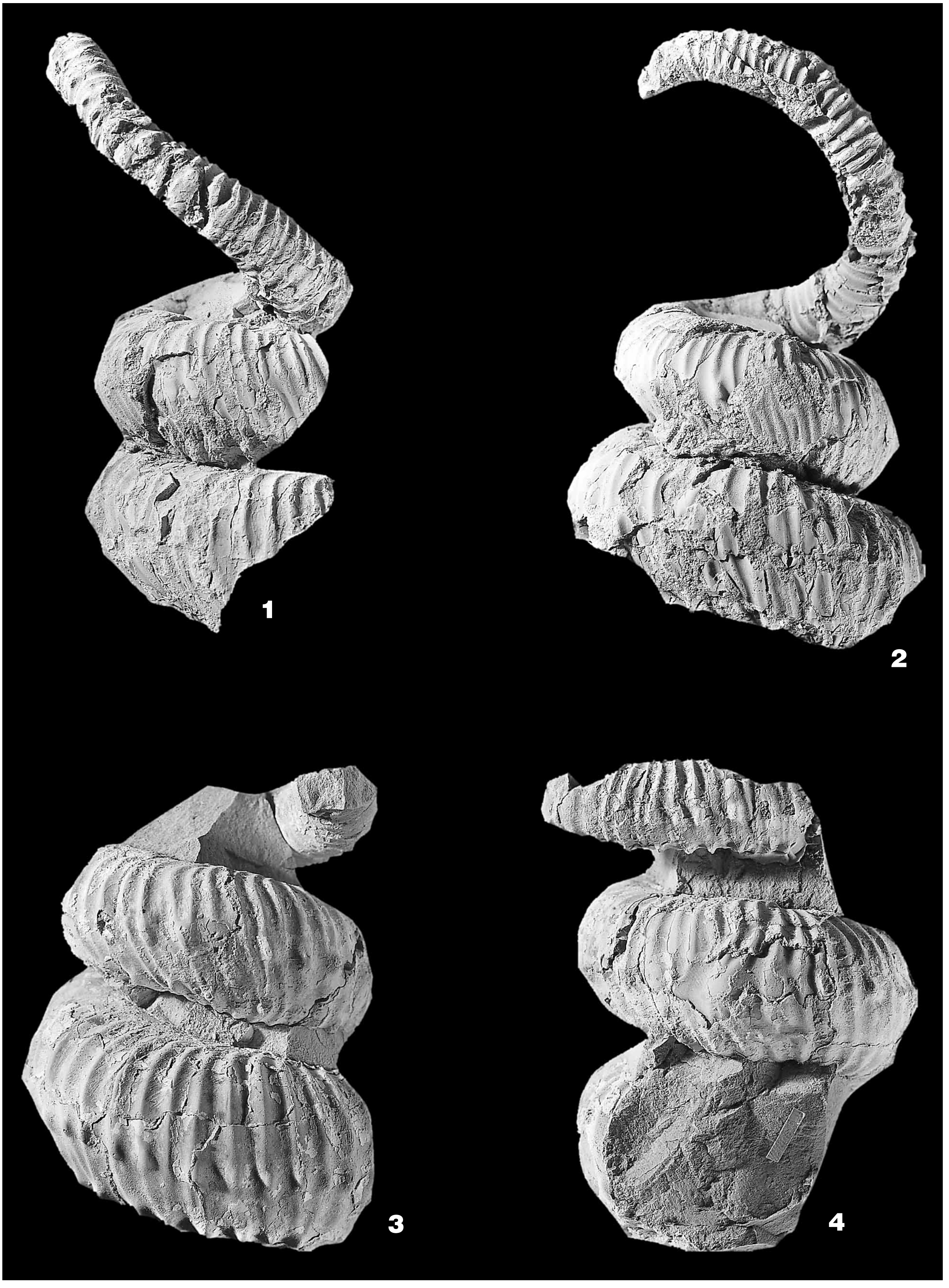
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PLATE 8

Didymoceras jorgenseni sp. nov.

1 – paratype USNM 501736, from USGS Mesozoic locality D1410
2 – paratype USNM 501737, from USGS Mesozoic locality D1413
3 – paratype USNM 501738, from USGS Mesozoic locality 1273
4 – latex cast of paratype USNM 501739, from USGS Mesozoic locality D1413
5 – paratype USNM 501740, from USGS Mesozoic locality 1271
6 – paratype USNM 501741, from USGS Mesozoic locality D1413
7 – holotype USNM 501733, from USGS Mesozoic locality D1413
8 – paratype USNM 501742, from USGS Mesozoic locality 1271
9 – paratype USNM 501743, from USGS Mesozoic locality D1413

