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Some Acanthoceratid Ammonites from Upper Cenomanian (Upper Cretaceous) Rocks of Wyoming

By WILLIAM A. COBBAN

U.S. GEOLOGICAL SURVEY PROFESSIONAL PAPER 1353

Ammonites of the genera
Calycoceras, Dunveganoceras, *and* Metoicoceras
from the Frontier Formation and equivalent rocks
are described and illustrated

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SOME ACANTHOCERATID AMMONITES FROM UPPER CENOMANIAN (UPPER CRETACEOUS) ROCKS OF WYOMING

By WILLIAM A. COBBAN

ABSTRACT

Ammonites of the genera *Calycoceras*, *Dunveganoceras*, and *Metoicoceras* are useful in zoning the Frontier Formation of central and north-central Wyoming and the mostly undifferentiated rocks of northeastern Wyoming that are equivalent in age to the Belle Fourche Shale and Greenhorn Formation. The oldest of the four zones identified contains *Dunveganoceras pondi* Haas, *Calycoceras canitaurinum* (Haas), *C. newboldi* (Kossmat), and *Metoicoceras praecox* Haas. *Calycoceras newboldi* has not previously been reported from North America. The second zone is characterized by the new species *Dunveganoceras problematicum*, *Calycoceras rubeyi*, *C.* aff. *C. canitaurinum*, and *Metoicoceras frontierense*. A subspecies, *D. problematicum natronense*, is recognized in this zone in one area of central Wyoming. The third zone has *Dunveganoceras albertense* (Warren) and *Metoicoceras mosbyense* Cobban, as well as a new geographic subspecies, *D. albertense regale*. The fourth and youngest zone may be that of *Dunveganoceras conditum* Haas. *Dunveganoceras* is not known in the western interior of the United States above the zone of *D. conditum*. *Metoicoceras*, however, ranges higher and terminates in the species *M. geslinianum* (d'Orbigny).

INTRODUCTION

An undescribed ammonite fauna of early late Cenomanian age was discovered in 1950 by R.K. Hose and W.J. Mapel, both then with the U.S. Geological Survey. Until 1974, this fauna, characterized by new species of *Dunveganoceras* and *Metoicoceras*, was known only from the original locality at Dry Muddy Creek, about 20 km south-southwest of Buffalo, Wyo. In 1974, E.A. Merewether of the U.S. Geological Survey and I discovered a closely related fauna at Emigrant Gap Ridge, about 15 km west of Casper, Wyo., and in the following year, Merewether and I, together with E.T. Cavanaugh, then a graduate student at Colorado School of Mines, found another locality 3 km farther northwest. In the course of investigating this new fauna near Casper, we discovered *Calycoceras newboldi* (Kossmat), a Cenomanian ammonite known from India, Japan, Madagascar, north Africa, and western Europe, in the rocks a little below the level of the new fauna. Further investigations revealed a large, robust undescribed species of *Calycoceras* and a new species of *Metoicoceras*. Specimens from Wyoming that occur in the rocks a little above the stratigraphic level of the new species were found to represent a new geographic subspecies of the Canadian *D. albertense* (Warren). The present work reports on these new discoveries.

The specimens described in this report are in the U.S. National Museum of Natural History in Washington, D.C., and have USNM catalog numbers. Plaster casts of a few of the specimens are in the U.S. Geological Survey's (USGS) reference collections of Mesozoic molluscan fossils at the Denver Federal Center in Lakewood, Colo. All photographs were made by Robert E. Burkholder of the U.S. Geological Survey. The author made the drawings of sutures and whorl sections.

LOCALITIES AT WHICH FOSSILS WERE COLLECTED

Ammonites described or reported in this paper came from 19 localities in the northeastern quarter of Wyoming (fig. 1). The U.S. Geological Survey Mesozoic locality number, names of collectors, year of collection, locality, and stratigraphic position are as follows (prefix D indicates Denver Mesozoic locality numbers; the rest are Washington, D.C., USGS Mesozoic locality numbers):

D5723. W.A. Cobban, 1966. Northwest of Kaycee in the SW¼ sec. 2, T. 43 N., R. 82 W., Johnson County. Frontier Formation, from sandy septarian concretions in Belle Fourche Member 38 m below base of Wall Creek Member.

D5944. Cobban, 1967. About 3.7 km west of Upton in the NW¼ sec. 33, T. 48 N., R. 65 W., Weston County. From unit of highly septarian limestone concretions in undifferentiated rocks of Belle Fourche-Greenhorn age and about 30 m below base of Carlile Shale.

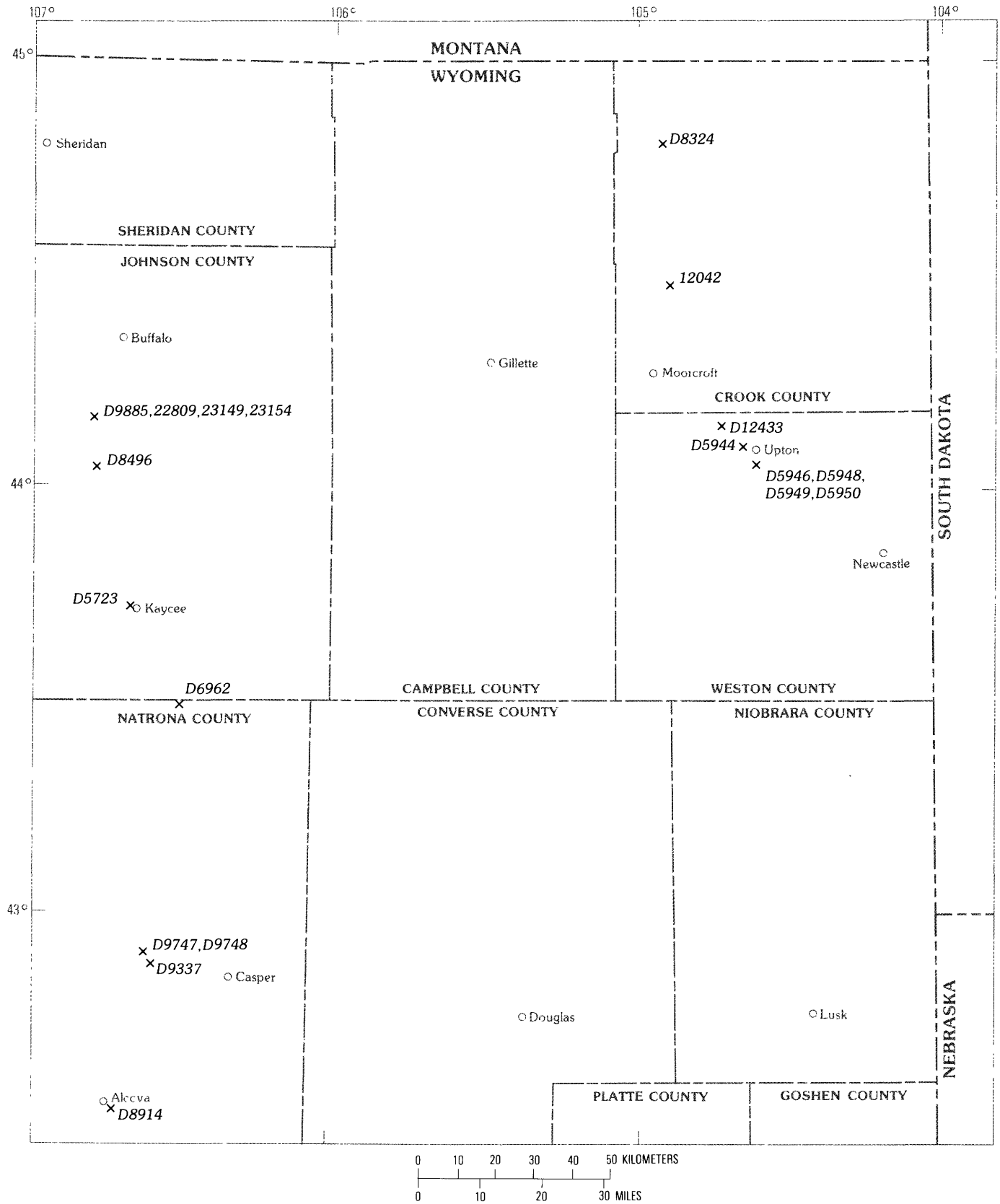

FIGURE 1.—Map of the northeastern part of Wyoming showing localities (X) of fossil collections. Numbers are U.S. Geological Survey Mesozoic localities.

D5946. Cobban, 1967. About 5 km south of Upton in the NW¼ sec. 14, T. 47 N., R. 65 W., Weston County. From septarian limestone concretions in undifferentiated rocks of Belle Fourche-Greenhorn age and about 91 m below base of Carlile Shale.

D5948. Cobban, 1967. Same locality as D5946. From septarian limestone concretions in undifferentiated rocks of Belle Fourche-Greenhorn age and about 72 m below base of Carlile Shale.

D5949. Cobban, 1967. Same locality as D5946. From septarian limestone concretions in undifferentiated rocks of Belle Fourche-Greenhorn age and about 53 m below base of Carlile Shale.

D5950. Cobban, 1967. Same locality as D5946. From septarian limestone concretions in undifferentiated rocks of Belle Fourche-Greenhorn age and about 40 m below base of Carlile Shale.

D6962. Cobban, 1970. SW¼ sec. 30, T. 41 N., R. 80 W., Natrona County. Frontier Formation, from a 2-m-thick bed of orange-brown-weathering, fine-grained sandstone 41 m above a 1.5-m-thick bed of bentonite in Belle Fourche Member.

D8324. E.A. Merewether, 1971. NE¼ sec. 30, T. 56 N., R. 67 W., Crook County. Belle Fourche Shale, from septarian limestone concretions 3.6 m below top of formation.

D8496. Merewether, 1972. South of Middle Fork of Crazy Woman Creek in the SE¼ sec. 13, T. 47 N., R. 83 W., Johnson County. Frontier Formation, from a sandy, septarian concretion in the Belle Fourche Member 21 m below sandy concretions that contain a varied fauna of the zone of *Sciponoceras gracile*.

D8914. Merewether, W.J. Kennedy, and Cobban, 1973. About 3 km south-southeast of Alcova in the NE¼ sec. 31, T. 30 N., R. 82 W., Natrona County. Frontier Formation, from brown-weathering, sandy limestone concretions at top of a soft sandstone unit in the Belle Fourche Member.

D9337. Merewether and Cobban, 1974. NW¼ sec. 32, T. 34 N., R. 81 W., Natrona County. Frontier Formation, from a lenticular bed of chert conglomerate or pebbly sandstone in the Belle Fourche Member 14 m below a ridge of coarse-grained sandstone that contains a fauna of the zone of *Collignoniceras woollgari* (Mantell).

D9747. Merewether, E.T. Cavanaugh, and Cobban, 1975. NW¼ sec. 30, T. 34 N., R. 81 W., Natrona County. Frontier Formation, from brown-weathering limestone concretions in the Belle Fourche Member just below a 2-m-thick bed of bentonite that lies 17 m below the stratigraphic level of D9337.

D9748. Merewether, Cavanaugh, and Cobban, 1975; Merewether, S.C. Hook, and Cobban, 1978. SW¼ sec. 19, T. 34 N., R. 81 W., Natrona County. Frontier Formation, from a lenticular bed of chert conglomerate in the Belle Fourche Member at same stratigraphic level as D9337.

D9885. Cobban, 1976. NW¼ sec. 1, T. 48 N., R. 83 W., Johnson County. Frontier Formation, from a septarian limestone concretion in the Belle Fourche Member 12.8 m below a bed of bentonite that lies in or near the zone of *Sciponoceras gracile* (Shumard).

D12433. Cobban, 1959. NE¼ sec. 13, T. 48 N., R. 66 W., Weston County. Belle Fourche Shale, from septarian limestone concretions about 61 m below base of Carlile Shale.

12042. W.W. Rubey, 1924. About 24 km north of Moorcroft, Crook County. Belle Fourche Shale.

22809. R.K. Hose and W.J. Mapel, 1950. North of Dry Muddy Creek in the NE¼ sec. 1, T. 43 N., R. 83 W., Johnson County. Frontier Formation, from conglomeratic sandstone in upper part (Hose, 1955, p. 99).

23149. Hose and Mapel, 1950. Same locality as 22809. From septarian limestone concretions 19.5–35 m above base of Cody Shale of Hose (1955, p. 99).

23154. Hose and Mapel, 1950. Same locality and stratigraphic position as 22809.

SYSTEMATIC DESCRIPTIONS

In describing sutures, E denotes the external (siphonal) lobe; L, the lateral lobe; and E/L, the saddle that separates the external and lateral lobes. In the drawings of whorl sections, the solid outer line is the costal section, the short dashed inner line is the intercostal section, and the longer dashes represent broken or missing areas. The numbers in parentheses after the umbilical diameters are ratios of umbilical to shell diameters.

