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Ammonites from the Upper Part of the Pierre Shale and Fox Hills Formation of Colorado

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ABSTRACT

The upper part of the Pierre Shale and Fox Hills Formation were deposited in the Late Cretaceous (Maastrichtian) Western Interior Seaway. They crop out in a belt that roughly parallels the Front Range of the Rocky Mountains from Douglas to Weld County, Colorado. These rocks consist of sandy shales and sandstones and are overlain by the nonmarine Laramie Formation. A sparse assemblage of ammonites is present consisting of *Coahuilites sheltoni* Böse, 1928, *Sphenodiscus pleurisepta* (Conrad, 1857), *Trachybaculites* sp. cf. *T. columna* (Morton, 1834), *Hoploscaphites birkelundae* Landman and Waage, 1993, *Hoploscaphites* sp. cf. *H. birkelundae*, *Jeletzkytes dorfi* Landman and Waage, 1993, and *Jeletzkytes* sp. cf. *J. dorfi*. *Hoploscaphites birkelundae* and *Jeletzkytes dorfi* define the *H. birkelundae* Zone in the Western Interior, which represents the lower part of the upper Maastrichtian. These rocks are thus equivalent in age to the Fox Hills Formation in Niobrara County, Wyoming, and older than the type Fox Hills Formation in north-central South Dakota. An analysis of the ratio of $^{87}Sr/^{86}Sr$ in a belemnite from this zone in Morgan County, Colorado, yields a value of 0.707790 ± 0.000008 (2-sigma SE), nearly identical to that of a bivalve from the same zone in Niobrara County, Wyoming (McArthur et al., 1994). The western shoreline of the seaway during the time of *H. birkelundae* extended as far west as northwestern Colorado and southwestern Wyoming.

INTRODUCTION

Uppermost Cretaceous marine strata along the Rocky Mountain Front Range are referred to as the Pierre Shale and Fox Hills Formation (fig. 1). These units represent thick sedimentary accumulations relatively

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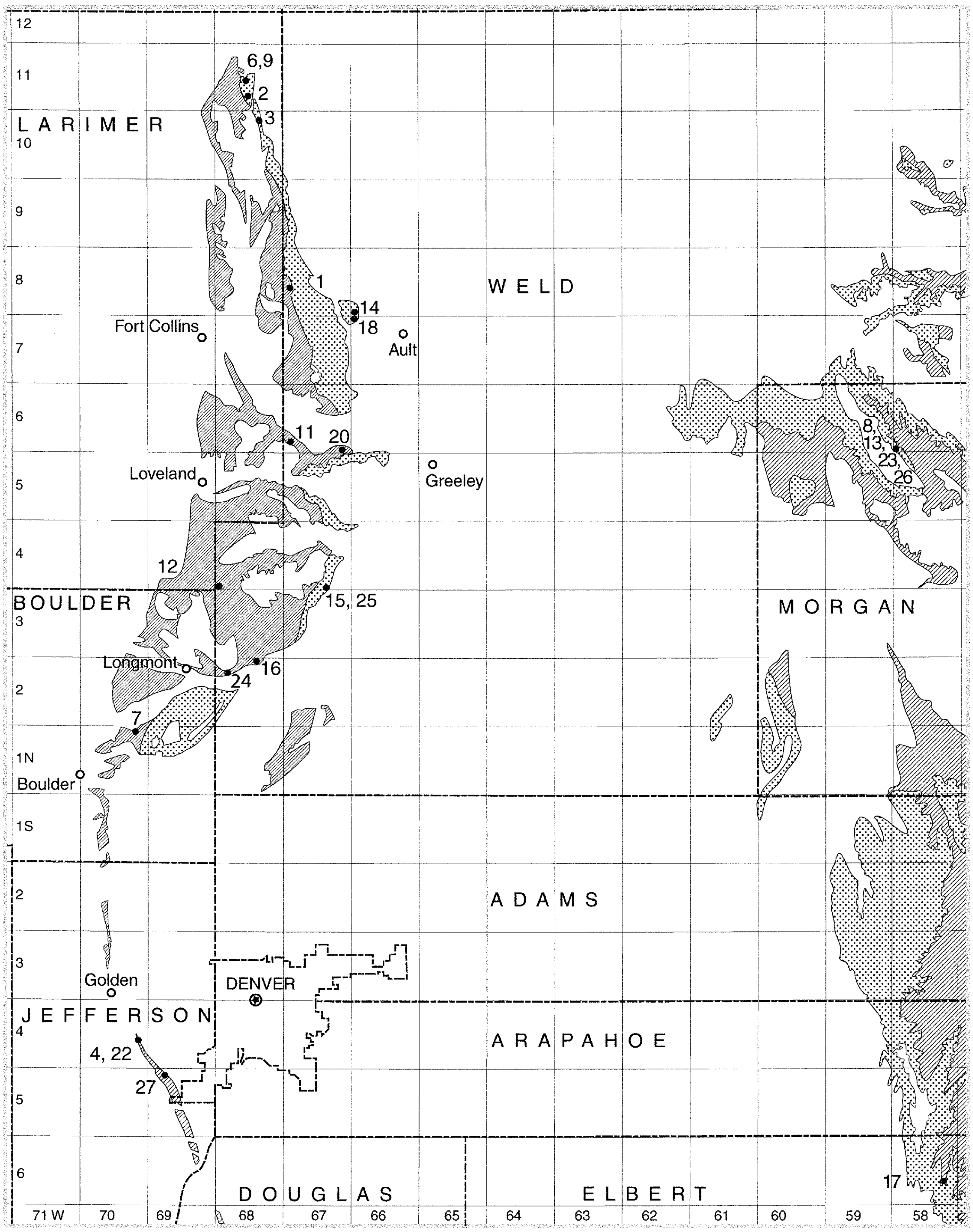


Fig. 1. Outcrop of the upper transition member of the Pierre Shale (lined) and Fox Hills Formation (dotted) along the Front Range of the Rocky Mountains, Colorado, with localities of most of the fossils mentioned in the text.

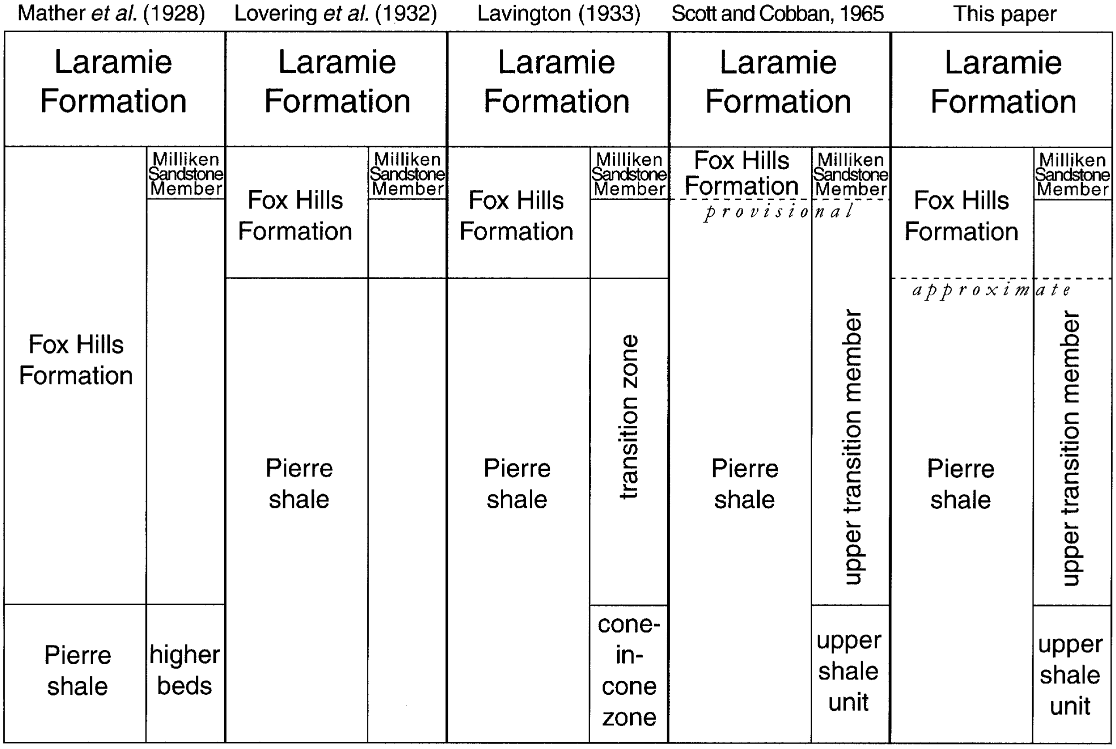


Fig. 2. Chart documenting the terms used to describe the upper part of the Pierre Shale and Fox Hills Formation by various authors, including ourselves. The thickness of the units is not drawn to scale.

rich in marine fossils that were deposited along the western margin of the Western Interior Seaway.