All figures are × 1

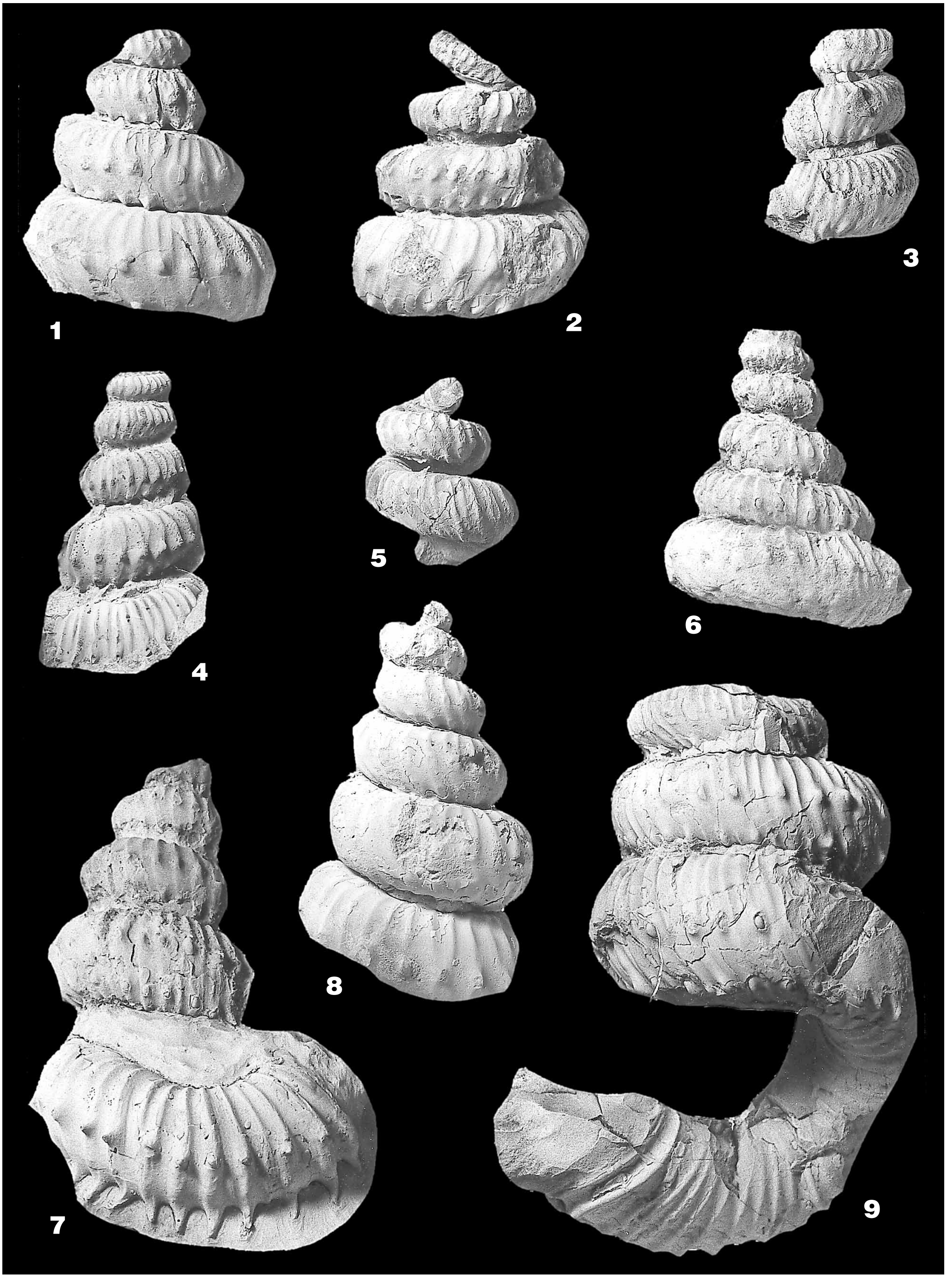
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PLATE 9

Didymoceras jorgenseni sp. nov.

1-2 – paratype USNM 501744, from USGS Mesozoic locality D1413
3 – paratype USNM 501745, from USGS Mesozoic locality 1273
4 – paratype USNM 501746, from USGS Mesozoic locality D1410
5 – paratype USNM 501747, from USGS Mesozoic locality 1271
6-7 – paratype USNM 501748, from USGS Mesozoic locality D792
8 – paratype USNM 401749, from USGS Mesozoic locality D1058