Phylum MOLLUSCA
Class CEPHALOPODA
Order AMMONOIDEA
Suborder AMMONITINA
Superfamily ACANTHOCERATACEAE de Grossouvre, 1894
Family ACANTHOCERATIDAE de Grossouvre, 1894
Subfamily MANTELLICERATINAE Hyatt, 1903

Genus CALYCOCERAS Hyatt, 1900

Type species.—Ammonites navicularis Mantell, 1822, p. 198, pl. 22, fig. 5.

This genus includes rather large, moderately evolute ammonites that have rounded to subquadrate whorl sections. Ornament consists of strong, usually straight ribs that alternate in length and cross the broadly rounded to flattened venter. Umbilical, inner and outer ventrolateral, and siphonal tubercles are present on the earliest whorls, and midlateral tubercles may occur. The genus is found worldwide in rocks of middle to late Cenomanian age.

Calycoceras rubeyi Cobban, n. sp.

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

This species is characterized by its huge size, by its inflated whorls that are wider than they are high, by its flattened venter on the adult body chamber, and by its spinose inner whorls. The holotype (USNM 376905) was collected by the late W.W. Rubey of the U.S. Geological Survey. The specimen came from a septarian limestone concretion in the upper part of the Belle Fourche Shale on the west flank of the Black Hills uplift in northeastern Wyoming. In addition to the holotype, the type lot, from USGS Mesozoic locality 12042 (fig. 1), consists of a figured paratype (USNM 376906) and four unfigured fragments.

The holotype (pl. 1; text fig. 2), an internal mold 422 mm in diameter that is moderately evolute with an umbilical diameter of 187 mm (0.44), consists of a phragmocone and a quarter whorl of the body chamber. Diameter at the base of the body chamber is 330 mm. The younger part of the phragmocone and the part of the body chamber preserved have a trapezoidal section much broader than high, with the greatest width at the umbilical shoulder. Ornament on the outer whorl consists of 26 slightly rursiradiate ribs alternating in length. Longer ribs originate in umbilical bullae, and all ribs on the younger part of the phragmocone and on the body chamber bear a row of blunt ventrolateral tubercles.

In the course of extracting the specimen from the septarian concretion, the specimen came apart. Before cementing the fragments together, the late J.B. Reeside, Jr., of the U.S. Geological Survey, had a plaster cast prepared of the innermost whorl preserved (pl. 2, figs. 2, 3). Only the venter and the outermost part of the flank were preserved at this diameter (99 mm). Ornament on the cast consists of primary and secondary rectiradiate ribs that trend straight across the venter. Ribs are rounded on the older third of the whorl, where they are as broad as the interspaces. On the rest of the whorl, the ribs flatten on the venter and become a little broader than the interspaces. Primary ribs support a row of sharp, outward-directed inner ventrolateral spines. Two to four nonspinose secondary ribs separate the primary ribs.

The outer whorl and the penultimate whorl are visible on the holotype. The penultimate whorl has a diameter of about 190 mm and a cross section that is widest at the umbilical shoulder. Ornament on this whorl consists of 27 slightly rursiradiate primary and secondary ribs that are narrow on the flank and flat on the venter. Most of the primary ribs are separated by two secondary ribs. The primaries support two rows of outward directed spines, an umbilical one and a ventrolateral one. These spines disappear before the end of the whorl

On the outer whorl of the holotype, ribs become alternate in length; they continue to be straight and a little rursiradiate. At first, the ribs and interspaces are about equal in width, but as the whorl enlarges, the ribs become farther apart and narrower than the interspaces. Primary ribs arise from rounded umbilical bullae located on the umbilical shoulder. On the older part of this whorl, the costal section is rounded, but on the younger part, a ventrolateral shoulder forms and then develops into a row of low bullate tubercles accompanied by a flattening of the ribs as they cross the venter. The result is a trapezoidal cross section that has its greatest width at the umbilical shoulder (fig. 2*A*). When the specimen was removed from its matrix, a damaged area that included the last two ribs of the phragmocone was restored in plaster. This restoration is incorrect in that the two ribs were made equal in length and too straight.

The external suture of the holotype is incompletely exposed. The external lobe (E) is fairly long and broad. The first lateral saddle (E/L) is broader than E and asymmetrically bifid, and the lateral lobe (L) is rectangular, bifid, and narrower than E/L. Part of the external suture is shown in figure 2*B*.

Although the holotype is a large adult, a paratype (USNM 376907) from the same general area as the type is 451 mm in diameter with an umbilical diameter of 188 mm (0.42). Like the holotype, the larger specimen consists of a phragmocone and about a quarter of a whorl of body chamber. The diameter at the base of the body chamber is 357 mm. Ornament on the last whorl

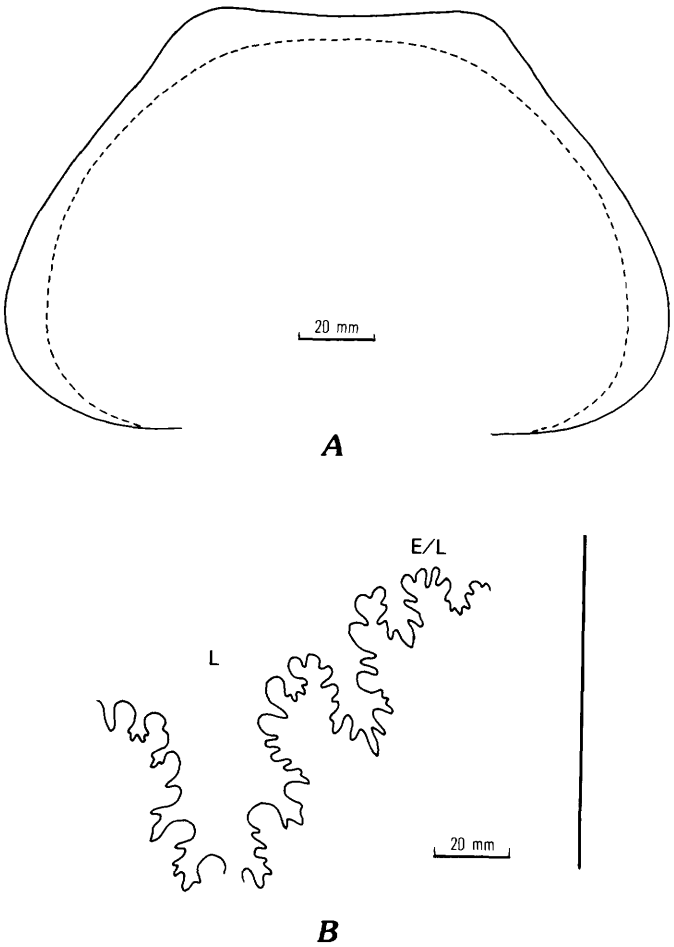

FIGURE 2.—Whorl section and suture of the holotype of *Calycoceras rubeyi* Cobban, n. sp., from the Belle Fourche Shale at USGS Mesozoic locality 12042 (fig. 1). USNM 376905. *A*, whorl section at a diameter of 306 mm. *B*., part of the external suture at a diameter of 312 mm. The straight line marks the middle of the venter. L, lateral lobe; E/L, first lateral saddle.

consists of 22 straight, rectiradiate to slightly rursiradiate ribs of alternate lengths. Ribs are thick and rounded on the older part of the whorl, where they are as wide as the interspaces. The ribs gradually become farther apart on the younger part, where they may be only half as wide as the interspaces. Primary ribs arise from prominent bullate umbilical tubercles located on the umbilical shoulder. Secondary ribs arise low on the flank, where all ribs rise into a row of blunt ventrolateral tubercles. The ribs then trend straight across the flattened venter as low, flat swellings. An occasional flat rib that crosses the venter on the outer whorl is elevated a little along its adapical and adoral margins to form weak, looped ribs connecting opposite ventrolateral tubercles.

Very small juvenile whorls of *C. rubeyi* have not been found; none of the specimens at hand has the innermost whorls preserved. Aside from the innermost whorl preserved on the holotype, the smallest whorl in the type lot is a paratype (USNM 376906) that consists of half a whorl of about 70 mm diameter (pl. 2, fig. 1). Like the innermost whorl of the holotype, the paratype has only the ventral area preserved. Ornament on the paratype consists of 14 ribs in half a whorl, all of which are rounded, are as wide as the interspaces, and trend straight across the venter. Every third or fourth rib rises into an outward-directed sharp inner ventrolateral tubercle. All ribs have an incipient outer ventrolateral tubercle and a faint siphonal swelling, which suggest that the earliest whorls of this species have siphonal and inner and outer ventrolateral tubercles.

The early whorls of *C. rubeyi* are like those of the much smaller *Calycoceras* (*Lotzeites*) Wiedmann (1964, p. 121), which has a well-ribbed venter and outward-directed spines on the primary ribs, and which may have incipient siphonal and outer ventrolateral tubercles (Wiedmann, 1964, figs. 2b, 3) or lack them (Kossmat, 1895, pl. 24, fig. 4b).

Calycoceras rubeyi is probably derived from *C. canitaurinum* (Haas, 1949, p. 9, pls. 1–3; pl. 4, figs. 1, 2, 4; text figs. 1–4). Haas' species is smaller, is less inflated, and lacks spinose inner whorls. The inner whorls of *C. canitaurinum* are more like those of *C. newboldi* (Kossmat, 1897, p. 111, pl. 12, fig. 3a, b) and its varieties *spinosum* (Kossmat, 1897, p. 114, pl. 13, fig. 3a, b) and *planecostatum* (Kossmat, 1897, p. 116, pl. 13, fig. 1a, b).

Calycoceras rubeyi was listed as *Acanthoceras*? n. sp. (Robinson and others, 1964, p. 56, loc. 12042). The collection from this locality includes a fragment of the outer septate whorl of a *Dunveganoceras* that has a narrower venter than that of *D. pondi* Haas (1949, p. 22).

Types.—Holotype USNM 376905, paratypes USNM 376906, 376907.

Calycoceras newboldi (Kossmat) wyomingense Cobban, n. subsp.

Plate 3, figure 5; plate 4, figures 2, 3; text figures 3, 4

This large, robust subspecies is characterized by its moderately sparse ribbing, by its weak tuberculation, and by its inflated primary ribs at midflank. The new form is represented by the holotype and a paratype from the same locality.

The holotype (USNM 376908) is an internal mold 236 mm in diameter that represents the last third of the outer septate whorl of an adult (pl. 3, fig. 5; pl. 4, fig. 3). Intercostal and costal sections are wider than they are high and have a broadly rounded venter (fig. 3*A*). Ornament consists of alternate, slightly rursiradiate, straight, rounded ribs that are narrower than the

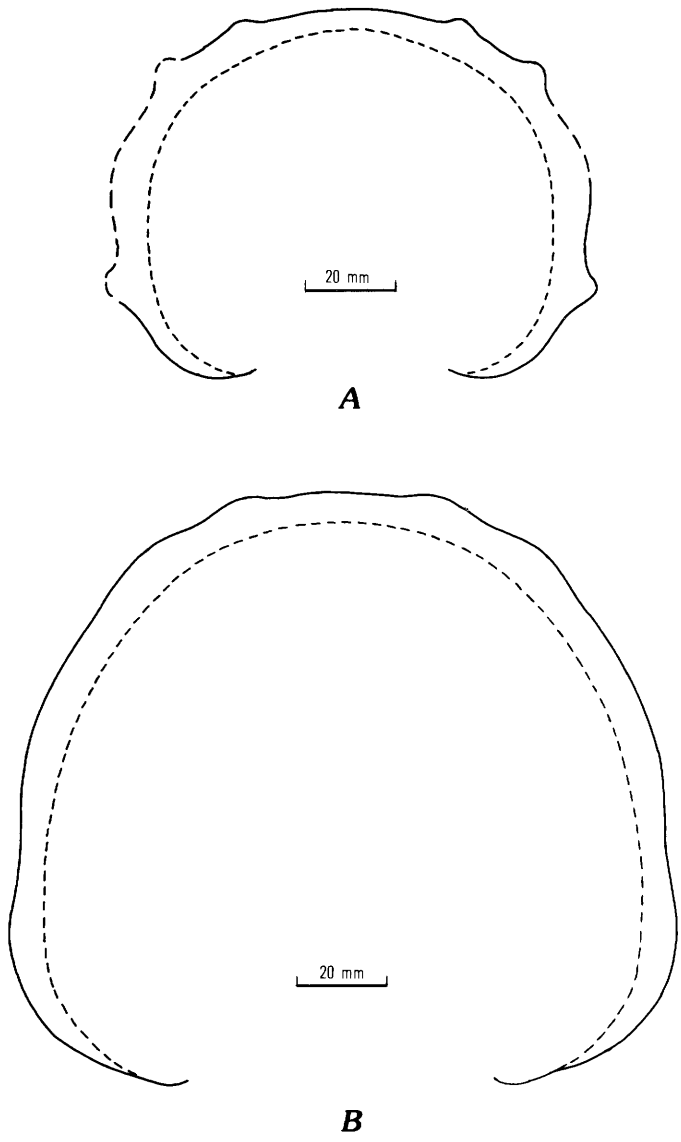

FIGURE 3.—Whorl sections of *Calycoceras newboldi wyomingense* Cobban, n. subsp., from the Frontier Formation at USGS Mesozoic locality D9747 (fig. 1). *A*, Holotype USNM 376908 at a whorl height of 80.5 mm (pl. 3, fig. 5; pl. 4, fig. 3). *B*, Paratype USNM 376909 at a diameter of 305 mm.

interspaces and bear low bullate to nodate inner ventrolateral tubercles and nodate outer ventrolateral ones. Longer ribs begin on the umbilical wall, rise into sharp umbilical tubercles a little ventral from the umbilical shoulder and bulge outward midway between the umbilical and inner ventrolateral tubercles. These ribs are narrower and sharp on the flank and broad but rounded on crossing the venter. Shorter ribs arise at midflank and rapidly attain the size of the longer ribs at the ventrolateral shoulder. Ribs probably totaled 13 or 14 on half a whorl. The external suture is fairly simple with a broad external lobe; a broader, deeply bifid first lateral saddle (E/L); and a broad, bifid, rectangular lateral lobe that is narrower than the E/L saddle (fig. 4).