We describe the ammonites from the upper part of the Pierre Shale and Fox Hills Formation in northeastern Colorado. Ammonites are somewhat rare in this part of the section and, to make matters worse, there are few exposures—even these are disappearing due to urban sprawl. Our study is largely based on a collection of ammonites housed at the Colorado School of Mines (CSM), which was assembled over the last 70 years, supplemented by material from the U.S. National Museum and the American Museum of Natural History.

STRATIGRAPHIC SETTING

The relationship of the Fox Hills Formation to the underlying Pierre Shale and overlying Laramie Formation in northeastern Colorado has always been controversial. This is due to the complex vertical and lateral variation in lithology associated with repetitive interfingering of shales and sandstones in this part of the section. It also reflects the paucity of good outcrops in the area. We briefly review some of the most important papers on the subject to provide a background for our study (fig. 2).

One of the first descriptions of the upper part of the Pierre Shale and overlying Fox Hills Formation in the Denver Basin was given by Eldridge (1896). He characterized the Pierre Shale as "a great body of plastic clays, carrying small, lenticular bodies of impure limestone and, at a horizon about one-third the distance from base to summit, a zone of sandstone from 100 to 300 ft [30.5 to 91.4 m] thick" (ibid.: 69). He identified a "zone transitional to Fox Hills" marking "a change from the pure clay of the one to the arenaceous shales of the other" (ibid.: 71). According to him, the Fox Hills Formation consists "mainly of soft, friable, arenaceous shales, with occasional interstratified bands of clay. . . . The entire formation has a yellowish cast, but while the shales are generally of a grayish-yellow the sandstone itself has a pronounced tint of green'' (ibid.: 71). He estimated the thickness of the formation as between 800 and 1000 ft (243.8 and 304.8 m), diminishing to 500 ft (152.3 m) near Golden, Jefferson County, Colorado. According to him, the top of the formation is capped by a ''persistent and characteristic sandstone, usually about 50 ft [15.2 m] thick'' (ibid.: 71). He described this sandstone as transitional to the Laramie Formation.

Henderson (1920) defined the Milliken Sandstone Member as the top unit of the Fox Hills Formation, describing it as a massive cliff-forming sandstone. He named it after the town of Milliken, Weld County, Colorado, where it is well exposed.

Mather et al. (1928: 90), in a geologic study of northeastern Colorado, identified what they called the ''higher beds'' of the Pierre Shale as showing ''a progressive reduction in the quantity of sand and a consequent increase in the purity of the shaly strata'' (fig. 2). They estimated the thickness of these beds as between 2500 and 5200 ft (762 and 1,585 m) and observed ''no sharp break, either faunal or lithologic, to mark the contact between the Pierre and Fox Hills formations'' (ibid.: 93). They stated that the boundary was ''drawn primarily to indicate the contrast between the nongritty shale of the upper Pierre and the sandy shale or sandstone . . . of the overlying Fox Hills Formation'' (ibid.: 93). They described the Fox Hills Formation as consisting of ''soft crumbly sandstone and sandy shale with here and there a bed or two of firmly indurated massive sandstone'' (ibid.: 92) and considered the Milliken Sandstone Member, where present, as the top of the formation. They estimated the thickness of the formation as between 1,200 and 1,800 ft (365.8 and 548.6 m) near the eastern margin of Larimer County and characterized the boundary with the overlying Laramie Formation as transitional representing ''the interfingering of brackish-water and fresh-water beds with marine sandstone and shale'' (ibid.: 93).

Mather et al. (1928) presented three measured sections of the Fox Hills Formation in northeastern Colorado. The section at Wildcat Mound in the NW¼ sec. 26, T4N, R6W, south of Milliken, Weld County, is illustrated in figure 3. The portion of the Fox Hills Formation exposed at this locality is 166 ft (50.6 m) thick and consists of three massive sandstone units separated by thinner shalier units. The uppermost sandstone, approximately 40 ft (12.2 m) thick, is the Milliken Sandstone Member and forms the top of the formation.

Lovering et al. (1932) elevated the base of the Fox Hills Formation to approximately 250 ft (76.2 m) below the base of the Laramie Formation (fig. 2). They defined the base of the Fox Hills Formation as ''the horizon below which the section is predominantly gray marine clay shales and sandy shales of Pierre age, and above which the section changes rapidly to a buff to brown sandstone containing numerous large gray to brown, hard, sandy concretions'' (ibid.: 702). They considered the top of the Fox Hills Formation ''as the horizon above which the section is composed predominantly of fresh- and brackish-water deposits accompanied by coals and lignitic shales, and below which it is predominantly marine'' (ibid.: 703). They briefly described four localities where these relationships could be observed.

Lavington (1933: 403) introduced the term ''transition zone'' for the upper part of the Pierre Shale lying ''between the mappable group of sandstones and sandy concretion beds of the Fox Hills sandstone . . . and the lower beds which contain typical Pierre fossils'' (fig. 2). He described this zone as consisting of ''gray, blue, and buff shales and sandy shales, scattered buff calcareous concretions, sandstones and several thin gray-to-buff concretionary limestone beds'' (ibid.: 403). He estimated the thickness of the transition zone as between 650 and 875 ft (198.1 and 266.7 m) in Lincoln County, southeast of Denver. He followed the suggestion of Lovering et al. (1932) and restricted the Fox Hills Formation to ''the mappable group of buff sandstones and sandy concretion beds at the top of the Fox Hills, as previously defined'' (ibid.: 405).

LeRoy (1946) also followed the usage of Lovering et al. (1932) in defining the Fox Hills Formation in a stratigraphic study of the Golden-Morrison area, Jefferson County, Colorado. He interpreted the Fox Hills Formation as ''a transitional depositional phase between marine (Pierre) and nonmarine (Lar-