All figures are × 1

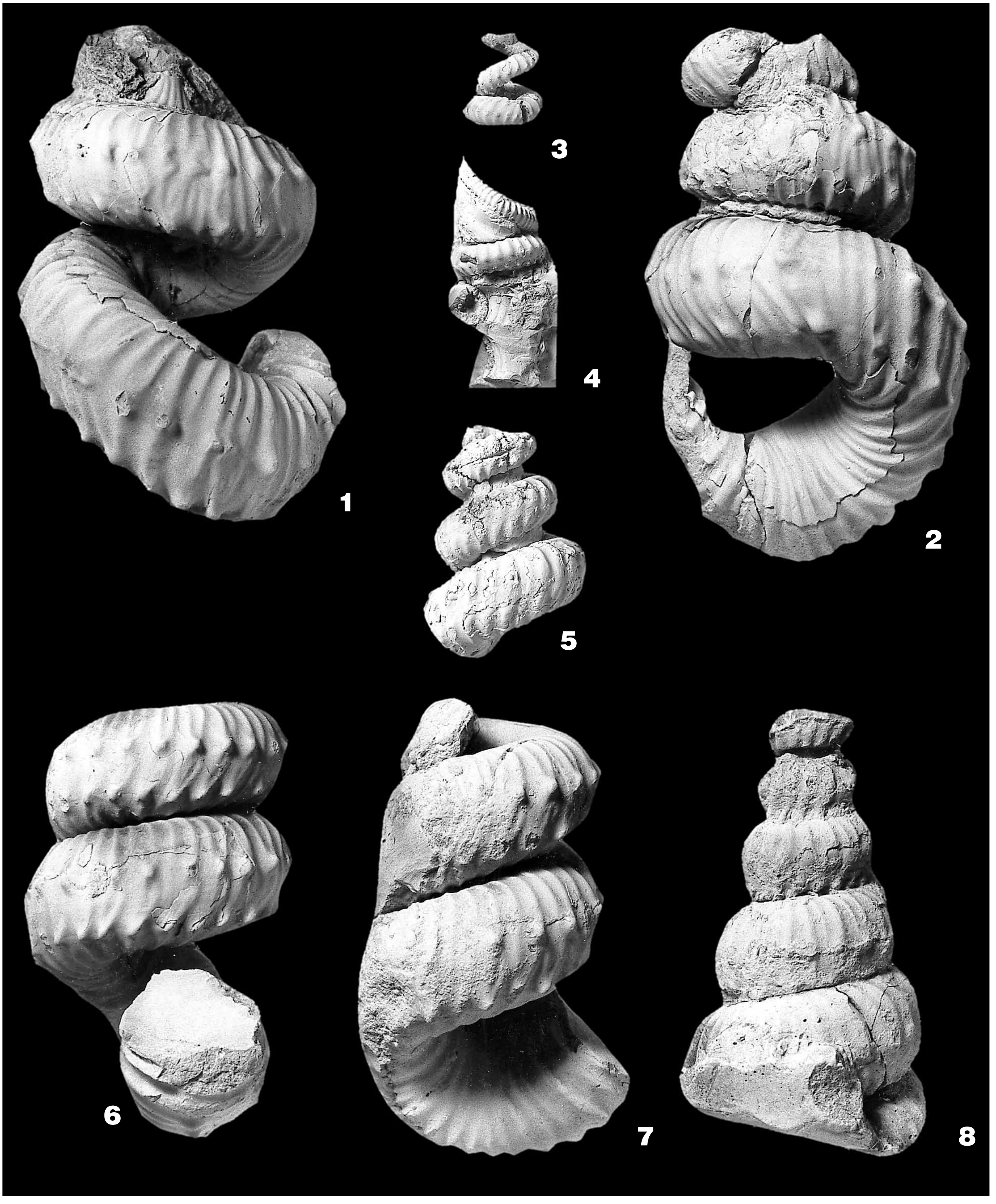
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PLATE 10

1 – *Didymoceras jorgenseni* sp. nov.; Karl HIRSCH Collection, now housed in the University of Colorado, Boulder, from the Pierre Shale of Colorado

2-4 – *Didymoceras binodosum* (KENNEDY & COBBAN, 1993a); USNM 501722, from USGS Mesozoic locality D1925