A robust paratype (USNM 376909) from the same locality as the holotype consists of a whorl and a quarter of a phragmocone and the basal part of the adult body chamber. The specimen has a diameter of 306 mm and an umbilical diameter of 102.5 mm (0.33). The smaller inner whorls are not preserved. Whorl section (fig. 3*B*) and ornament are much like those of the holotype. Ribs on the last half whorl number 13 and those on the last complete whorl number 27. Ribs are tuberculate almost to the end of the phragmocone, where the tubercles gradually weaken into bulges on the ribs, and continue in this manner onto the basal part of the body chamber.

The holotype and a paratype of the new subspecies came from USGS Mesozoic locality D9747, about 19 km west of Casper in Natrona County (fig. 1). Associated ammonites are *Calycoceras canitaurinum* (Haas), *Dunveganoceras* cf. *D. pondi* Haas, and *Metoicoceras* cf. *M. praecox* Haas. An inner whorl (USNM 376910) from another locality (fig. 1, loc. D8914), 88.5 mm in diameter, seems assignable to *C. newboldi wyomingense* (pl. 4, fig. 2). The umbilicus and much of the flank are not preserved. Ribs are narrow and tuberculate and number 19 per half whorl. Associated ammonites are *C. canitaurinum*, *D. pondi*, and *M. praecox*.

Calycoceras newboldi wyomingense is interpreted as a geographic subspecies of *C. newboldi* (Kossmat, 1895, p. 111) of India. The new subspecies resembles a large septate fragment figured by Kossmat (1895, pl. 14, fig. 1a, b) as *Acanthoceras newboldi* var. *spinosa*. Kossmat's form, however, is more densely ribbed, has stronger tubercles, and lacks the midflank swelling on the ribs. Matsumoto and others (1957, p. 13) regarded Kossmat's variety as an independent species, and they figured several examples including an adult 220 mm in diameter. This adult resembles *C. newboldi wyomingense* in that

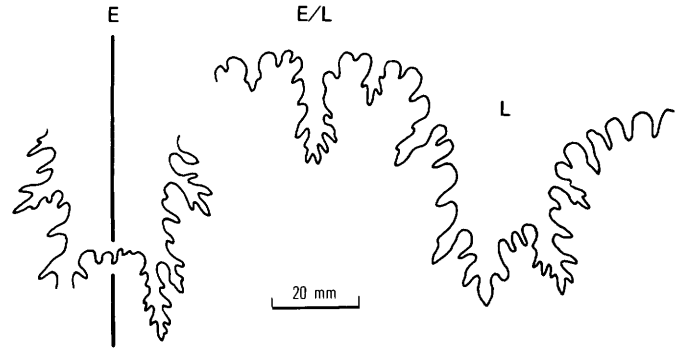

FIGURE 4.—Part of the external suture at a whorl height of 98.5 mm of the holotype USNM 376908 of *Calycoceras newboldi wyomingense* Cobban, n. subsp., from the Frontier Formation at USGS Mesozoic locality D9747 (fig. 1). Heavy line marks the middle of the venter. E, external lobe; L, lateral lobe; E/L, first lateral saddle.

it has ribs inflated at midflank (Matsumoto and others, 1957, text fig. 3A, B). The Japanese specimen differs in that it has more ribs, and these are narrower and sharper and more conspicuously tuberculate. In addition, the secondary ribs are longer. Thomel (1972, p. 110) also regarded Kossmat's variety as a full species and he assigned it to the new genus *Newboldiceras*. A large specimen from southeastern France was illustrated by Thomel (1972, pl. 42, figs. 1, 2). The French example differs from *C. newboldi wyomingense* mainly in that tuberculation on the body chamber is more pronounced, and the ribs are narrower. A moderately large specimen from Madagascar figured by Collignon (1964, pl. 363) as *C. newboldi* var. *spinosa* is more densely ribbed than *C. newboldi wyomingense* and has more distinct tubercles.

Types.—Holotype USNM 376908, paratypes USNM 376909, 376910.

Calycoceras aff. C. canitaurinum (Haas)

Plate 5; plate 6, figures 1, 2

Calycoceras canitaurinum (Haas, 1949, p. 9, pls. 1–3, pl. 4, figs. 1, 2, 4; text figs. 1–4) is a large, stout species further characterized by its broad or flat ventral ribs and its trapezoidal whorl section, which is broader than it is high, with steep umbilical wall, flattened flanks, and flattened venter bounded by nodate to bullate ventrolateral tubercles. These tubercles develop early as blunt swellings on the ventrolateral shoulder and gradually rise into upward- and outward-directed tubercles on the last septate whorl and on the body chamber.

Fragments of a *Calycoceras* from conglomeratic sandstone beds in the Frontier Formation in central and north-central Wyoming (fig. 1, locs. D9337, D9748, 23154, 22809) differ mainly from typical specimens of *C. canitaurinum* in that distinct ventrolateral tubercles form at a later growth stage, usually on the younger part of the body chamber. Umbilical bullae also seem to be stronger, and on some specimens they are extended into conspicuous nodate tubercles. Some specimens seem to have more rounded, thicker ribs than on comparable size specimens of typical *C. canitaurinum* (pl. 6, figs. 1, 2).

The best specimen (USNM 376912) at hand is part of a body chamber with parts of the phragmocone (pl. 5). Maximum diameter is 265 mm with an umbilical ratio of 0.34. The whorl section through the body chamber is fairly quadrate, a little broader than high, with a steep, slightly rounded umbilical wall, a broadly rounded flank, and a flattened venter. Thick, rounded prorsiradiate ribs alternate in length and number 12 on the last half whorl. Longer ribs begin from prominent umbilical bullae, and shorter ribs begin on the lower part of the flank. All ribs on the older three-fourths of the outer whorl widen and rise a little on the ventrolateral shoulder before flattening into broad ribs that trend straight across the venter. This ventrolateral bulge gradually develops into a low nodate tubercle on the last quarter of the whorl. Most of the penultimate whorl is preserved. The 14 ribs on the last half of the whorl are prorsiradiate, and they mostly alternate in length.

Ammonites associated with *Calycoceras* aff. *C. canitaurinum* include *Dunveganoceras problematicum*, n. sp., and *Metoicoceras frontierense*, n. sp.

Figured specimens.—USNM 376911, 376912.

Subfamily ACANTHOCERATINAE de Grossouvre, 1894
Genus DUNVEGANOCERAS Warren and Stelck, 1940

Type species.—*Acanthoceras albertense* Warren, 1930, p. 21, pl. 1, figs. 1, 2.

This genus was named by Warren and Stelck (1940, p. 149) to include "ammonites of a large size with wide umbilicus. There are three rows of nodes on either flank on the initial whorls connected by incipient ribs which do not cross the venter but on the ultimate whorl the ribs strengthen, completely incorporate the nodes and cross the venter, being very conspicuous there. The suture line is Acanthoceroid in type."

The type species, *Acanthoceras albertense* Warren, was based on a nearly complete adult of 350 mm diameter with an umbilical ratio of 0.31. Its whorl section is ogival, but not pointed as shown in a sketch by Warren (1930, pl. 1, fig. 2). A plaster cast of the type reveals a much more rounded venter. The holotype consists of a phragmocone of several whorls with a little more than a quarter whorl of body chamber. All whorls have straight, rectiradiate to slightly prorsiradiate ribs of equal length. On the inner whorls, ribs arise from umbilical bullae on the umbilical shoulder. The ribs weaken on the middle of the flank and then rise into prominent nodate inner ventrolateral tubercles. Outer ventrolateral tubercles are not visible on Warren's illustration nor on the plaster cast, but, according to Warren (1930, p. 21), they are clavate. Ribs number 19 on the complete outer whorl and 14 on the penultimate whorl.

Dunveganoceras albertense (Warren) regale Cobban, n. subsp.

Plate 4, figure 1; plate 7, figures 1, 2; plate 8, figure 3; plate 9, figures 1, 2; text figures 6, 7

This form differs from *Dunveganoceras albertense albertense* (Warren, 1930, p. 21, pl. 1 figs. 1, 2), as well as from *D. albertense montanense* Cobban (1953, p. 51, pl. 10, figs. 1–7; pl. 11; text figs. 3b–e), in having more slender and more densely ribbed inner whorls and in

having the ribs on the body chamber raised into high midventral tubercles that impart an acute whorl section. The new form is interpreted as a southern geographic subspecies.

The holotype (pl. 7, figs. 1, 2; text fig. 5*B*) is an internal mold 374 mm long that represents about two-thirds of a large adult body chamber. Whorl section is that of a pointed arch with the greatest width a little above the umbilical shoulder (fig. 5*B*). The umbilical wall is fairly steep and rounded, the flanks are broadly rounded, and the venter is narrowly rounded. Dimensions of the costal whorl section at the larger end are 180 mm high and 142 mm wide. Ornament consists of six prorsiradiate ribs that begin on the umbilical wall and curve gently forward on crossing the flank, where each rib is considerably narrower than the interspaces. On the venter the ribs thicken and rise into high prominent swellings that are steeper on the adapical side. These swellings become narrower on the younger part of the body chamber, where the last one forms a tonguelike, adapically concave arch. Total number of ribs per half whorl is estimated at 12 or 13.

The holotype is from a sandstone concretion in the Belle Fourche Member of the Frontier Formation at USGS Mesozoic locality D5723 near Kaycee in north-central Wyoming (fig. 1). Parts of three other large adults were found there. The whorl section of one of them is shown in figure 5*A*. No inner whorls were found.

Innermost whorls of *Dunveganoceras albertense regale* have not been found. Parts of the penultimate whorls have been found at several localities in north-central and northeastern Wyoming, but all were broken or distorted in septarian concretions. One of the best specimens, from USGS Mesozoic locality D5944 (fig. 1), consists of a little less than half a whorl that is attached along its venter to part of the outer whorl of a small adult (pl. 4, fig. 1; pl. 8, fig. 3). This inner whorl has a rectangular section higher than it is wide (fig. 6). Ribs are straight, quite prorsiradiate, and narrower than the interspaces. They probably numbered 13 in a half a whorl. Most ribs begin on the umbilical wall, but a few arise on the umbilical shoulder. All ribs rise into nodate inner ventrolateral tubercles. From each of these tubercles, a low broad rib extends to a larger clavate outer ventrolateral tubercle, which is steeper on the adoral side than on the adapical side. Opposite outer ventrolateral tubercles are connected by a very low, broad ventral rib. The outer whorl of this specimen is pathologic with an offcenter suture (fig. 7). Almost half a whorl is preserved. Most of this outer whorl is septate, but a small part of the body chamber is present. The diameter of the whorl is about 285 mm allowing for a broken end, and its umbilical ratio is about 0.46. Ribs probably numbered 13 or 14 per half whorl.