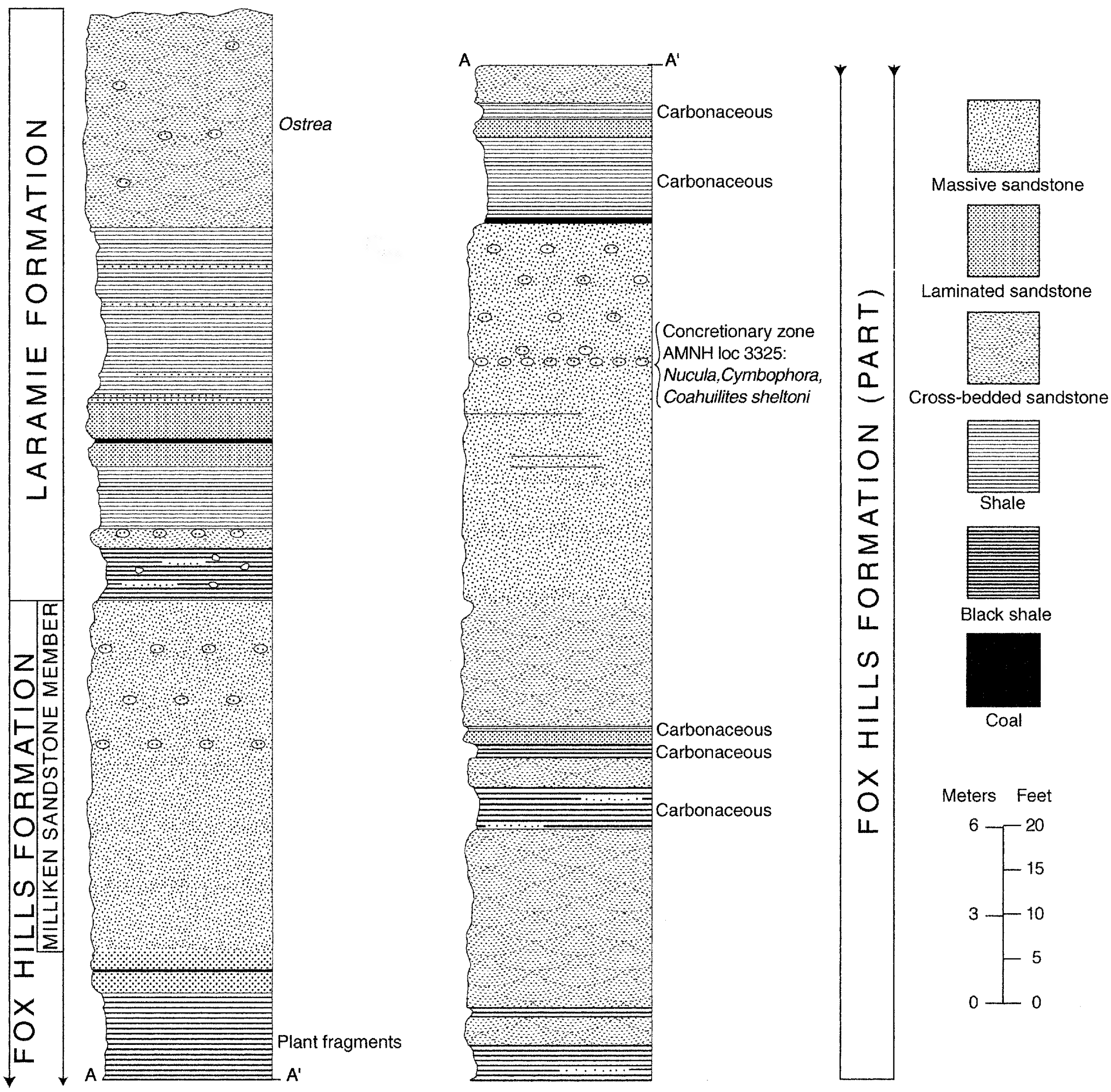


Fig. 3. Stratigraphic section of the Fox Hills Formation and overlying Laramie Formation at Wildcat Mound, sec. 26, T4N, R67W, Weld County, Colorado, described in Mather et al. (1928).

amie) deposits; thus its limits, lithic components, and relationships to overlying and underlying sediments are expected to be variable" (ibid.: 85–86). He considered the contact between the Pierre Shale and Fox Hills Formation as "the base of the sandstone unit, which may be equivalent to the Milliken sandstone of eastern Colorado" (ibid.: 87). He estimated the thickness of the Fox Hills Formation as between 64 and 117 ft (19.5 and 35.7 m) with a possible maximum of 142 ft (43.3 m) and pointed out that "a specific correlation of the Fox Hills of the Golden-Morrison area with the Fox Hills of eastern Colorado is not feasible at this time, owing to extreme variations of the deposits in this part of the section" (ibid.: 90). As for the relationship between the Fox Hills Formation and the overlying Laramie, he wrote that "owing to the variable nature of sedimentation from marine to nonmarine conditions, lithic and faunal affinities in this part of the section may change rapidly both laterally and vertically" (ibid.: 90).

In a series of publications, Scott and Cobban (1965, 1975, 1986a, 1986b) mapped the distribution and biostratigraphy of the Pierre Shale and Fox Hills Formation in eastern Colorado (fig. 2). Like Lavington (1933), they called the upper part of the Pierre Shale ''the upper transition member'' to describe beds ''intermediate in character between the Pierre and the Fox Hills'' (Scott and Cobban, 1965: 3). This unit varies in thickness from 2,000 ft (609.6 m) near Loveland, Colorado, to 1200 ft (365.8 m) near Jarre Creek farther south. It consists of ''friable sandstone and soft shaly sandstone containing thin-bedded sandy shale and large calcareous sandstone concretions'' (ibid.: 3).

The upper transition member is bounded below by the upper shale unit of the Pierre Shale, the upper 270 ft (82.3 m) of which consist of silty and sandy shale near Boulder, Colorado. The upper transition member is bounded above by the Fox Hills Formation. However, Scott and Cobban (1965, 1986b) reported that the lower boundary of the Fox Hills Formation selected by Lovering et al. (1932) was impractical for mapping and used instead the base of the Milliken Sandstone Member. Even this boundary proved difficult to map because it was concealed in many areas. Scott and Cobban (1965: 3) concluded that ''we do not propose that the base of the Milliken be designated as the base of the Fox Hills, but a more satisfactory boundary will have to await a detailed stratigraphic study of the Fox Hills.''

The difficulty of selecting the lower boundary of the Fox Hills Formation is particularly well illustrated in sections of the Pierre Shale and Fox Hills Formation near Golden, Colorado. Covington (1966) studied two sections of the Fox Hills Formation in this area. In both sections, he described the base of the Fox Hills as transitional with the underlying Pierre Shale. At the first site north of Golden (SW¼ sec. 21, T2S, R70W; same as section 3 in fig. 19 of LeRoy, 1946), he chose the contact at ''the first continuous sandstone unit one and one-half feet [0.46 m] thick'' (ibid.: 161). At the second site near Green Mountain (SW¼ sec. 24, T4S, R70W; same as section 1 in fig. 19 of LeRoy, 1946), he selected the boundary at ''the point where sandstones become predominant over the marine shales and thin sandstones of the Pierre Shale below'' (ibid.: 161).

The complex nature of the relationship between the Pierre Shale and Fox Hills Formation was further explored in Weimer and Land (1975) in their study of deltaic sedimentation in the western Denver basin. They described the Pierre Shale as consisting of ''grey, fissile, non-calcareous shale, thin beds and laminae of siltstones, and very fine-grained sandstone'' (ibid.: 636) and the Fox Hills Formation as dominantly ''tan, fine- to medium-grained sandstone with sub-parallel laminations or bedding''(ibid.: 640). They stated that ''the upper contact [of the Pierre Shale] is normally placed in beds transitional to the overlying Fox Hills, but lateral facies changes by intertonguing and penecontemporaneous faulting sometimes make the contact difficult to determine'' (ibid.: 636).

In our paper, we use the term ''upper transition member'' for the upper part of the Pierre Shale, as suggested by Scott and Cobban (1965). However, we expand the definition of the Fox Hills Formation to include the upper part of this unit, as originally defined. This definition of the Fox Hills Formation is essentially that of Lovering et al. (1932). However, we are not prepared to specify an actual boundary between the Pierre Shale and Fox Hills Formation, and the relationship between these two units is yet to be fully resolved (R. Raynolds, personal commun. 2002).

PREVIOUS REPORTS OF AMMONITES

There are several reports of ammonites from the upper part of the Pierre Shale and Fox Hills Formation in northeastern Colorado. We list the species below as originally given, with our current interpretation, if different, in parentheses.

Mather et al. (1928) reported *Discoscaphites conradi* Morton (probably *Jeletzkytes dorfi* Landman and Waage, 1993) and several bivalves and gastropods from the Fox Hills Formation in NW¼, SW¼ sec. 6, T5N, R57W, Morgan County. They also listed many fragments of *Sphenodiscus* sp. (probably either *Sphenodiscus pleurisepta* (Conrad, 1857) or *Coahuilites sheltoni* Böse, 1928) and several bivalves and gastropods from the beds immediately underlying the Milliken Sandstone Member at Wildcat Mound in sec. 26, T4N, R67W, Weld County (fig. 3). They enumerated a long list of bivalves and gastropods, but no ammonites, from the type locality of the Milliken Sandstone Member on the north bank of Thompson Creek near center sec. 6, T4N, R66W, Weld County.

Scott and Cobban (1986b) reported *Baculites* sp., *Discoscaphites* sp. (probably *Jeletzkytes dorfi*), *Hoploscaphites* n. sp. (probably *Hoploscaphites birkelundae* Landman and Waage, 1993), and *Sphenodiscus* (*Coahuilites*) sp. (probably *Coahuilites sheltoni*), in addition to numerous bivalves and gastropods from the upper transition member of the Pierre Shale between Loveland and Round Butte in Larimer County. Scott and Cobban (1965: 3) explained that "at the north edge of the area [near Round Butte], the lower one half [of the upper transition member] contains a few *B. clinolobatus*, and the upper three-fourths contains sparse *Sphenodiscus* (*Coahuilites*) [probably *Coahuilites sheltoni*]; the two ammonites overlap slightly in range."

Weimer and Land (1975) listed *Baculites clinolobatus* and *Sphenodiscus coahuilites* (probably *Coahuilites sheltoni*) from the upper 250 ft (76.2 m) of the Pierre Shale near Golden, Jefferson County, Colorado. K.M. Waage in an unpublished study (1967) recorded scaphites and various bivalves and gastropods in addition to a belemnite from the Fox Hills Formation in SW¼, NE¼ sec. 31, T6N, R58W, Morgan County, Colorado (fig. 4).

AMMONITE ZONATION

On the basis of previous studies (Gill and Cobban, 1966; Scott and Cobban, 1986b; Landman and Waage, 1993), the Maastrichtian of the Western Interior has been subdivided into seven zones. They are, from oldest to youngest, *Baculites eliasi*, *B. baculus*, *B. grandis*, *B. clinolobatus*, *Hoploscaphites birkelundae*, *H. nicolletii*, and *Jeletzkytes nebrascensis*.