All figures are × 1

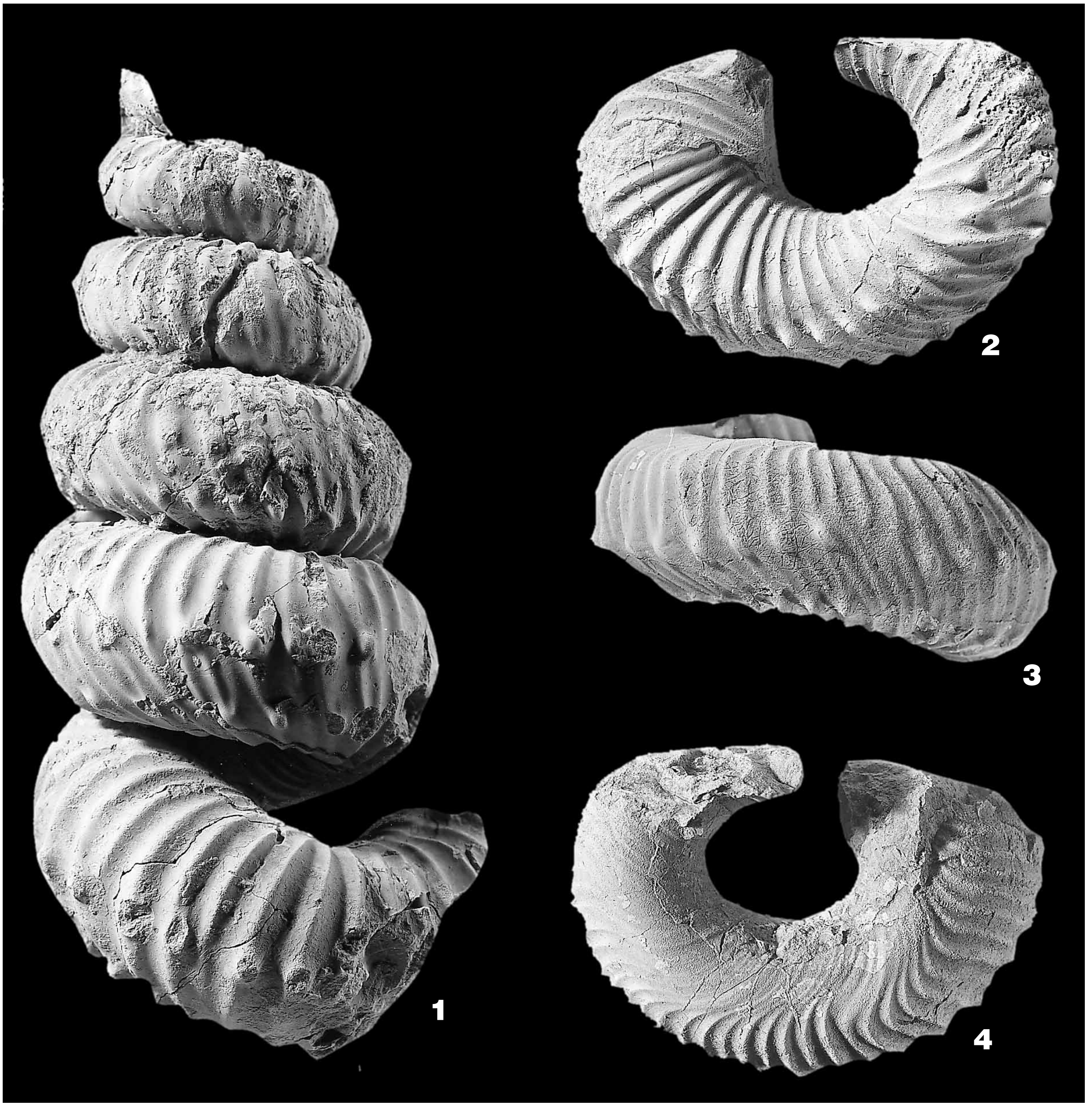
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PLATE 11

Didymoceras jorgenseni sp. nov.

1-2 – SDJ Di389H; 2, SDJ Di984E, from the *Baculites scotti* Zone of the Pierre Shale near Oral, South Dakota

All figures are × 1

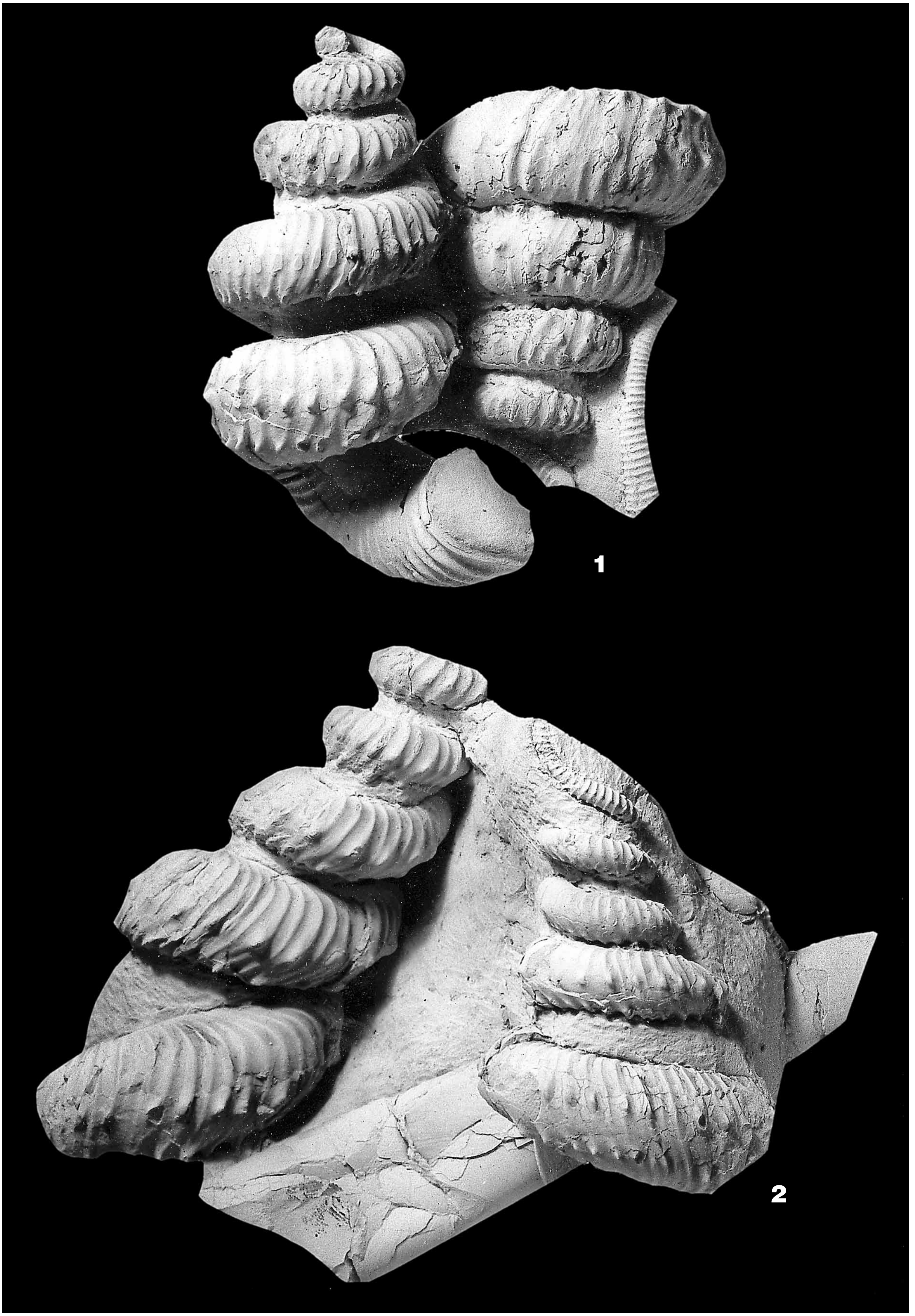
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PLATE 12