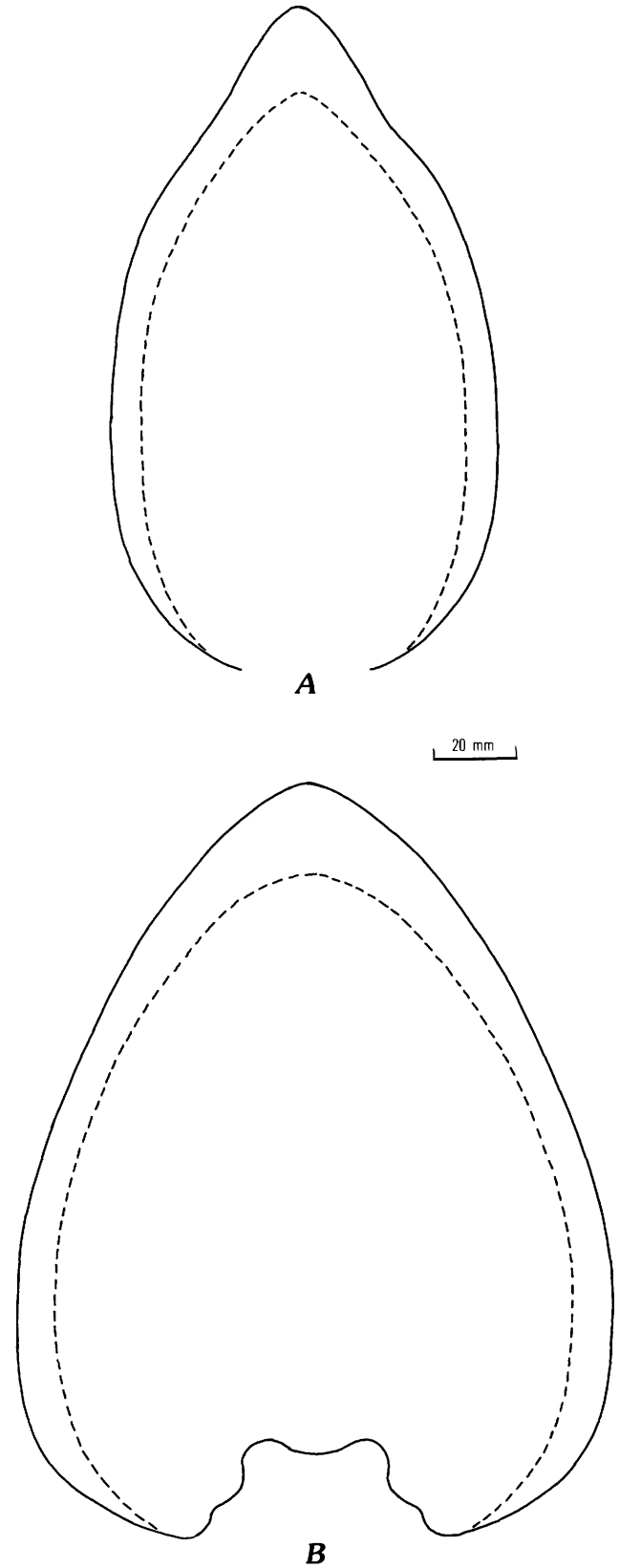

FIGURE 5.—Whorl sections of *Dunveganoceras albertense regale* Cobban, n. subsp., from USGS Mesozoic locality D5723 (fig. 1). *A*, Paratype USNM 376914 at a whorl height of 160 mm. *B*, Holotype USNM 376913 at a whorl height of 180 mm (pl. 7, figs. 1, 2).

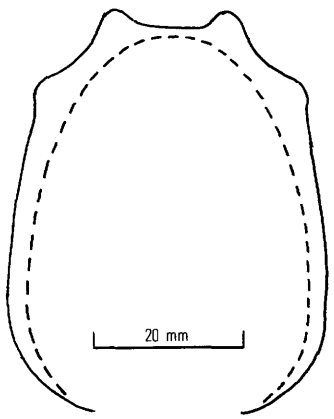

FIGURE 6.—Whorl section of *Dunveganoceras albertense regale* Cobban, n. subsp., at a whorl height of 53.5 mm from USGS Mesozoic locality D5944 (fig. 1). Paratype USNM 376916 (pl. 4, fig. 1; pl. 8, fig. 3).

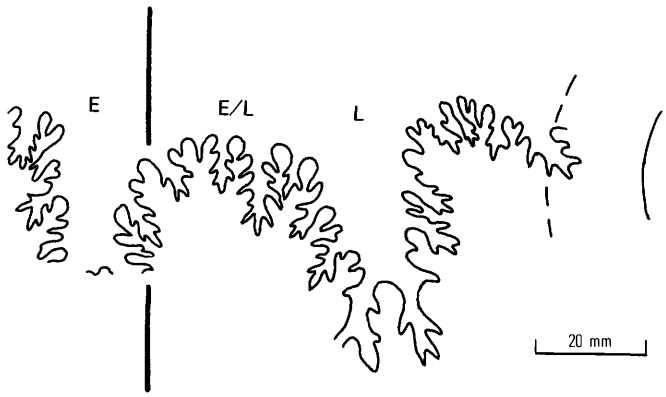

FIGURE 7.—Most of the external suture at a costal whorl height of 78 mm of a specimen of *Dunveganoceras albertense regale* Cobban, n. subsp., from USGS Mesozoic locality D5944 (fig. 1). The heavy line marks the middle of the venter. Note the off-centered external lobe (E). The solid curved line marks the umbilical seam, and the dashed curved line marks the umbilical shoulder. L, lateral lobe; E/L, first lateral saddle. Paratype USNM 376916.

Part of a body chamber (USNM 376915), presumably near the aperture, of an adult from another locality (fig. 1, loc. D8324) differs from other specimens in that ribs are closely spaced (pl. 9, figs. 1, 2). Each rib is narrow, prorsiradiate, slightly flexuous, and equal in length. Each rib rises high on the venter into a tongue-like arch that is bent backward a little.

Dunveganoceras albertense regale is known only from northeastern Wyoming, where it occurs in the Frontier Formation, Belle Fourche Shale, and Greenhorn Formation. Along the northwestern flank of the Black Hills uplift, the Greenhorn Formation loses much of its calcareous content and becomes more like the underlying Belle Fourche Shale (Robinson and others, 1964, p. 60–62). As a result, some collections of *D. albertense regale* have been assigned by their collectors to the Greenhorn and others to the Belle Fourche.

The holotype of *D. albertense regale* was associated with *Metoicoceras mosbyense* Cobban and a single specimen of *Sciponoceras*.

Types.—Holotype USNM 376913, paratypes USNM 376914–376916.

Dunveganoceras problematicum Cobban, n. sp.

Plate 2, figures 4–6; plate 3, figure 4; plate 8, figures 1, 2; plates 10–12; plate 13, figure 3; text figures 8–11

Involute inner whorls and ribs mostly or entirely of alternate lengths characterize this species, which thus departs from the usual concept of the genus as having fairly evolute whorls and ribs of equal length. The species is known only from central and north-central Wyoming. Two forms are recognized, the nominate subspecies and a new subspecies, *D. problematicum natronense*.

Dunveganoceras problematicum problematicum Cobban, n. subsp.

Plate 2, figures 4–6; plate 8, figures 1, 2; plate 10; text figures 8, 9

This form is most unusual in that all ribs are of alternate lengths. The collection from the type locality (fig. 1, loc. 23154) includes the holotype and two paratypes.

The holotype consists of part of the phragmocone attached to a fragment of the adult body chamber (pl. 10). Although both parts are crushed, the cross section of the inner whorls is much higher than wide, with flattened flanks; low, sloping umbilical wall; and narrow, flattened venter. The phragmocone has a diameter of 127 mm and an umbilical diameter of 19.5 mm (0.15). Ornament on this whorl consists of weak prorsiradiate ribs, umbilical bullae, and inner and outer ventrolateral tubercles. Ribs are of two lengths: the longer ribs begin on the umbilical wall and rise into low, inconspicuous bullae on the umbilical shoulder before crossing the flank, and one or two shorter ribs arise at midflank between the longer ones. All ribs support inner and outer ventrolateral tubercles, which are nodate and nearly equal in size on the older part of the whorl. The inner ventrolateral tubercles weaken and almost disappear near the larger end of the whorl, but the outer ones become clavate and remain strong. Ribs between the two rows of ventrolateral tubercles become low and flattened on the younger part of the whorl. There are 37 ribs on the complete outer septate whorl. The remainder of the holotype consists of about one-third or one-half of the adult body chamber attached to the venter of the

inner septate whorl (pl. 10). A bit of the final septum preserved at one end of the body chamber reveals that this is the older part. Enough of the umbilicus is preserved to indicate that the outer adult whorl was considerably more evolute than the inner whorls. Although the body chamber is crushed a little and only one side is preserved, the outer whorl section is that of a pointed arch and it is much higher than wide (fig. 8*B*). Like that of the inner whorl, the umbilical wall of the outer whorl is low and sloping, and the umbilical shoulder is broadly rounded. Ribs alternate in length and are straight and rectiradiate to prorsiradiate. They are narrow on the flank and somewhat thickened and rounded on crossing the venter. Longer ribs begin on the umbilical wall, and shorter ribs arise at midflank. The total number of ribs per half whorl on this body chamber is estimated at 16. There are no tubercles.

The holotype is from a conglomeratic sandstone bed in the Frontier Formation at USGS Mesozoic locality 23154 south of Buffalo in central northern Wyoming (fig. 1). Other specimens from this locality include a phragmocone of one complete whorl and a fragment of an adult body chamber. The phragmocone (USNM 376926), has an umbilical ratio of 0.18 at a diameter of 160 mm and a ratio of 0.17 at a diameter of 120 mm. About 38 ribs are present on the complete whorl of 160 mm diameter. The fragment of a body chamber (USNM 376918) has a whorl height of 118 mm and a broadly ovate section with the greatest width at the umbilical shoulder (fig. 8*A*).

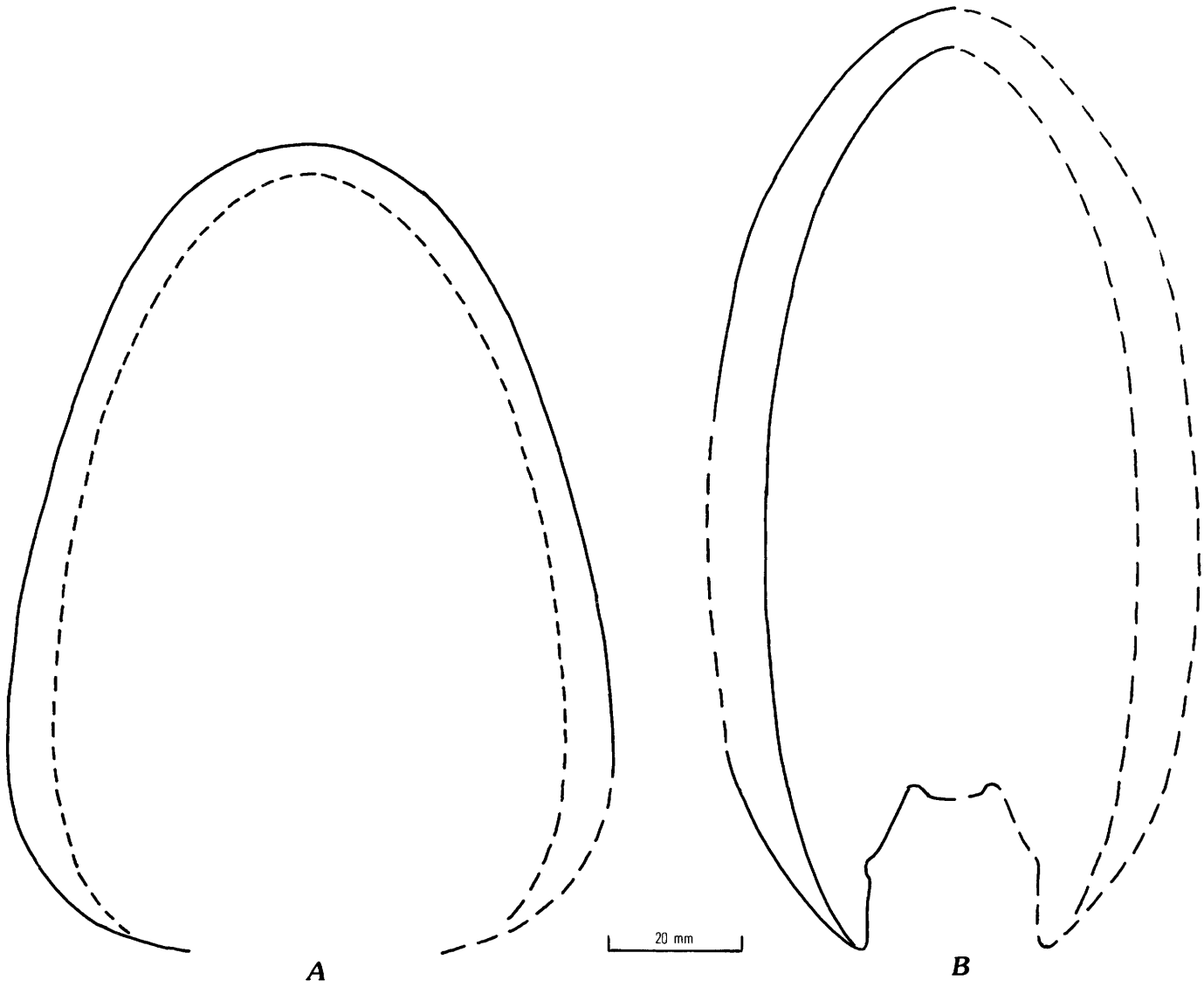

FIGURE 8.—Whorl sections of *Dunveganoceras problematicum problematicum* Cobban, n. subsp., from USGS Mesozoic 23154 (fig. 1), *A*, Paratype USNM 376918 at a whorl height of 119 mm. *B*, Holotype USNM 376917 at a whorl height of 138 mm (pl. 10).