We describe *Hoploscaphites birkelundae* and *Jeletzkytes dorfi* from the upper transition member of the Pierre Shale and overlying Fox Hills Formation in northeastern Colorado. These fossils define the *Hoploscaphites birkelundae* Zone, which represents the lower part of the upper Maastrichtian in the Western Interior. The presence of this zone indicates that these rocks are equivalent in age to the Fox Hills Formation in Niobrara County, Wyoming, and older than the Fox Hills Formation in its type area in north-central South Dakota (Waage, 1968).

We also confirm the presence of *Coahuilites sheltoni* and *Sphenodiscus pleurisepta* from the upper transition member of the Pierre Shale and Fox Hills Formation in northeastern Colorado. The former occurs in both the *Baculites clinolobatus* and *Hoploscaphites birkelundae* zones, whereas the latter only occurs in the younger of these two zones.

PALEOGEOGRAPHY

As documented by Cobban et al. (1994), the shoreline of the Western Interior Seaway changed markedly during the Late Cretaceous. The *Baculites reesidei* Zone marks the upper part of the upper Campanian. During this time, the seaway extended northwest–southeast across Montana, across the eastern third of Wyoming, and covered most of Colorado as a broad embayment (fig. 5). During the *Baculites clinolobatus* Zone (upper part of the lower Maastrichtian), Montana was emergent (fig. 6). The sea extended much farther west along the Wyoming–Colorado border and formed a prominent embayment covering much of northern Colorado. During the succeeding *Hoploscaphites birkelundae* Zone (lower part of the upper Maastrichtian), the configuration of the western shoreline remained nearly the same.

STRONTIUM ISOTOPE ANALYSIS

The ratio of $^{87}Sr/^{86}Sr$ has been used as a tool to date sedimentary rocks based on the change in the value of this ratio in the oceans over time. McArthur et al. (1994) applied this methodology to rocks from the Upper Cretaceous Western Interior relying on well-preserved fossil material from each of 39 biostratigraphic zones. They presented a plot of the ratio of $^{87}Sr/^{86}Sr$ versus biostratigraphic zone as well as absolute age.

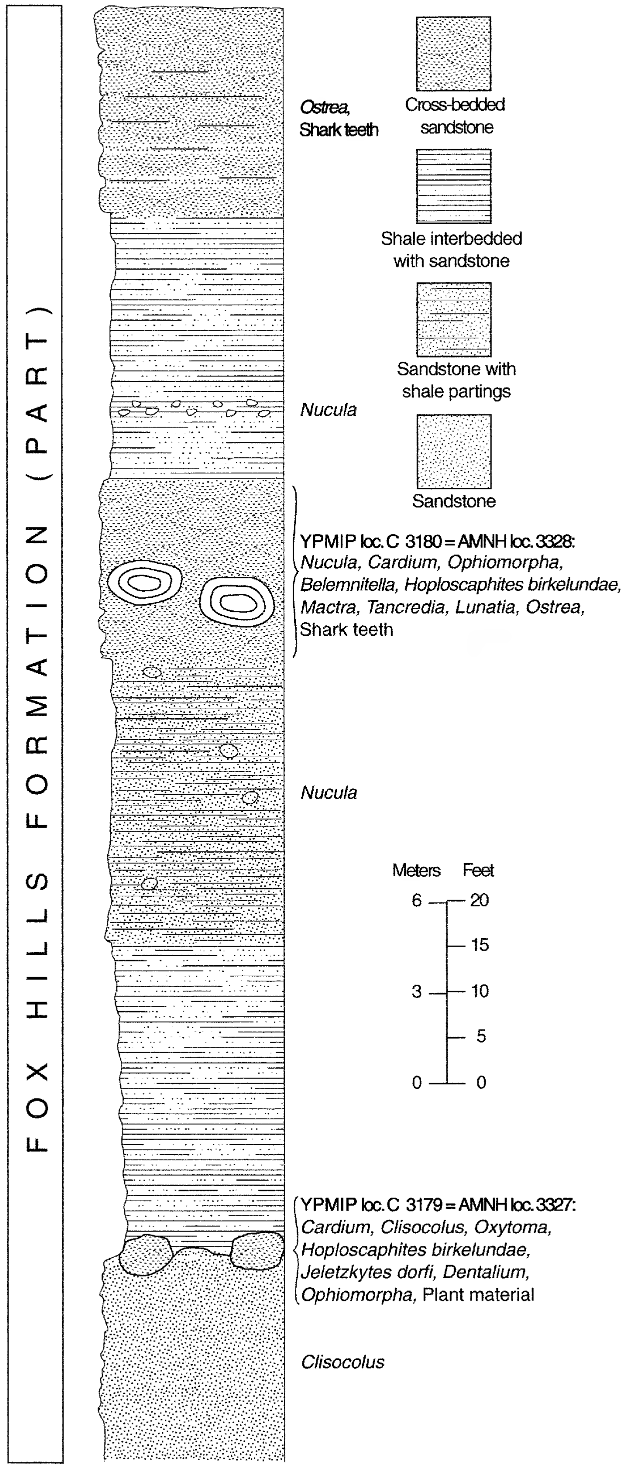


Fig. 4. Stratigraphic section of part of the Fox Hills Formation on the south side of Big Draw and the west side of Wildcat Creek, SW¼, NE¼ sec. 31, T6N, R58W, Morgan County, Colorado, as measured by K.M. Waage in 1967.

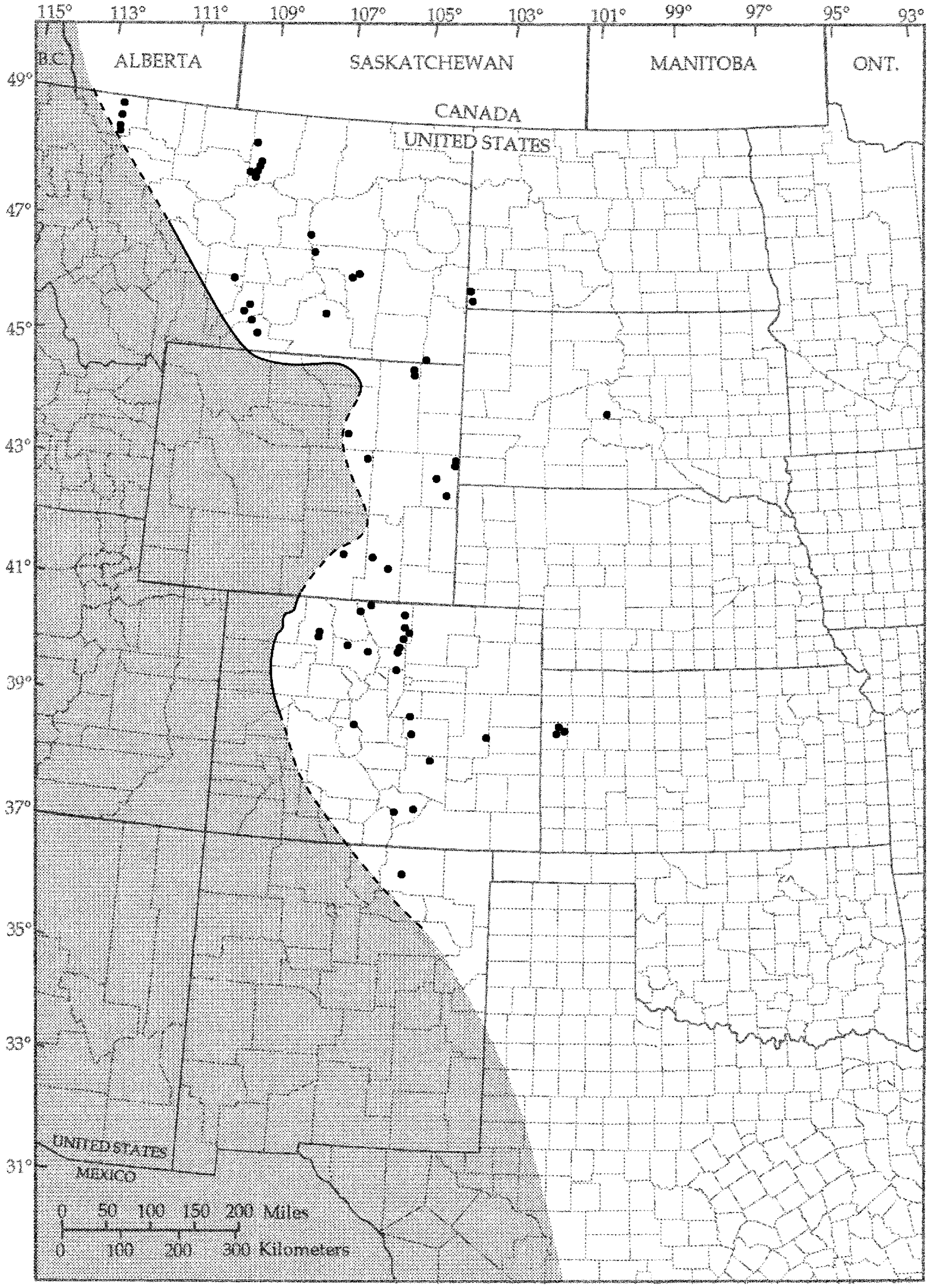


Fig. 5. Western shoreline of the Western Interior Seaway during the time of the *Baculites reesidei* Zone (upper part of the upper Campanian). Dots indicate localites at which *B. reesidei* occurs.