1-13 – *Anaklinoceras incertum* sp. nov.
1-4 – **holotype**, USNM 501751, from USGS Mesozoic locality D1925
5-6 – paratype USNM 501752, from USGS Mesozoic locality D13027
7-8 – paratype USNM 501753
9-10 – paratype 501754
11-13 – paratype USNM 501755, all from USGS Mesozoic locality D1925

14-15 – *Didymoceras binodosum* (COBBAN & KENNEDY, 1993a); USNM 501723, from USGS Mesozoic locality D1924

All figures are × 1

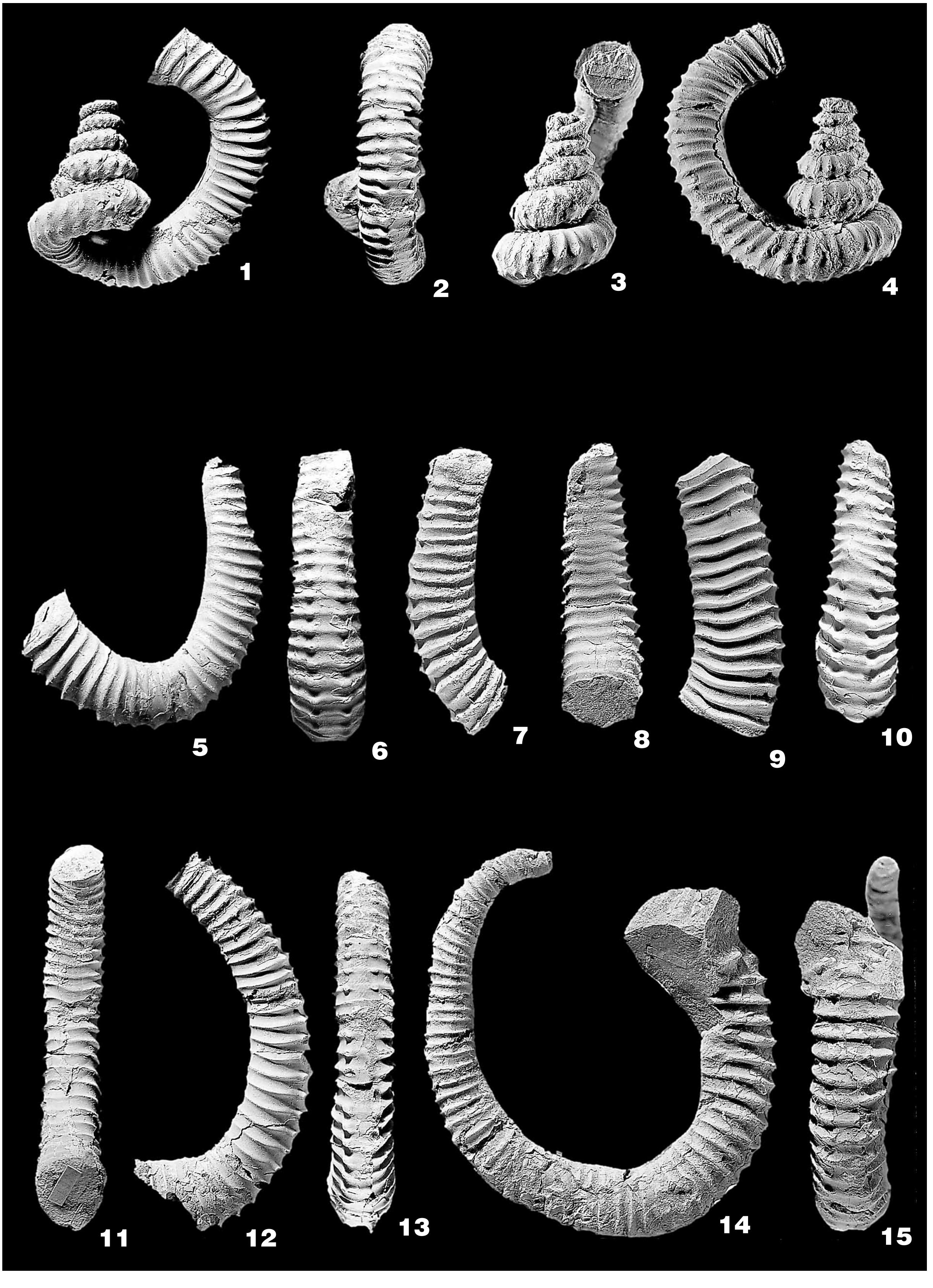
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PLATE 13