A collection (loc. 22809), made at an earlier date apparently from the same locality as 23154, contains several very large septate fragments and parts of two large body whorls. One of the septate fragments, which has a whorl height of 95 mm, is most unusual in having the long ribs on each side matched by short ribs on the opposite side (pl. 8, figs. 1, 2). Another septate fragment, which has a whorl height of 120 mm, reveals a subtriangular section at that diameter with a narrow venter bounded by nodate outer ventrolateral tubercles (fig. 9).

A complete external suture is not visible on any specimen. The lateral lobe (L) is moderately broad, bifid, and rectangular, but narrower than the deeply bifid first lateral saddle (E/L). The second lateral saddle is about as wide and not deeply divided.

Dunveganoceras problematicum problematicum differs from other described species of the genus in its involute inner whorls and in the differentiation of ribs into primaries and secondaries. *D. problematicum problematicum* has been found only in north-central Wyoming, in an area about 21 km south-southwest of Buffalo in Johnson County (fig. 1, locs. 22809, 23154, D9885). Associated fossils include *Calycoceras* aff. *C. canitaurinum* (Haas) and *Metoicoceras frontierense*, n. sp. The classification of this unusual species has always been a problem, as reflected in its name. The compressed, involute inner whorls resemble *Metoicoceras*, and *D. problematicum* was originally listed as *Metoicoceras* n. sp. (Hose, 1955, p. 99).

Types.—Holotype USNM 376917, paratypes USNM 376918–376920, 376926.

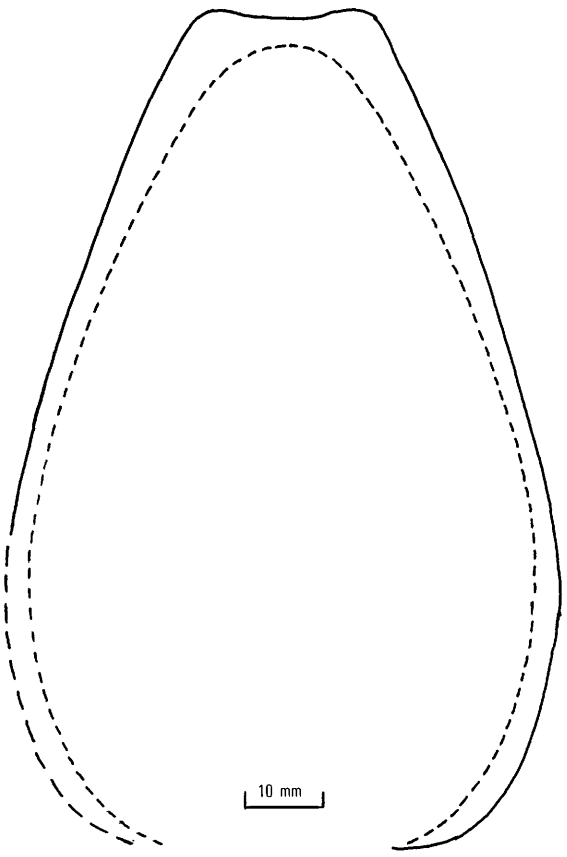

FIGURE 9.—Whorl section at a height of 110 mm of a large septate fragment of *Dunveganoceras problematicum problematicum* Cobban, n. subsp., from the Frontier Formation at USGS Mesozoic locality 22809 (fig. 1). Paratype USNM 376920.

Dunveganoceras problematicum natronense Cobban, n. subsp

Plate 3, figure 4; plates 11, 12; plate 13, figure 3; text figures 10, 11

Dense ribbing on the adult body chamber and a tendency for these ribs to be of equal length distinguish this subspecies from *D. problematicum problematicum*. All specimens in the type lot are fragmentary and came from a conglomeratic sandstone bed in the Frontier Formation at USGS Mesozoic locality D9337 near Casper, Wyo. (fig. 1).

The holotype (USNM 376921) is a fragment 277 mm long that represents the younger two-thirds of an adult body chamber enclosing part of a crushed penultimate whorl (pl. 11). The complete body chamber had a diameter estimated to be 265 mm and an umbilical ratio of about 0.31. The body chamber is characterized by a fairly inflated ovate whorl section with the greatest width on the lower part of the flank (fig. 10*B*). The umbilical wall is low and sloping, and the venter is narrowly rounded. Ornament on the preserved part of the body chamber consists of 15 narrow, prorsiradiate ribs that begin on the umbilical wall, cross the flanks, and thicken a little on crossing the venter. The total number of ribs per half whorl is estimated at 23. About half the penultimate whorl is present but badly crushed. It may have had about 20 weak ribs per half whorl.

Only fragments of inner whorls are present in the type lot from locality D9337, and all are parts of the penultimate whorls. The inner whorls have a slender rectangular section with flattened flanks, gently rounded umbilical shoulder, and flattened to slightly concave venter (fig. 10*A*). Ornament consists of rather weak, prorsiradiate ribs that are narrower than the interspaces and alternate in length. Longer ribs begin on the umbilical wall, and shorter ones arise at midflank. All bear nodate inner ventrolateral tubercles and clavate outer ventrolateral ones. Fragments of the larger penultimate whorls show that the inner ventrolateral tubercles weaken and disappear near the end of the phragmocone, and that the outer ones persist onto the older part of the body chamber where they gradually become lower and rounded before being replaced by the

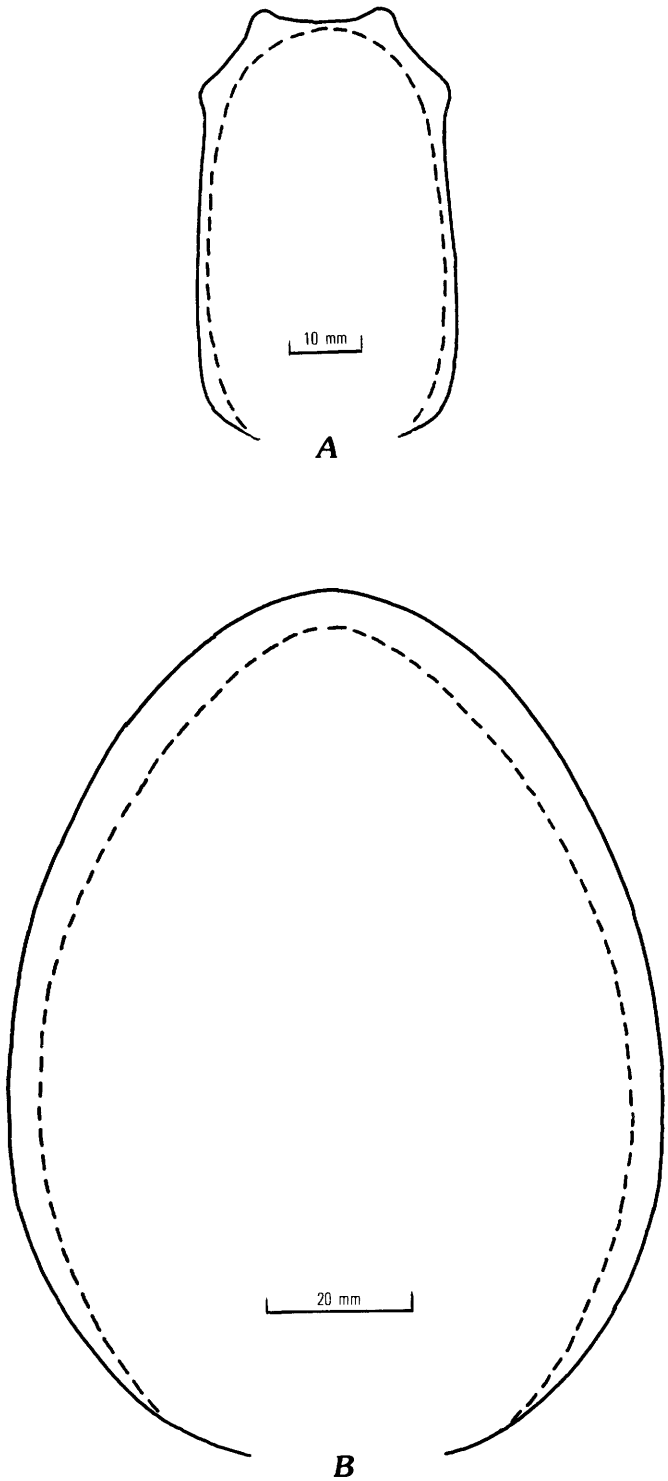

FIGURE 10.—Whorl sections of *Dunveganoceras problematicum natronense* Cobban, n. subsp., from USGS Mesozoic locality D9337 (fig. 1). *A*, Paratype USNM 376922 at a whorl height of 59 mm. *B*, Holotype USNM 376921 at a whorl height of 118 mm (pl. 11).

ribs. All ribs become low and flattened between the inner and outer ventrolateral tubercles as well as on crossing the venter. Only one badly crushed phragmocone consists of more than half a whorl (pl. 12). This specimen (USNM 376923), which has a diameter of about 216 mm and an umbilical ratio of 0.25, has 16 straight, prorsiradiate ribs per half whorl. Another specimen (USNM 376924), which is less than half a whorl, probably had as many as 23 or 24 ribs per half whorl (pl. 3, fig. 4; pl. 13, fig. 3).

Sutures are incomplete and poorly preserved on the septate fragments from locality D9337. Part of the external suture of a fragment from a nearby locality (fig. 1, loc. D9748) is shown in figure 11. The E/L saddle is broad and deeply bifid, L is narrower than E/L and bifid, and the second lateral saddle is broad with shallow indentations.

Fragments of *D. problematicum natronense* are abundant in a bed of conglomeratic sandstone in the Frontier Formation about 19 km west of Casper in Natrona County (fig. 1, locs. D9337, D9748). Part of a crushed body chamber may represent this form farther north at the type locality of *D. problematicum problematicum* (fig. 1, loc. 22809). Associated fossils at all localities include *Calycoceras* aff. *C. canitaurinum* (Haas) and *Metoicoceras frontierense* Cobban, n. sp.

Types.—Holotype USNM 376921, paratypes USNM 376922–376925.

Subfamily MAMMITINAE Hyatt, 1900
Genus METOICOCERAS Hyatt, 1903

Type species.—*Ammonites swallovii* Shumard, 1860

Metoicoceras is a highly to moderately involute ammonite that usually has compressed whorls, a slightly uncoiled body chamber, primary and secondary ribs, umbilical bullae, and inner and outer ventrolateral tubercles. Weak siphonal tubercles are present on the inner whorls of early species. Ribs are straight to slightly flexuous and strongest on the outer part of the flank where they may flatten on the ventrolateral shoulder. The venter may be crossed transversely by broad ribs,

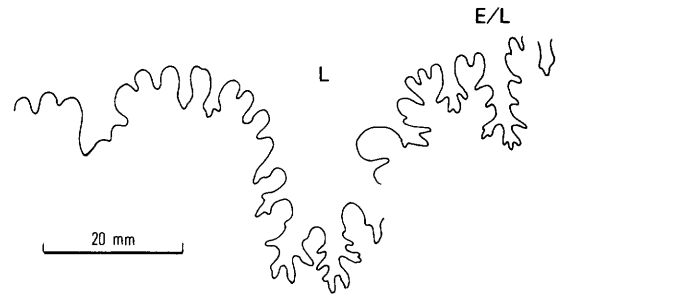

FIGURE 11.—Part of the external suture at a whorl height of 89 mm of *Dunveganoceras problematicum natronense* Cobban, n. subsp. USGS Mesozoic locality D9748 (fig. 1). Heavy line marks the middle of the venter. L, lateral lobe; E/L, first lateral saddle. Paratype USNM 376925.

or it may be flat or even a little concave and bordered by clavate outer ventrolateral tubercles. Inner ventrolateral tubercles usually weaken and disappear on or before the penultimate whorl, but they may persist onto the adult body chamber. The suture is fairly simple with little-divided saddles and a rectangular, bifid lateral lobe narrower than the first lateral saddle.

Metoicoceras is known only from Cenomanian rocks in Europe, central Asia, Africa, and North America. The type species, *Ammonites swallovii* Shumard (1860, p. 591), came from the Templeton Member of the Woodbine Formation in Lamar County, Tex. (Stephenson, 1952, p. 209).