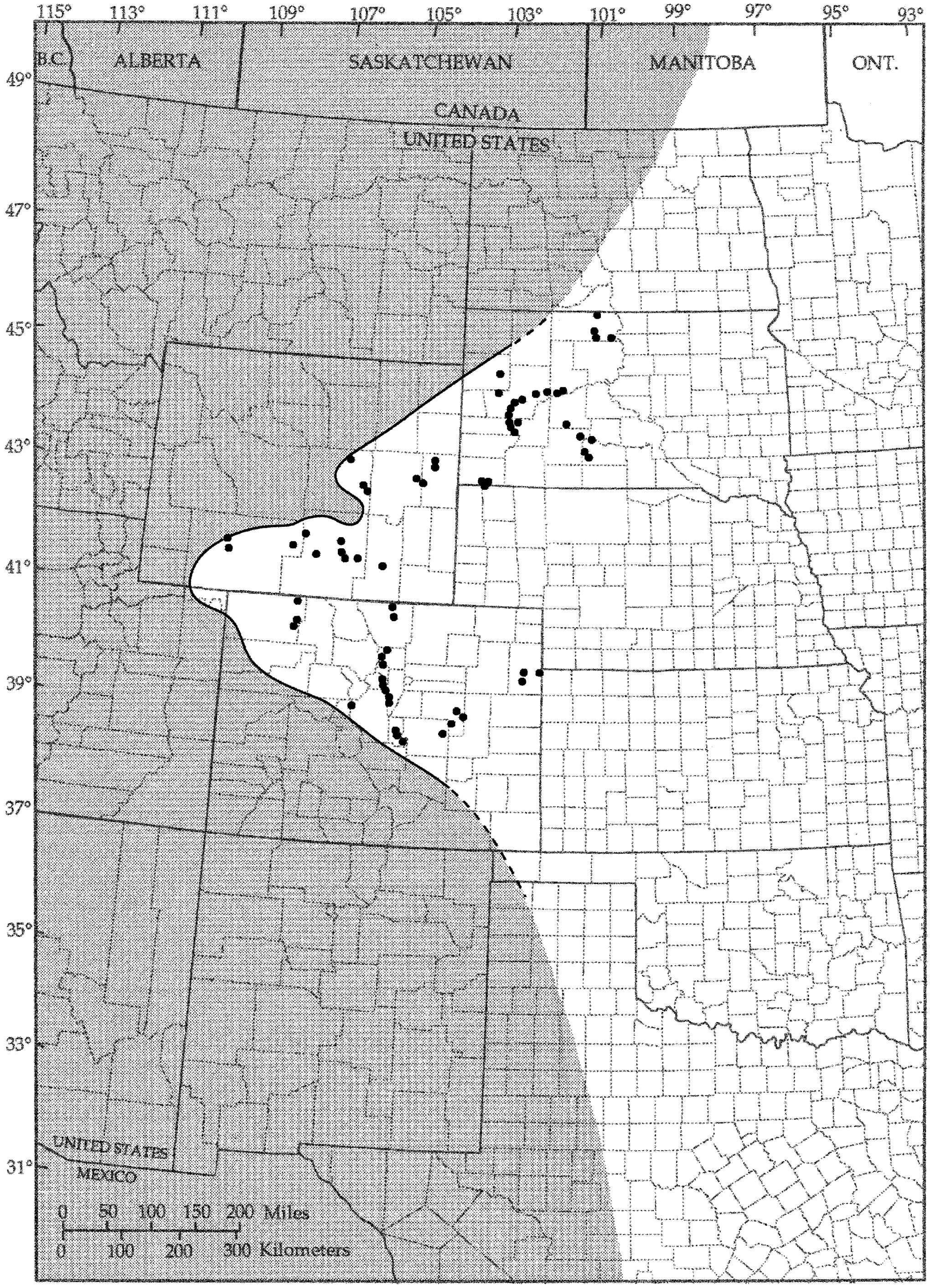


Fig. 6. Western shoreline of the Western Interior Seaway during the time of the *Baculites clinolobatus* Zone (upper part of the lower Maastrichtian). Dots indicate localities at which *B. clinolobatus* occurs. (Modified after Cobban et al., 1994: fig. 13.)

We report the strontium isotope ratio of YPM 202272, a belemnite from the *Hoploscaphites birkelundae* Zone of the Fox Hills Formation in SE¼, NW¼ sec. 31, T6N, R58W, Morgan County, Colorado. Geochron Laboratories, Cambridge, Massachusetts, performed the analysis. They reported that the sample was rich in strontium, perhaps suggesting that it may have undergone some recrystallization. The value of the ratio is 0.707790 ± 0.000008 (2-sigma SE).

This value is nearly identical to the average value of 0.707789 for a single specimen of *Veniella humilis* from the *Hoploscaphites birkelundae* Zone in Niobrara County, Wyoming, analyzed by McArthur et al. (1994: 105, table 3, called by them the *Hoploscaphites* aff. *nicolleti* Zone). By comparison, they reported values of 0.707720 to 0.707738 for four specimens of *Baculites clinolobatus* Elias, 1933, from the zone just below and a value of 0.707759 for a single specimen of *Hoploscaphites nicolletii* (Morton, 1842) from the zone just above.

In an extensive study of the ratio of ^{87}Sr/^{86}Sr in marine molluscs from the *Jeletzkytes nebrascensis* Zone of the Fox Hills Formation in north-central South Dakota, Cochran et al. (in press) reported a wide range of variation from 0.707605 to 0.707827. They argued that this variation correlated with the environment in which the animals lived, and primarily reflected differences in salinity concentration. Values were lowest in brackish water environments and highest in nearly fully marine environments. Values for four molluscs in the most fully marine environment ranged from 0.707801 to 0.707827 with an average of 0.707808. A belemnite from this environment yielded a value of 0.707801; another specimen from a more nearshore environment yielded a value of 0.707795.

In a study of the upper part of the Fox Hills Formation in the Badlands National Park, South Dakota, Stoffer et al. (1998) analyzed the ratio of ^{87}Sr/^{86}Sr in eight belemnites, which Terry et al. (2001) interpreted as occurring just below the Cretaceous–Tertiary boundary. The few ammonite fragments at the site suggest that the belemnites occur either in the *Jeletzkytes nebrascensis* or *Hoploscaphites nicolletii* Zone, but it is difficult to be any more precise than that. According to Stoffer et al. (1998), the average value of the ratio of ^{87}Sr/^{86}Sr in these eight specimens is 0.707812 (SD = 0.000005).

LIST OF LOCALITIES

Most of the localities mentioned in the text are illustrated in figure 1, provided that enough geographic data were available to map them. We report stratigraphic information as originally given, except where noted.

1. 4 mi (6.4 km) north and 7 mi (11.3 km) east of Fort Collins, Larimer County, Colorado, Fox Hills Formation.
2. 13 mi (20.9 km) north of Wellington, Larimer County, Colorado, Fox Hills Formation.
3. 11 mi (17.7 km) north of Wellington, Larimer County, Colorado, Fox Hills Formation.
4. Green Mountain (probably sec. 11, T4S, R70W, Morrison quadrangle) near Golden, Jefferson County, Colorado, upper transition member of the Pierre Shale.
5. Near Wellington, Larimer County, Colorado, Fox Hills Formation.
6. USGS loc. 10663. N 75°E from Round Butte, Larimer County, Colorado, Fox Hills Formation.
7. USGS loc. D3719. SW¼, SE¼ sec. 2, T1N, R70W, Niwot quadrangle, Boulder County, Colorado, near the base of the upper transition member of the Pierre Shale (locality no longer accessible).
8. USGS loc. D12207 (≈YPMIP locs. C3179, C3180; AMNH loc. 3327). Center sec. 31, T6N, R58W, Judson Hills quadrangle, Morgan County, Colorado, Fox Hills Formation.
9. USGS loc. 9426. Just south of the Wyoming line and east of Round Butte, Larimer County, Colorado, white sandstone, Fox Hills Formation.
10. USGS loc. D12233. North side of Park Gulch at King Coal Mine, NE¼, SW¼ sec. 2, T9S, R76W, Milligan Lakes quadrangle, Park County, Colorado, concretionary layer in shaly unit in the upper part of the Fox Hills Formation.
11. USGS loc. D3729. Draw, NE¼, NW¼ sec. 30, T6N, R67W, Timnath quadrangle, Weld County, Colorado, grey limestone concretions in the upper transition member of the Pierre Shale, ~400 ft (121.9 m) below the Milliken Sandstone Member of the Fox Hills Formation.
12. USGS loc. 9205. NE¼, SE¼ sec. 31, T4N,

R68W, about 4 mi (6.4 km) southeast of Berthoud in ravine 1.5 mi (2.4 km) south of Little Thompson River, Berthoud quadrangle, Weld County, near base of upper transition member of the Pierre Shale (locality no longer accessible).