1, 3-4 – *Spiroxybeloceras kimbroense* KENNEDY & COBBAN, 1999.
- 1 – Karl HIRSCH Collection, now housed in the University of Colorado, Boulder, from the Pierre Shale near Pueblo, Colorado
- 3 – USNM 501757, from USGS Mesozoic locality D1211
- 4 – USNM 501758, from USGS Mesozoic locality D13939

2 – *Spiroxybeloceras meekanum* (WHITFIELD, 1877); USNM 411291, from the *Didymoceras cheyennense* Zone, Pierre Shale, Lone Tree Reservoir, near Fort Collins, Larimer County, Colorado

5-6, 10-13 – *Lewyites sulcatus* sp. nov.
- 5 – paratype, UND 10743c
- 6 – paratype UND 10743b
- 10 – holotype UND 10743a
- 11 – paratype UND 10743d, from the Gregory Member of the Pierre Shale, *Baculites scotti* Zone, roadcut in SW1/4 sec. 9, T.140 N., R.58 W., 1.2 km (0.7 mi) NW of North Valley City, Barnes County, North Dakota

12-13 – paratype USNM 501756, from the Gregory Member of the Pierre Shale, Lyman County, South Dakota.

7-9 – *Anaklinoceras incertum* sp. nov. Paratype, BHI 2092, from the Pierre Shale, Lyman County, South Dakota; for suture, see Text-fig. 9

All figures are × 1

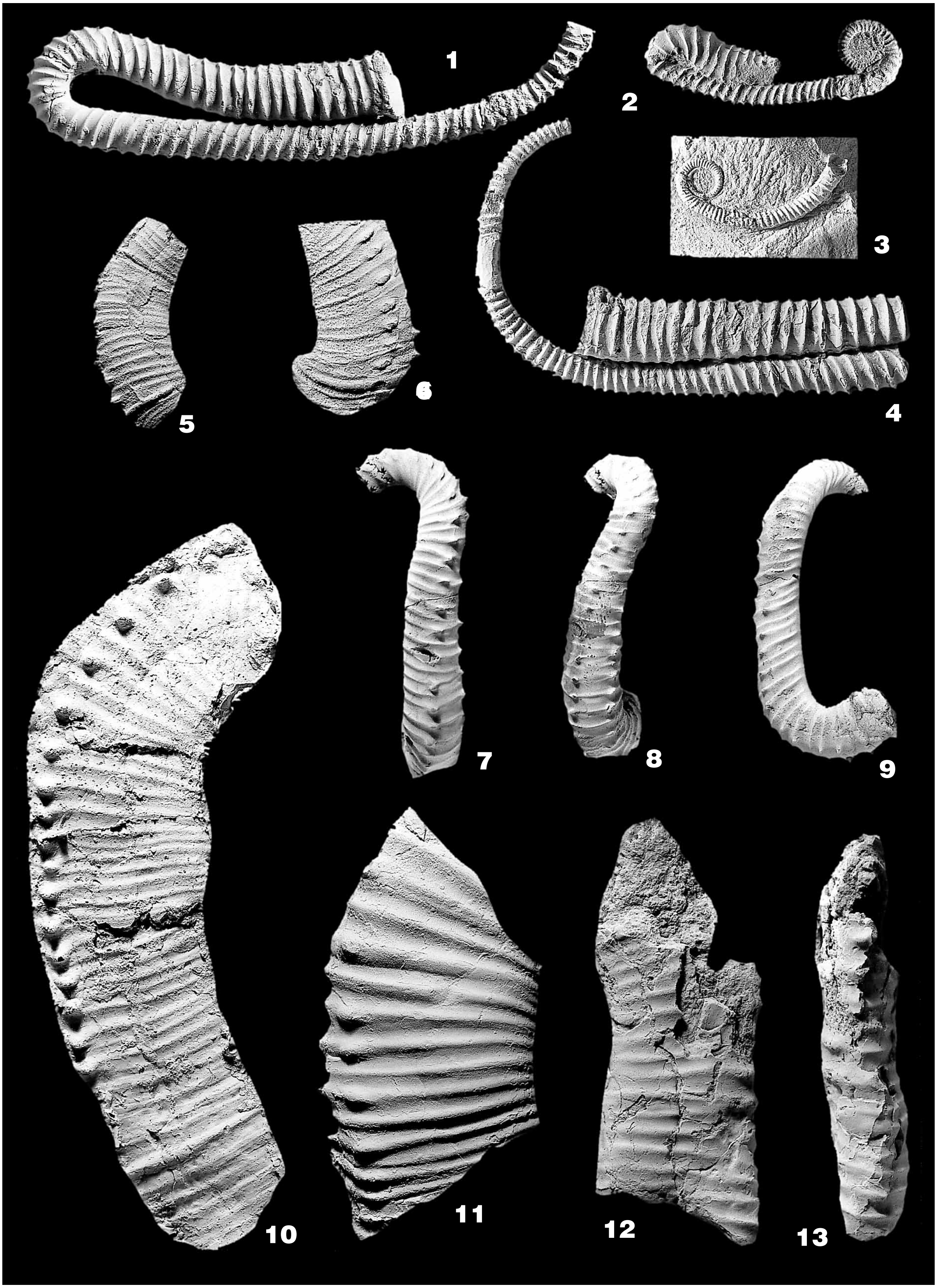
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PLATE 14