Metoicoceras frontierense Cobban, n. sp.

Plate 3, figures 1–3; plate 13, figures 1, 2; plate 14; text figure 12

This species is small to medium size for the genus. Body chambers of most specimens have a smooth or nearly smooth venter except for prominent ribs at the adoral end.

The type lot, from the Frontier Formation at locality 22809 at Dry Muddy Creek (fig. 1), contains six complete adults 70–92 mm in diameter and many other fragments. All are crushed to some degree. The holotype (pl. 14, figs. 8–10) has a diameter of 80 mm and an umbilicus of 9 mm (0.11). The umbilicus is mostly smooth with sloping walls. Ribs on the visible part of the last whorl of the phragmocone are straight, narrow, rectiradiate to slightly prorsiradiate, and mostly alternate in length with the longer ones having weak umbilical bullae. All ribs on this whorl have nodate inner ventrolateral tubercles and stronger clavate outer ones. All tubercles weaken and disappear about at the base of the body chamber. The only ornaments on the body chamber are low, rounded ribs on the outer part of the flank and a few strong, rounded ribs that cross the venter at the adoral end. The ribs on the body chamber are accentuated a little at the position where inner ventrolateral tubercles occur on the phragmocone. Aside from its younger end, the venter of the body chamber is smooth and rounded.

Some specimens from locality 22809 have nearly smooth body chambers except for a few apertural ribs (pl. 14, figs. 1, 2), and an occasional individual may have strong apertural ribs (pl. 14, figs. 11, 12).

Whorls less than 25 mm in diameter are not preserved on specimens from locality 22809. At that diameter, ornament consists of narrow primary and secondary ribs, umbilical bullae, and nodate inner ventrolateral tubercles and clavate outer ones. Smaller specimens are present in the collections from Emigrant Gap Ridge near Casper (fig. 1, locs. D9337, D9748) and from the northwest flank of the Black Hills uplift (fig. 1, loc. D12433; pl. 3, figs. 2, 3). These smaller specimens reveal the presence of weak siphonal clavi.

The largest adult of *M. frontierense* at hand is from locality D9337 (pl. 13, figs. 1, 2). This specimen (USNM 376931), a body chamber 176 mm in diameter, has a smooth, broadly rounded venter except for the adoral end, which has four or five wide, flattened ribs.

The suture of *M. frontierense* is typical of the genus (fig. 12).

Metoicoceras frontierense resembles its ancestor, *M. praecox* Haas (1949, p. 15, pls. 5–7; text figs. 5–9) in its size and apertural ribbing, but *M. praecox* has stronger ribs on all parts of the body chamber, and these cross the venter. In addition, *M. praecox* has stronger siphonal tubercles on the early whorls.

Aside from the three localities in north-central Wyoming, *M. frontierense* occurs farther east in Wyoming on the west flank of the Black Hills uplift where the species was recorded as *Metoicoceras*? n. sp. from the base of the Greenhorn Formation (Mapel and Pillmore, 1963, p. N44). The species also occurs in the lower part of the Colorado Formation in southwestern New Mexico.

Types.—Holotype USNM 376927, paratypes USNM 376928–376932, 377371, 377372.

AGE RELATIONSHIPS OF THE AMMONITES

The acanthoceratid ammonites treated in this report can be related to the sequence of Cenomanian ammonite zones shown in figure 13. This zonation is based on the present investigation and on two recent reports (Cobban, 1984; 1987).

The oldest species seems to be *Calycoceras newboldi*. At locality D8914, near Alcova, this species was associated with *Dunveganoceras pondi*, *Calycoceras canitaurinum*, and *Metoicoceras praecox*.

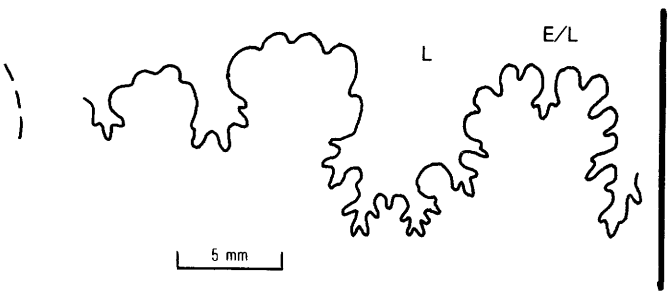

FIGURE 12.—Most of external suture of *Metoicoceras frontierense* Cobban, n. sp., from USGS Mesozoic locality D9337 (fig. 1). Vertical line marks middle of venter. L, lateral lobe; E/L, first lateral saddle. Paratype USNM 376932.

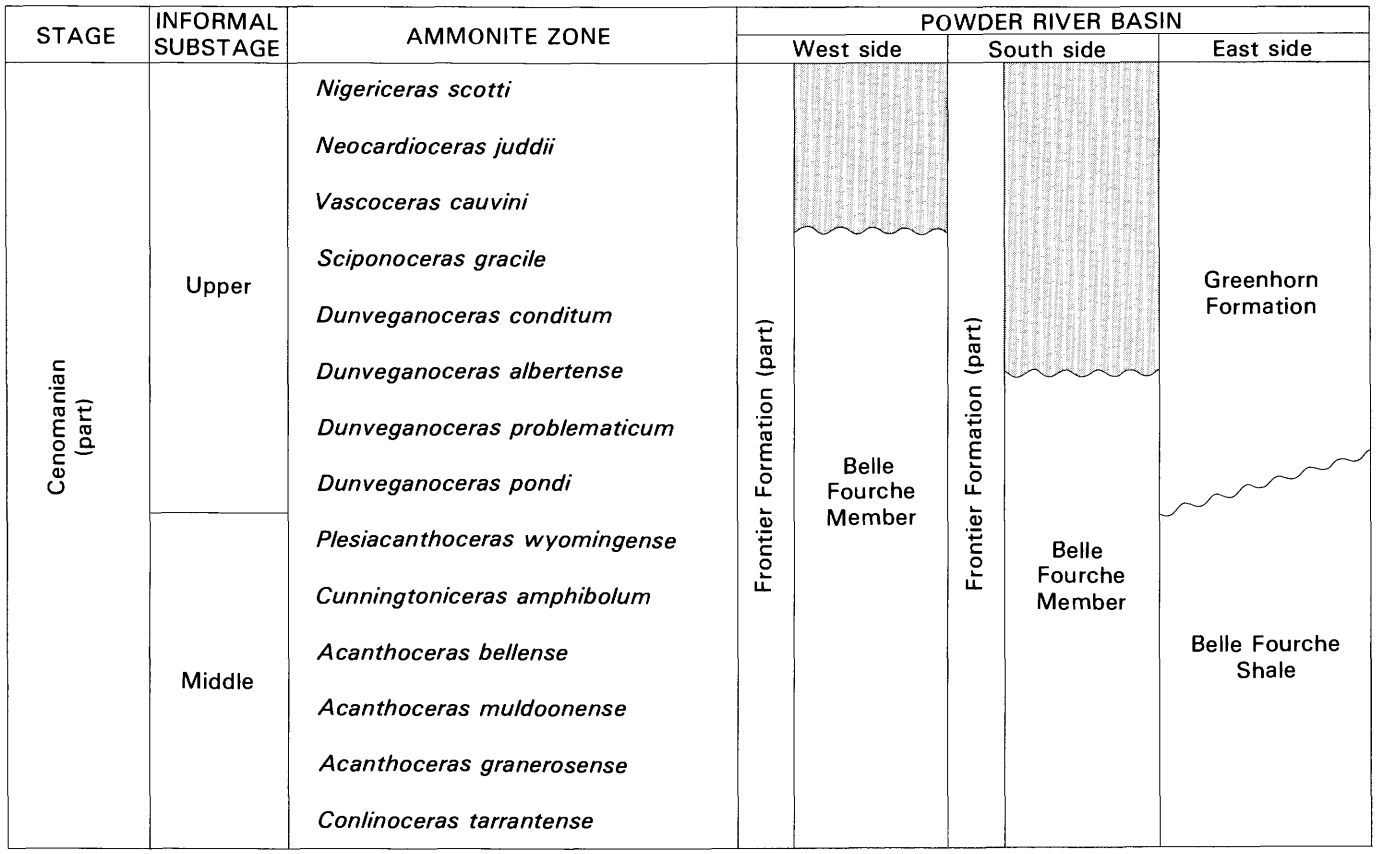

FIGURE 13.—Correlation chart of middle and upper Cenomanian formations in Powder River Basin, Wyoming. Shaded area represents a hiatus in the sequence of beds.

Calycoceras rubeyi was probably derived from *C. canitaurinum* by becoming more inflated and in developing *Lotzeites*-like innermost whorls. The species occurs above *Dunveganoceras pondi* at several localities on the northwest flank of the Black Hills uplift in northeastern Wyoming. One of the better documented sequences is near Upton where *C. rubeyi* was collected from septarian limestone concretions in undifferentiated rocks of Belle Fourche-Greenhorn age 53 m below the base of the Carlile Shale. *Dunveganoceras pondi* was found at 91 m below the base (fig. 1, locs. D5949, D5946).

Age relationships of the *Dunveganoceras problematicum* fauna are not as clear. Neither *D. pondi* nor *C. canitaurinum* were found in the type area of *D. problematicum* near Buffalo (fig. 1, locs. 22809, 23154). However, a few crushed fragments of inner whorls of a *Calycoceras* from locality 22809 may represent *C. rubeyi*. A large crushed phragmocone of that species was collected at locality D8496 (fig. 1), 13.7 km south of locality 22809, from 21 m below beds that contain a *Sciponoceras gracile* fauna of very late Cenomanian age. According to Hose (1955, p. 98, 99), locality 22809 lies 49 m below rocks that have a *S. gracile* fauna. These measurements suggest that *C. rubeyi* may range higher than *D. problematicum*. Collections of *D. problematicum* in the Casper area do not add anything to the stratigraphic range of the species other than to verify its post-*D. pondi* age. At localities D9337 and D9748, *D. problematicum* occurs in lenticular beds of chert conglomerate or conglomeratic sandstone 19 m above a 12-m-thick shale unit that contains *D. pondi*. An unconformity, 14 m above the pebbly sandstone, is overlain by a 12-m-thick sandstone unit that contains a *Collignoniceras woollgari* (Mantell) fauna of middle Turonian age.

Dunveganoceras albertense regale occurs above *D. problematicum* in the Buffalo area. Distorted fragments from septarian limestone concretions at locality 23149 (fig. 1), identified as *Dunveganoceras* cf. *D. conditum* Haas (Hose, 1955, p. 99), are *D. albertense regale*. The collection is from 19.5 to 35 m above the level of *D. problematicum* (locs. 22809, 23154).

Along the northwestern flank of the Black Hills uplift, *D. albertense regale* has been found at many localities

above beds that contain *Calycoceras rubeyi*. One of the best documented sequences is in the Upton area, where *D. albertense regale* occurs in septarian limestone concretions in undifferentiated rocks of Belle Fourche-Greenhorn age 40 m below the base of the Carlile Shale at locality D5950 (fig. 1), and *C. rubeyi* occurs in septarian limestone concretions at about 53 m and 72 m below the base of the Carlile at localities D5949 and D5948 (fig. 1).

Another species, *Dunveganoceras conditum* Haas (1951, p. 5, text figs. 2–9), may be a little younger than *D. albertense*. The holotype of *D. conditum* has robust inner whorls and a body chamber that has a rounded whorl section and ornament of rather closely spaced, narrow, straight ribs. The specimen came from the Frontier Formation about 66 km northwest of Casper. Haas (1951) gave no further stratigraphic data. A collection of *D. conditum* made by the author 26 km southeast of Kaycee (fig. 1, loc. D6962) came from a part of the Frontier Formation that seems to be a little higher stratigraphically than the *D. albertense*-bearing beds at Kaycee (fig. 1, loc. D5723).

The sequence of *Dunveganoceras-Calycoceras* faunas seem to be as follows:

Dunveganoceras conditum (at top)
Dunveganoceras albertense
Dunveganoceras problematicum, *Calycoceras* aff. *canitaurinum*, *C. rubeyi*
Dunveganoceras pondi, *Calycoceras canitaurinum*, *C. newboldi*

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PLATES 1-15

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PLATE 1

[Figure about one-half natural size]

Calycoceras rubeyi Cobban, n. sp. (p. 4).

Side view of holotype USNM 376905, from Belle Fourche Shale at USGS Mesozoic locality 12042 (text fig. 1). See plate 2, figures 2 and 3 for the innermost preserved whorls and text figure 2 for the whorl section and suture.