13. YPMIP loc. C3179 (= AMNH loc. 3327; ≈USGS loc. D3719). Northeast trending spur along tributary draw in northeast-facing bluff, south side of Big Draw and west side of Wildcat Creek, 14.5 mi (23.3 km) north-northwest of Fort Morgan, SW¼, NE¼ sec. 31, T6N, R58W, Judson Hills quadrangle, Morgan County, Colorado, concretionary masses in the lower part of the Fox Hills Formation (fig. 4).
14. USGS loc. 5714. Sec. 31, T8N, R66W, 5 mi (8.0 km) west and 2.5 mi (4.0 km) north of Ault, Severance quadrangle, Weld County, Colorado, Fox Hills Formation.
15. USGS loc. 5719 (≈AMNH loc. 3325). Bluff southwest of Wildcat Mound, NW¼, NE¼ sec. 34, T4N, R67W, Johnstown and Milliken quadrangles, Weld County, Colorado, ~40 ft (12.2 m) below the base of the Milliken Sandstone Member of the Fox Hills Formation.
16. USGS loc. 9202. North side of St. Vrain River, 1.5 mi (2.4 km) below mouth of Boulder Creek, NW¼ sec. 3, T2N, R68W, Gowanda quadrangle, Weld County, Colorado, upper part of the Pierre Shale.
17. DMNH loc. 2304. NE¼ sec. 27, T6S, R58W, Barking Dog Spring quadrangle, Elbert County, Colorado, upper transition member of the Pierre Shale, 140 ft (42.7 m) below the base of the Fox Hills Formation.
18. Sec. 35, T7N, R66W, Eaton and Severance quadrangles, Weld County, Colorado, Milliken Sandstone Member of the Fox Hills Formation.
19. USGS loc. 16179. SW¼ sec. 34, T13S, R58W, Kutch SE quadrangle, Elbert County, Colorado, upper transition member of the Pierre Shale, ~400 ft (121.9 m) below Laramie coal.
20. USGS loc. D3726. Stream bank, SW¼, SE¼ sec. 35, T6N, R67W, Bracewell quadrangle, Weld County, Colorado, near top of Pierre Shale (probably lower part of Fox Hills Formation, according to current usage).
21. Deadman Gulch near Golden, Jefferson County, Colorado, Fox Hills Formation.
22. AMNH loc. 3320 (probably the same as loc. 4). Sec. 11, T4S, R70W, Morrison quadrangle, Jefferson County, Colorado, upper transition member of the Pierre Shale.
23. AMNH loc. 3327 (= YPMIP loc. C3179; ≈USGS loc. D12207). Big Drawer, SW¼, NE¼ sec. 31, T6N, R58W, 14.5 mi (23.3 km) north-northwest of Fort Morgan, Judson Hills quadrangle, Morgan County, concretionary masses in the lower part of the Fox Hills Formation (fig. 4).
24. AMNH loc. 3324. SE¼, NE¼ sec. 7, T2N, R68W, ~2 mi (3.2 km) east of Longmont, Longmont quadrangle, Boulder County, Colorado, crumbly sandstone that forms prominent cliff (Milliken Sandstone Member), Fox Hills Formation.
25. AMNH loc. 3325 (≈USGS loc. 5719). Center, line between secs. 23 and 26, T4N, R67W, Wildcat Mound, ~2 mi (3.2 km) south of Milliken, Johnstown quadrangle, Weld County, Colorado, sandstone about 40 ft (12.2 m) below the base of the Milliken Sandstone Member of the Fox Hills Formation (fig. 3).
26. YPMIP loc. C3180. Same locality as YPMIP loc. C3179, middle sandy unit, Fox Hills Formation (fig. 4).
27. USGS loc. D1545. NE¼, SW¼ sec. 5, T5S, R69W, Morrison quadrangle, Jefferson County, Colorado, base of the upper transition member of the Pierre Shale.

CONVENTIONS

The ammonites described in this paper are reposited in the Academy of Natural Sciences of Philadelphia (ANSP), the American Museum of Natural History (AMNH), the Black Hills Museum of Nature and Science (BHI), the Colorado School of Mines (CSM), the Denver Museum of Nature and Science (DMNH), the U.S. National Museum (USNM), and the Yale Peabody Museum (YPM). Dimensions of specimens are expressed in millimeters. Arrows on the photos indicate the base of the body chamber. All specimens are photographed in the conventional manner (with the aperture on top) except for the scaphites, in which the side views are oriented with the aperture on the bottom. Suture terminology is that of Wedekind (1916), as reviewed by Kullmann and Wiedmann (1970). The term "rib index" as applied to heteromorphs is the number of ribs in a distance equal to the whorl height at the midpoint of the interval counted.

SYSTEMATIC PALEONTOLOGY

CLASS CEPHALOPODA

ORDER AMMONOIDEA VON ZITTEL, 1884

SUBORDER AMMONITINA HYATT, 1889

SUPERFAMILY ACANTHOCERATACEAE DE GROSSOUVRE, 1894

FAMILY SPHENODISCIDAE HYATT, 1900

Genus *Coahuilites* Böse, 1928

TYPE SPECIES: *Coahuilites sheltoni* Böse, 1928: 283, pl. 13, figs. 4–11, by original designation.

Coahuilites sheltoni Böse, 1928

Figures 7–10

Coahuilites sheltoni Böse, 1928: 283, pl. 13, figs. 4–11.
Coahuilites sp. Scott and Cobban, 1965, 1975, 1986a, 1986b.
Coahuilites sheltoni Böse, 1928. Cobban and Kennedy, 1995: 12, figs. 2.8, 2.9, 7.1, 8.1–8.3 (with full synonymy).
Coahuilites sheltoni Böse, 1928. Kennedy et al., 1996:6, figs. 2, 3, 4B.