1-23 – *Solenoceras mortoni* (Meek & Hayden, 1857)
1, 2, 12, BHI 4019; 3, 4, 13, BHI 4023; 5, 6, 15, BHI 4021; 7, 8, 16, BHI 4026; 9, 10, 17, USNM 501762, a pathological specimen with only one row of ventral tubercles on the larger shaft; 11, 18, 19, BHI 4030; 14, 20-23, BHI 2147, all from the Gregory Member of the Pierre Shale, Lyman County, South Dakota

24-26 – *Spiroxybeloceras kimbroense* Kennedy & Cobban, 1999
24 – USNM 501759, from USGS Mesozoic locality D5298; 25 – USNM 501760; 26, USNM 501761, both from USGS Mesozoic locality D314

Figures 1-10, 18, 19, are × 2. Figs. 11-17, 24-26 are × 1. Figs. 20-23 are × 3

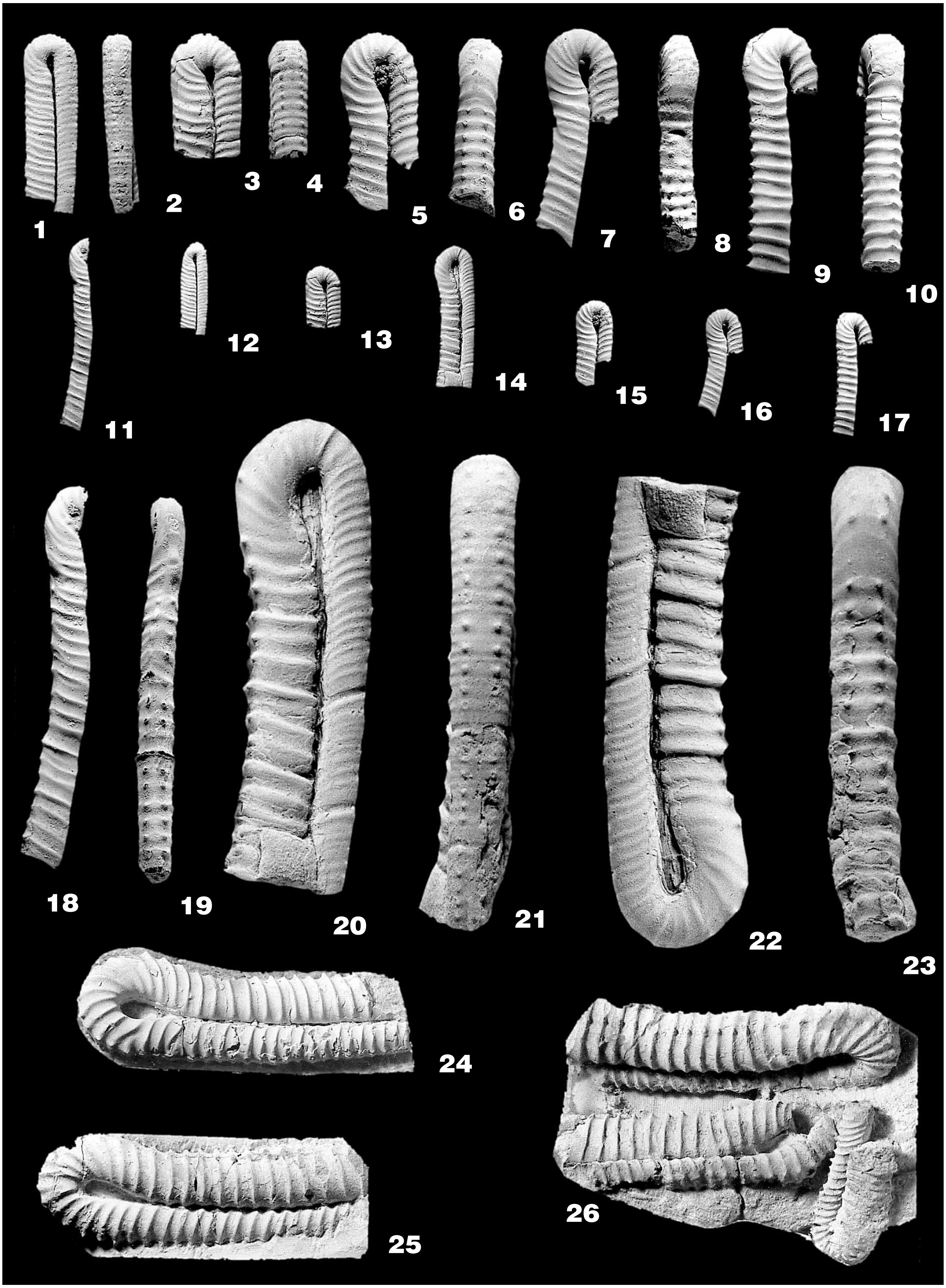
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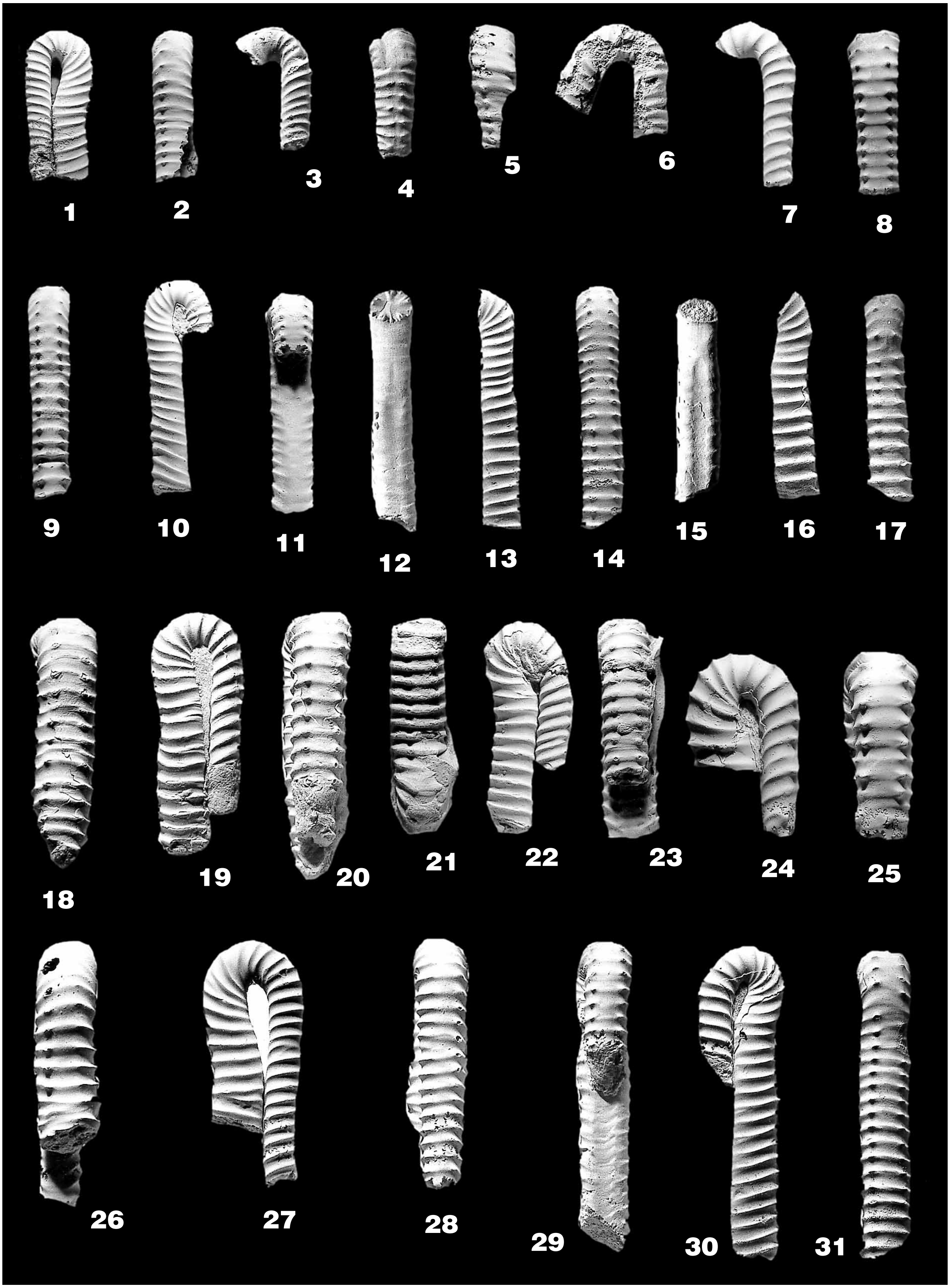
PLATE 15

Spiroxybeloceras kimbroense KENNEDY & COBBAN, 1999

1-17 are microconchs; 18-31 are macroconchs; 1-2 – BHI 4025; 3-4 – USNM 501763, with healed predation damage; 5-6 – USNM 501764, with pathological, open coiling; 7-8 – BHI 4029; 9-11 – USNM 501765; 12-14 – USNM 501766, showing dorsal impressed zone of larger shaft; 15-17 – USNM 501767, showing dorsal impressed zone of larger shaft; 18-20 – BHI 4686; 21-23 – BHI 4027; 24-25 – BHI 4031; 26-28 – BHI 4687; 29-31 – BHI 4688

All specimens are from the *Baculites scotti* Zone Gregory Member of the Pierre Shale of Lyman County, South Dakota

All figures are × 1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