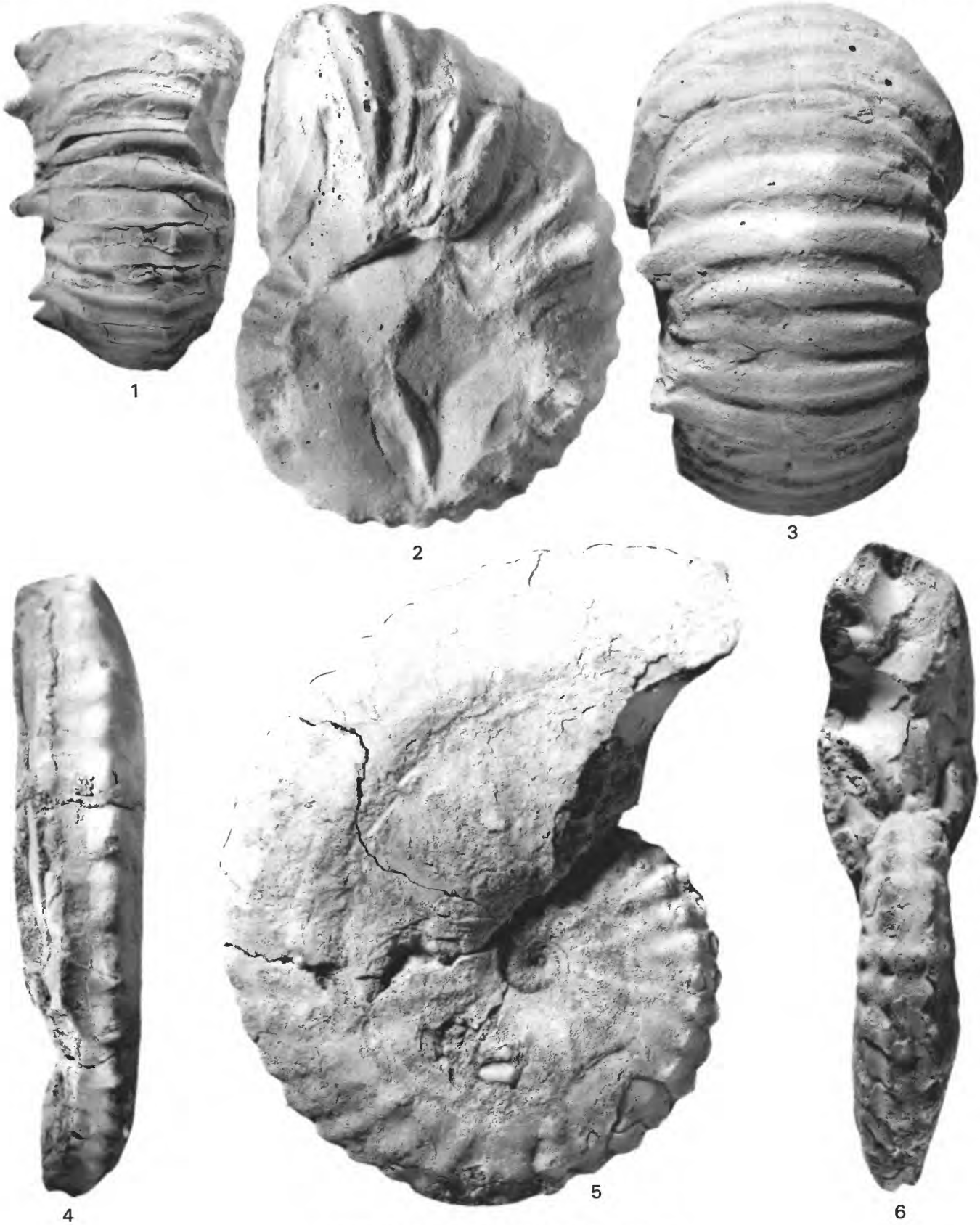
CALYCOCERAS

PLATE 2

[All figures natural size]

FIGURES 1–3. *Calycoceras rubeyi* Cobban, n. sp. (p. 4).
From Belle Fourche Shale at USGS Mesozoic locality 12042 (text fig. 1).
1. Rear view of paratype USNM 376906.
2,3. Side and rear views of a plaster cast of the innermost preserved whorls of the holotype USNM 376905 (pl. 1).

4–6. *Dunveganoceras problematicum problematicum* Cobban, n. subsp.
Rear, side, and front views of the inner whorls of the holotype USNM 376917, from the Frontier Formation at USGS Mesozoic locality 23154 (text fig. 1). See plate 10 for these whorls attached to the outer whorl.



CALYCOCERAS and *DUNVEGANOCERAS*

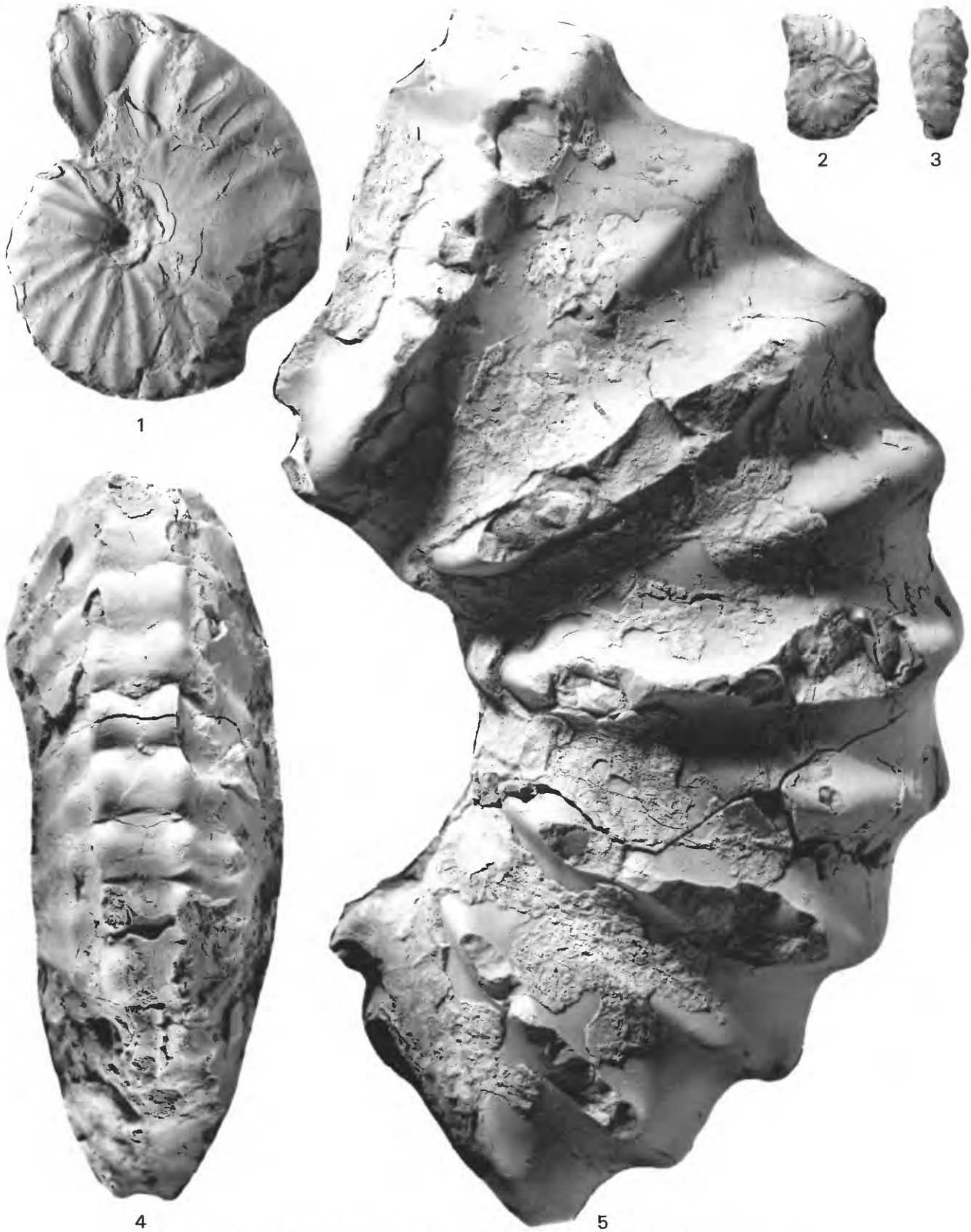
PLATE 3

[All figures natural size]

FIGURES 1–3. *Metoicoceras frontierense* Cobban, n. sp. (p. 13).
From Belle Fourche Shale at USGS Mesozoic locality D12433 (text fig. 1).
1. Side view of paratype USNM 377371.
2, 3. Side and rear views of paratype USNM 377372.

4. *Dunveganoceras problematicum natronense* Cobban, n. subsp. (p. 9).
Rear view of paratype USNM 376924, from USGS Mesozoic locality D9337 (text fig. 1). See plate 13, figure 3 for side view.

5. *Calycoceras newboldi wyomingense* Cobban, n. subsp. (p. 5).
Side view of holotype USNM 376908, from Frontier Formation at USGS Mesozoic locality D9747 (text fig. 1). See plate 4, figure 3 for rear view.



METOICOCERAS, DUNVEGANOCERAS, and *CALYCOCERAS*

PLATE 4

[All figures natural size]

FIGURE 1. *Dunveganoceras albertense regale* Cobban, n. subsp. (p. 7).
Rear view of paratype USNM 376916, from USGS Mesozoic locality D5944 (text fig. 1). See plate 8, figure 3 for side view.

2, 3. *Calycoceras newboldi wyomingense* Cobban, n. subsp. (p. 5).
2. Rear view of paratype USNM 376910, from USGS Mesozoic locality D8914 (text fig. 1).
3. Rear view of holotype USNM 376908, from USGS Mesozoic locality D9747 (text fig. 1). See plate 3, figure 5 for side view.

DUNVEGANOCERAS and *CALYCOCERAS*

PLATE 5

[Figure about seven-eighths natural size]

Calycoceras aff. *C. canitaurinum* (Haas) (p. 7).

Side view of most of an adult from the Frontier Formation at USGS Mesozoic locality 23154 (text fig. 1). Figured specimen USNM 376912. A missing piece near the locality number on the specimen is filled in with plaster.

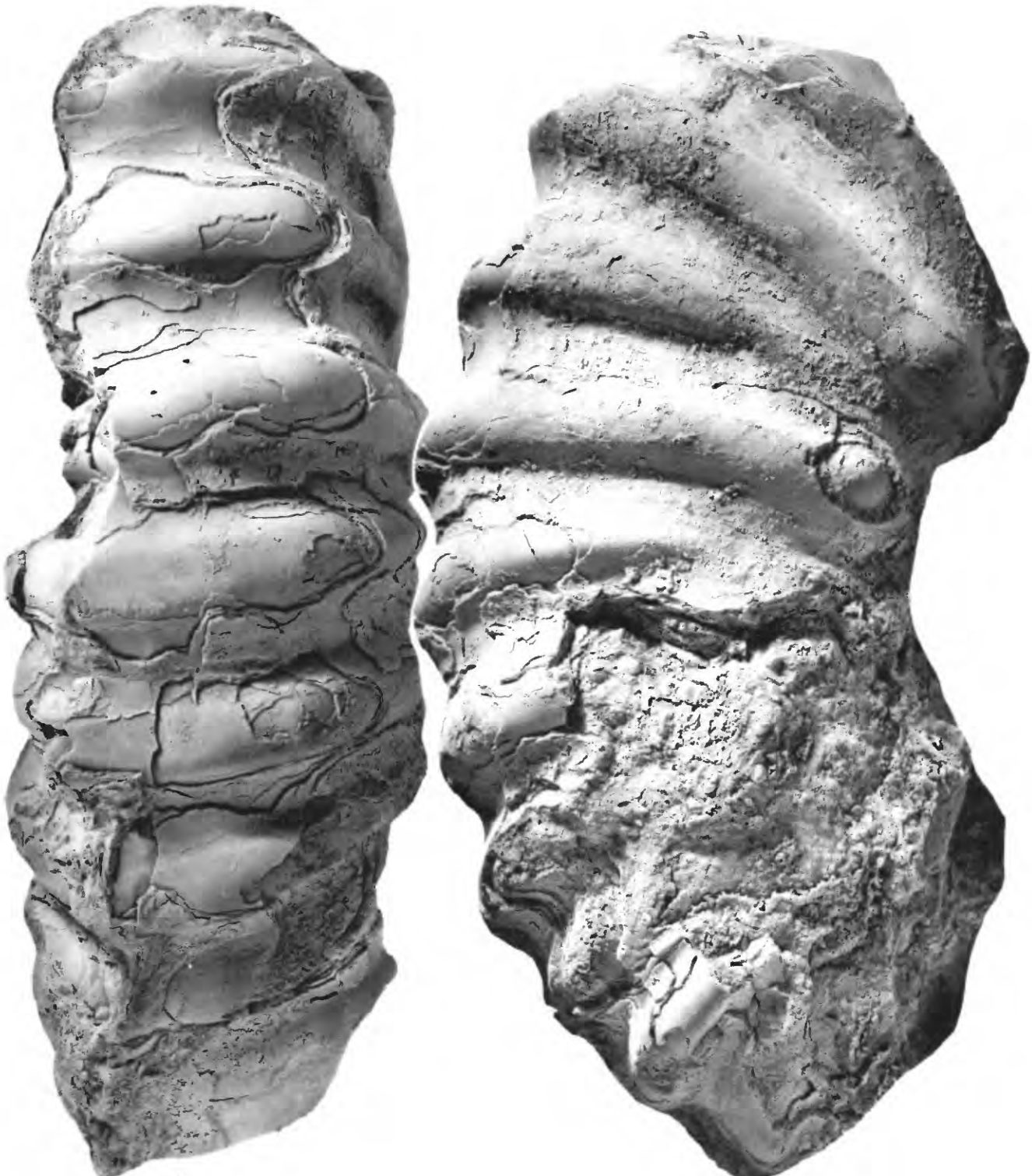
CALYCOCERAS

PLATE 6

[Both figures natural size]

FIGURES 1, 2. *Calycoceras* aff. *C. canitaurinum* (Haas) (p. 7).