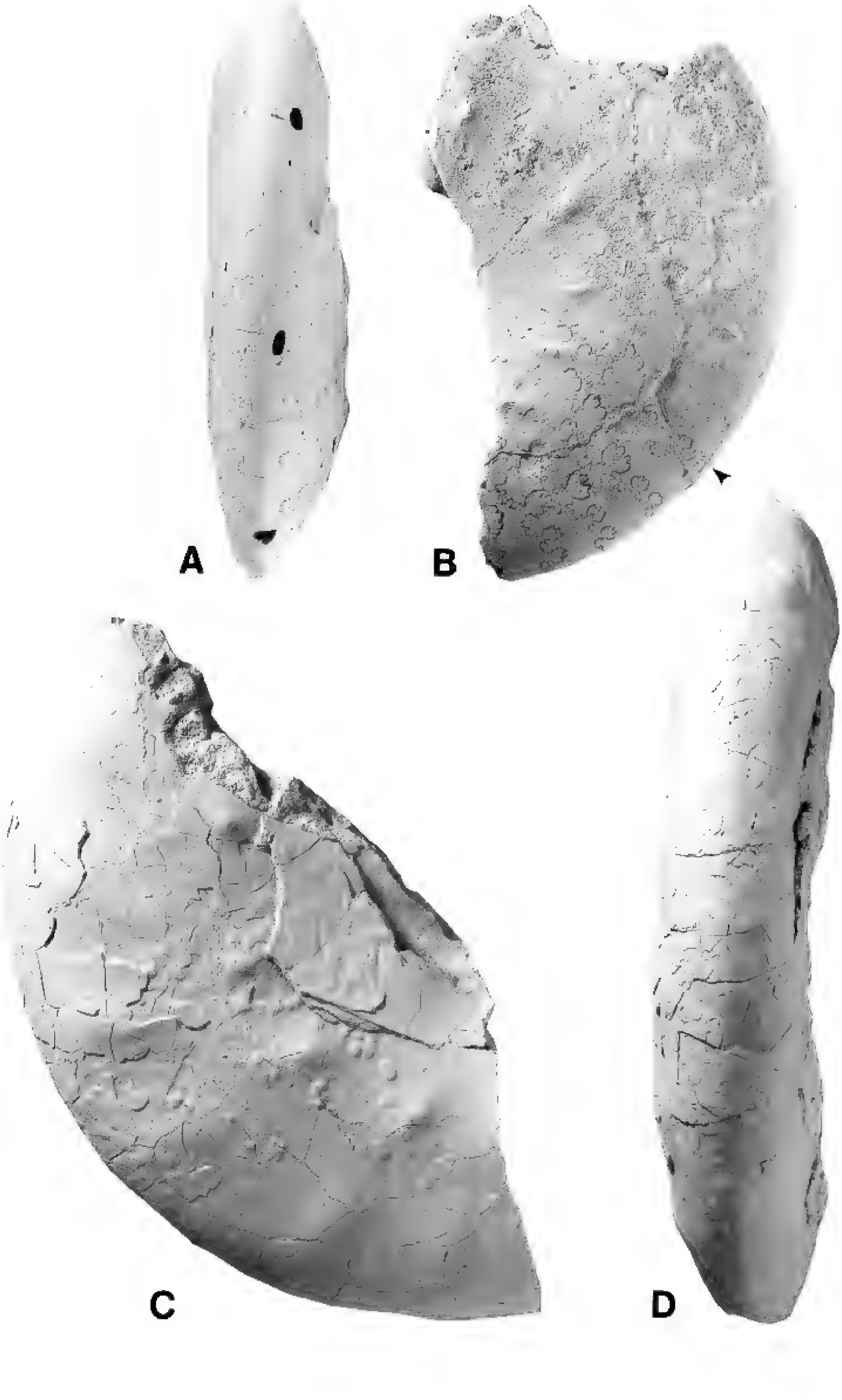
TYPE: Holotype, by original designation, is the original specimen of Böse (1928: pl. 13, fig. 7) from the Escondido Formation about 3 mi (4.8 km) south of Alamo Viejo in the region of Villa de Juarez, Coahuila, Mexico.

MATERIAL: Seven specimens, mostly whorl fragments without outer shell: USNM 519508 from the upper transition member of the Pierre Shale, about 400 ft (121.9 m) below the Laramie coal, SW¼ sec. 34, T13S, R58W, Elbert County, Colorado; USNM 519509, 519517, and 519518 from the Fox Hills Formation, about 40 ft (12.2 m) below the Milliken Sandstone Member, NW¼, NE¼ sec. 34, T4N, R67W, Weld County, Colorado (fig. 1, loc. 15); DMNH 23359 from the upper transition member of the Pierre Shale, NE¼ sec. 27, T6S, R58W, Elbert County, Colorado (fig. 1, loc. 17); AMNH 47397 from the Fox Hills Formation, about 40 ft (12.2 m) below the Milliken Sandstone Member, center, line between secs. 23 and 26, T4N, R67W, Wildcat Mound, about 2 mi (3.2 km) south of Milliken, Weld County, Colorado (fig. 1, loc. 25); and USNM 519520 from the base of the upper transition member of the Pierre Shale, NW¼, SW¼ sec. 5, T5S, R69W, Jefferson County, Colorado (fig. 1, loc. 27).

DESCRIPTION: DMNH 23359 is a fragment of a body chamber, a little less than one-half whorl in angular length, with most of the right side worn away (fig. 7C, D). The specimen is an internal mold with patches of nacreous shell still attached in places. An imprint of a large bryozoan colony occurs on the adapical half of the specimen. The estimated whorl height at the adoral end of the specimen is 65.0 mm. Coiling is very involute, but the umbilicus is not preserved. The inner flanks are slightly concave and the outer flanks are very broadly rounded to nearly flat and converge toward the venter. The ventrolateral shoulder is broadly rounded. The venter is moderately well rounded with a blunt midventral ridge on the adapical end of the specimen, which weakens adorally. The patch of shell on the inner flanks bears delicate, straight, prorsiradiate ribs. There is a row of four sharp nodes on the midflanks. The nodes are evenly spaced at distances of approximately 18–20 mm. They give rise to weak ribs that join six low, elongate nodes on the ventrolateral margin. These nodes are evenly spaced at distances of approximately 20–25 mm. The venter is smooth.

USNM 519508 is a fragment of an internal mold of the adoral end of the phragmocone and adapical end of the body chamber (fig. 7A, B). It is approximately one-third whorl in angular length. It is very involute, but the umbilicus is not preserved. The estimated whorl height at the adapical end of the specimen is 46.0 mm. The whorl section is compressed with maximum width at one-third whorl height. The ratio of whorl width to whorl height at the adapical end of the specimen is 0.48. The inner one-third of the flanks is very concave and the outer two-thirds is very broadly rounded and converges toward the venter. The venter is sharply rounded with a very weak midventral ridge on the phragmocone. There is a row of six concave bullae at one-third whorl height. They are evenly spaced at distances of approximately 10–11 mm. There is a row of seven low swellings on the ventrolateral margin. The venter is smooth.

The suture has a broad shallow external lobe (E) with a broad, little incised median


A
B
C
D

saddle (fig. 8). The first lateral saddle (E/L) is split in two by a broad, moderately incised lobe. All adjacent saddles have entire terminations.

USNM 519509 is a partially crushed internal mold 119.0 mm in diameter (fig. 9). It comprises part of the inner whorls of the phragmocone and approximately one-half whorl of the body chamber. The whorl section at the adoral end of the specimen is compressed with maximum width at midwhorl height; the ratio of whorl width to whorl height is 0.47. As in the other specimens, the shell is very involute. The inner flanks are concave and the outer flanks are very broadly rounded and converge toward the venter. The ventrolateral shoulder is moderately well rounded and the venter is well rounded to weakly fastigate. There is a row of 10 nodes on the midflanks of the last whorl, five on the phragmocone, and five on the body chamber. The nodes are more or less evenly spaced at distances of approximately 15 mm. A row of five nodate swellings occurs on the ventrolateral margin of the body chamber. No ribbing is present.

USNM 519520 is one-half whorl long and 125 mm in diameter (fig. 10). It comprises the adapical end of the phragmocone and most of the body chamber. It is an internal mold with patches of shell preserved. Most of the venter and left side of the specimen are missing. The inner whorls are preserved, showing an ontogenetic change in whorl shape, especially a progressive rounding of the venter. The whorl width and height at the base of the body chamber are 21.6 mm and 48.5 mm, respectively; the ratio of whorl width to height is 0.44. The inner one-third of the flanks is very concave and the outer two-thirds is broadly rounded and converges toward the venter. The venter is well rounded with a weak midventral ridge. Maximum width occurs at midwhorl height. There is a row of seven sharp bullae at one-third whorl height. The bullae become progressively

Fig. 8. Third from last suture of *Coahuilites sheltoni* Böse, 1928, USNM 519508, upper transition member of the Pierre Shale, SW¼ sec. 34, T13S, R58W, Elbert County, Colorado. Suture is drawn at a whorl height of 45.5 mm.

more widely spaced adorally; the distance between the two most adoral bullae is about 17 mm. A row of low nodate swellings is also present near the ventrolateral shoulder.

AMNH 47397 (not illustrated) is a small scrap of the ventral part of the phragmocone. The venter is well rounded to weakly fastigate. The suture is well exposed and matches that of USNM 519508 (fig. 8).

DISCUSSION: USNM 519508, which was collected by J.B. Reeside, Jr., in 1932, was described by Lavington (1933: 404) from the "transition zone" of the Pierre Shale below the Fox Hills Formation. All of the Colorado specimens are similar to those reported from the Fox Hills Formation of Niobrara County, Wyoming (Kennedy et al., 1996: 6–11, figs. 3, 4B).

OCCURRENCE: *Coahuilites sheltoni* occurs in the *Baculites clinolobatus* and *Hoploscaphites birkelundae* zones of the Western Interior (fig. 11, appendix). It is recorded from the Fox Hills Formation in Niobrara County, Wyoming (Kennedy et al., 1996), and the upper part of the Pierre Shale and Fox Hills Formation in Elbert, Jefferson, and Weld counties, Colorado (Kennedy et al., 1996). The species has also been reported from Trans-Pecos Texas and northern Mexico (Cooper, 1970) and from the Prairie Bluff Chalk in Alabama and Mississippi (Cobban and Kennedy, 1995).