Rear and side views of part of the outer whorl of a specimen from the Frontier Formation at USGS Mesozoic locality D9337 (text fig. 1). Figured specimen USNM 376911.



1 2

CALYCOCERAS

PLATE 7

[Both figures about six-tenths natural size]

FIGURES 1, 2. *Dunveganoceras albertense regale* Cobban, n. subsp. (p. 7).
Side and rear views of holotype USNM 376913, from the Frontier Formation at USGS Mesozoic locality D5723 (text fig. 1).

DUNVEGANOCERAS

PLATE 8

[All figures natural size]

FIGURES 1, 2. *Dunveganoceras problematicum problematicum* Cobban, n. subsp. (p. 9).
Side and rear views of a specimen that has long ribs on one side matched by short ribs on the opposite side. Paratype USNM 376919, from the Frontier Formation at USGS Mesozoic locality 22809 (text fig. 1).

3. *Dunveganoceras albertense regale* Cobban, n. subsp. (p. 7).
Side view of part of the penultimate whorl of an unusually small adult from USGS Mesozoic locality D5944 (text fig. 1). See plate 4, figure 1 for rear view. Paratype USNM 376916.

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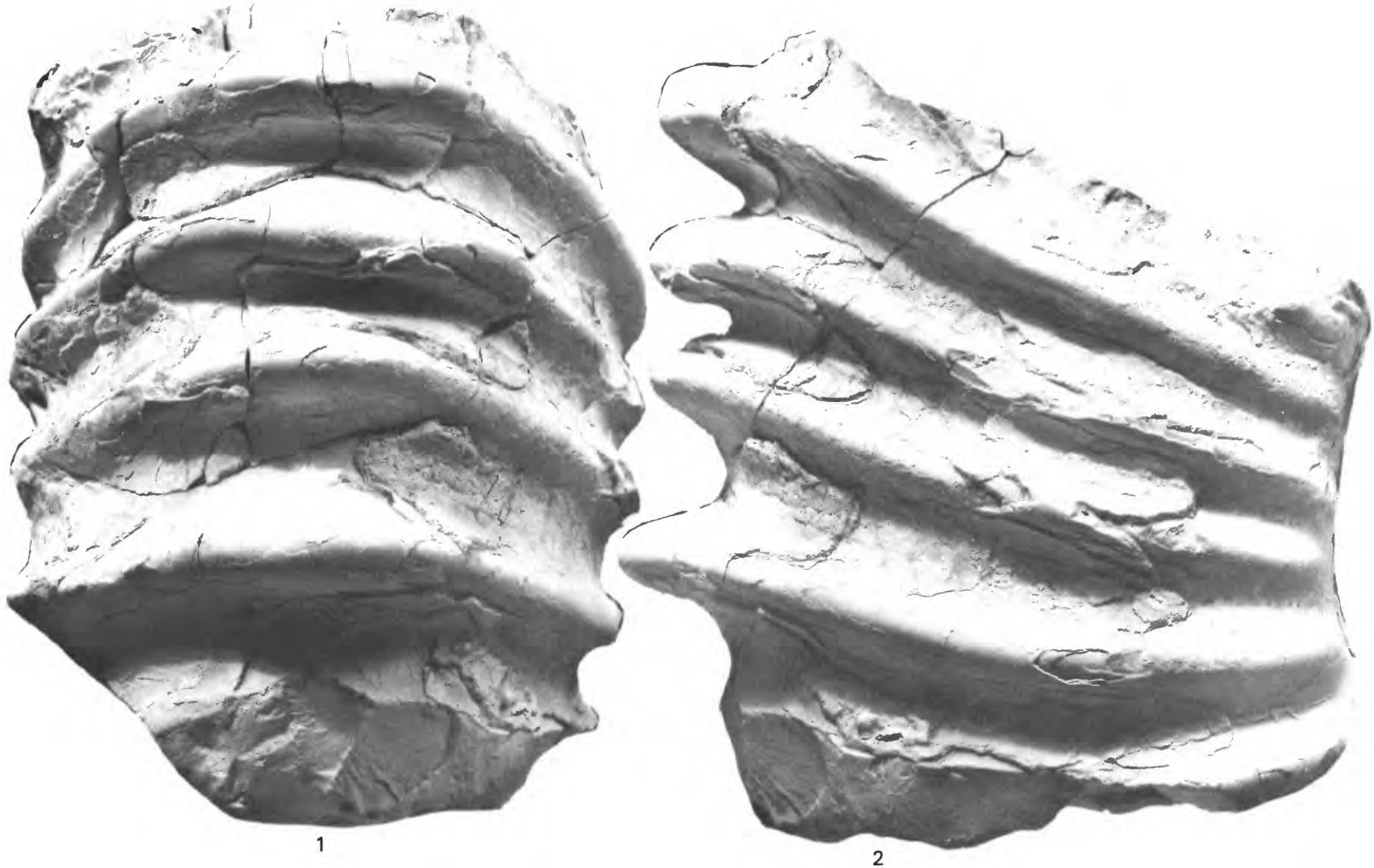
DUNVEGANOCERAS

PLATE 9

[Both figures natural size]

FIGURES 1, 2. *Dunveganoceras albertense regale* Cobban, n. subsp. (p. 7).
Rear and side views of the adoral end of an adult body chamber from USGS Mesozoic locality D8324 (text fig. 1). Paratype USNM 376915.



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DUNVEGANOCERAS

PLATE 10

[Figure about seven-eighths natural size]

Dunveganoceras problematicum problematicum Cobban, n. subsp. (p. 9).

Side view of holotype USNM 376917 from the Frontier Formation at USGS Mesozoic locality 23154 (text fig. 1). See plate 2, figures 4–6 for additional views of the inner whorls.

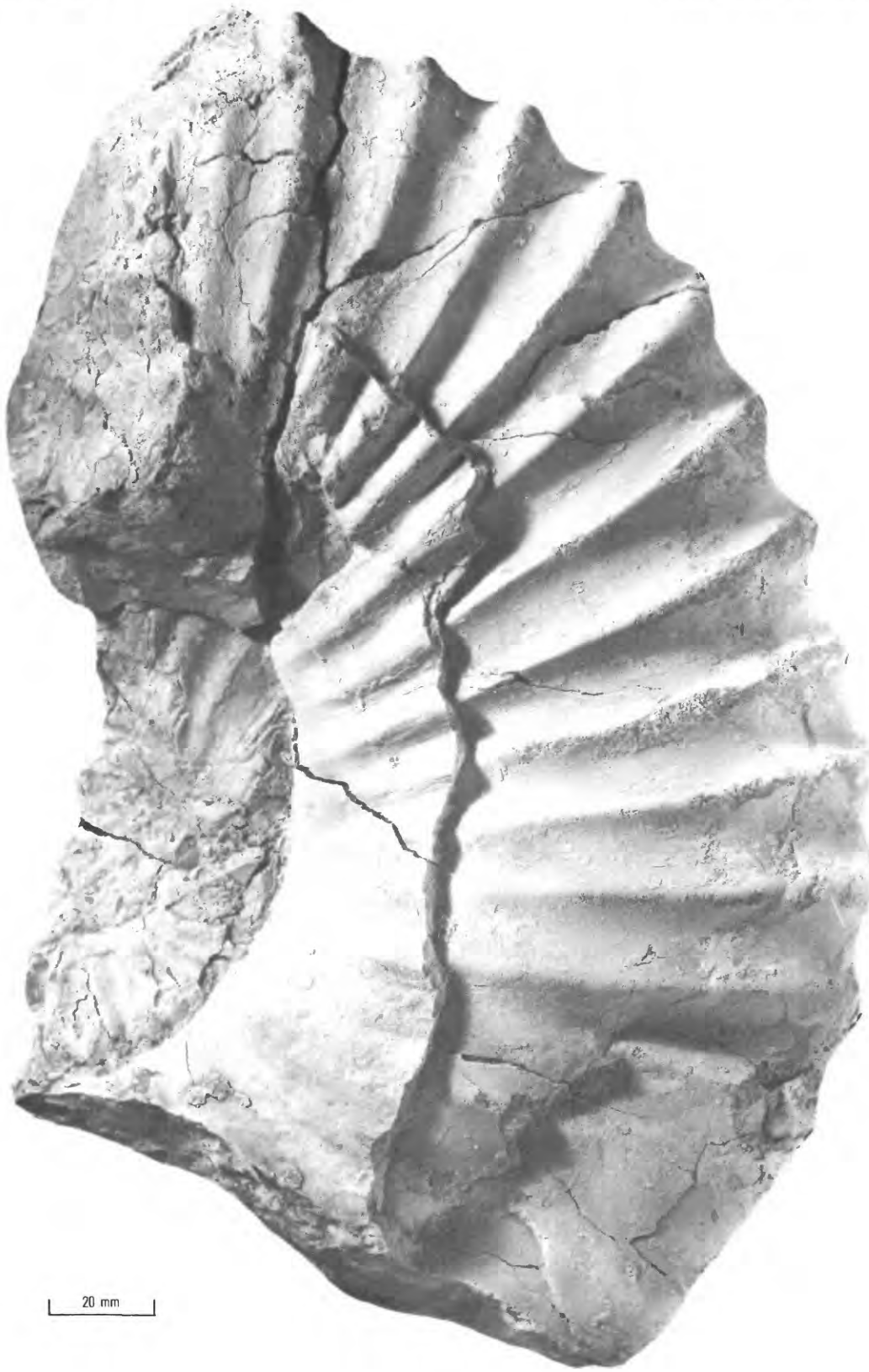
DUNVEGANOCERAS

PLATE 11

[Figure eight-tenths natural size]

Dunveganoceras problematicum natronense Cobban, n. subsp. (p. 11).

Side view of holotype USNM 376921, from the Frontier Formation at USGS Mesozoic locality D9337 (text fig. 1). See text figure 10*B* for whorl section.



DUNVEGANOCERAS

PLATE 12

[Figure natural size]

Dunveganoceras problematicum natronense Cobban, n. subsp. (p. 11).

Side view of paratype USNM 376923, from the Frontier Formation at USGS Mesozoic locality D9337 (text fig. 1).

DUNVEGANOCERAS

PLATE 13

[All figures natural size]

FIGURES 1, 2. *Metoicoceras frontierense* Cobban, n. sp. (p. 13).
Rear and side views of paratype USNM 376931, from the Frontier Formation at USGS Mesozoic locality D9337 (text fig. 1).

3. *Dunveganoceras problematicum natronense* Cobban, n. subsp. (p. 11).
Side view of paratype USNM 376924, from USGS Mesozoic locality D9337 (text fig. 1). See plate 3, figure 4 for rear view.

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METOICOCERAS and *DUNVEGANOCERAS*

PLATE 14

[All figures natural size]

FIGURES 1–13. *Metoicoceras frontierense* Cobban, n. sp. (p. 13).
From the Frontier Formation at USGS Mesozoic locality 22809 (text fig. 1).
1–3. Rear, side, and top views of paratype USNM 376928.
4–7. Top, rear, side, and front views of paratype USNM 376929.
8–10. Side, rear, and top views of holotype USNM 376927.
11–13. Top, side, and rear views of paratype USNM 376930.


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METOICOCERAS

PLATE 15

[Figure about seven-eighths natural size]

Dunveganoceras albertense regale Cobban, n. subsp. (p. 7).

Side view of paratype USNM 376916, from a septarian limestone concretion in undifferentiated rocks of Belle Fourche-Greenhorn age at USGS Mesozoic locality D5944 (text fig. 1). See plate 4, figure 1 and plate 8, figure 3 for other views of the inner whorl.

DUNVEGANOCERAS

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