Genus *Sphenodiscus* Meek, 1871

TYPE SPECIES: *Ammonites lenticularis* Owen, 1852: 579 (*non* Young and Bird,

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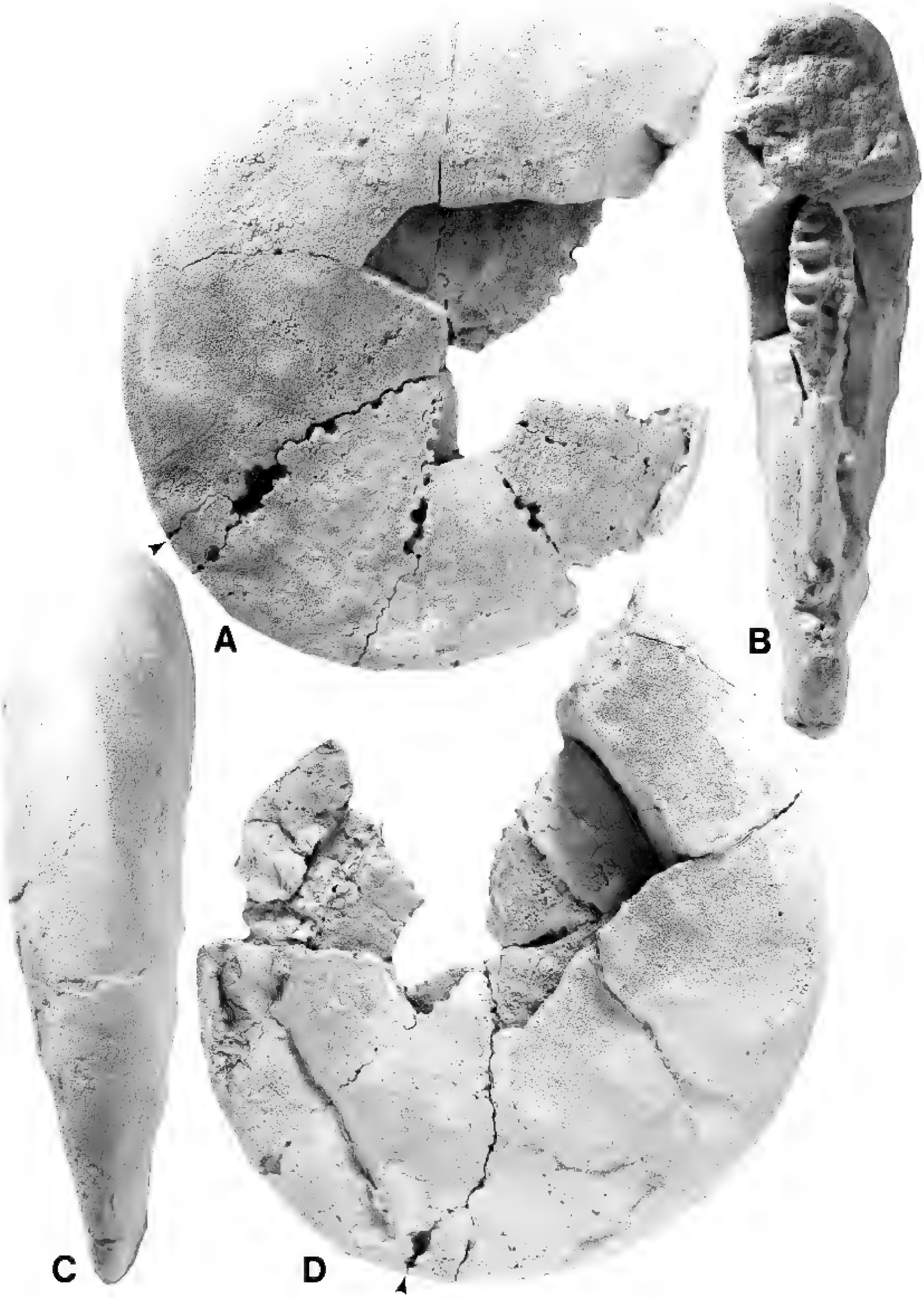
Fig. 7. *Coahuilites sheltoni* Böse, 1928. **A, B.** USNM 519508, upper transition member of the Pierre Shale, SW¼ sec. 34, T13S, R58W, Elbert County, Colorado. **A,** Ventral; **B,** right lateral. **C, D.** DMNH 23359, upper transition member, Pierre Shale, NE¼ sec. 27, T6S, R58W, Elbert County, Colorado. **C,** Left lateral; **D,** ventral. All figures are ×1.


A
B
C
D

1828: 269, fig. 5), by original designation, = *Ammonites lobata* Tuomey, 1856: 168.

Sphenodiscus pleurisepta (Conrad, 1857)
Figures 12–15

Ammonites pleurisepta Conrad, 1857: 159, pl. 15, fig. 1.

Sphenodiscus lenticularis (Owen). Kellum, 1962: 68, pl. 4, figs. 3, 4; pl. 5, fig. 1; pl. 6, figs. 1, 2.

Sphenodiscus pleurisepta (Conrad, 1857). Cobban and Kennedy, 1995: 12, fig. 8.5 (with full synonymy).

Sphenodiscus pleurisepta (Conrad, 1857). Kennedy et al., 1996: 11, figs. 4A, 5–12.

TYPE: The holotype is USNM 9888, said to be from "Jacun, 3 miles [4.8 km] below Laredo," but probably from the Escondido Formation of the Rio Grande Region, probably in Maverick County, Texas (Stephenson, 1941, 1955).

MATERIAL: Five USNM specimens, most of which are fragments: USNM 77358 from the Milliken Sandstone Member of the Fox Hills Formation, sec. 35, T7N, R66W, Weld County, Colorado (fig. 1, loc. 18); USNM 519507 from the upper part of the Pierre Shale, NW¼ sec. 3, T2N, R68W, Weld County, Colorado (fig. 1, loc. 16); USNM 519506 from the Fox Hills Formation, 5 mi (8.0 km) west and 2.5 mi (4.0 km) north of Ault, Weld County, Colorado (fig. 1, loc. 14); and USNM 519510 and 519519 from near the top of the Pierre Shale or lower part of the Fox Hills Formation, SW¼, SE¼ sec. 35, T6N, R67W, Weld County, Colorado (fig. 1, loc. 20).

DESCRIPTION: USNM 519506 is a fragment of an internal mold nearly one-half whorl long (fig. 12). It consists of the adoral part of the phragmocone and the adapical part of the body chamber. It retains part of the shell on the right side. The whorl height at the adoral end of the specimen is 80.8 mm. The whorl section is compressed oxyconic with maximum width at midwhorl height; the ratio of whorl width to whorl height is 0.35. The specimen is involute with a tiny umbilicus. The umbilical wall is inclined outward and the umbilical shoulder is broadly rounded on the adapical end of the specimen. The umbilical wall becomes steeper and the umbilical shoulder more sharply rounded toward the adoral end of the specimen. The inner flanks are concave, the midflanks are very broadly rounded, and the outer flanks are flat and converge to the acute venter. There is a row of midflank bullae—five on the left side—that are more or less equally spaced at distances of 11–13 mm. These bullae seem to disappear toward the adoral end of the specimen, which may be preservational. There is also a row of low swellings on the outer flanks—eight on the left side. They are more or less evenly spaced at distances of approximately 20 mm. Some of these swellings, especially those on the right side, appear to be crescentic. The patches of outer shell on the right side bear fine concave lirae. The suture is characterized by narrow stemmed saddles (fig. 13).

USNM 519519 (not illustrated) is a completely septate fragment approximately 0.25 whorl long. It is a slightly distorted internal mold missing part of the inner flanks on the left side. The whorl height at the adoral end of the specimen is approximately 87 mm. The whorl section is oxyconic and there is a row of swellings on the outer flanks (the inner flanks are too poorly preserved to detect bullae).

USNM 519510 (fig. 14) is in the same lot as USNM 519519. It is a fragment of the adapical part of the body chamber 0.125 whorl long. The two specimens may belong to the same individual but they do not obviously fit together. The whorl height at the adoral end of USNM 519510 is approximately 130 mm. The left side and the venter of the body chamber are missing. The flanks are very broadly rounded and converge toward the venter. There are two sharp tubercles on the midflanks. What appears to be a lobate muscle scar occurs just adoral of the ultimate septum on the right side (fig. 14). It

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Fig. 9. *Coahuilites sheltoni* Böse, 1928. **A–D.** USNM 519509, Fox Hills Formation, NW¼, NE¼ sec. 34, T4N, R67W, Weld County, Colorado. **A,** Left lateral; **B,** apertural; **C,** ventral; **D,** right lateral. All figures are ×1.

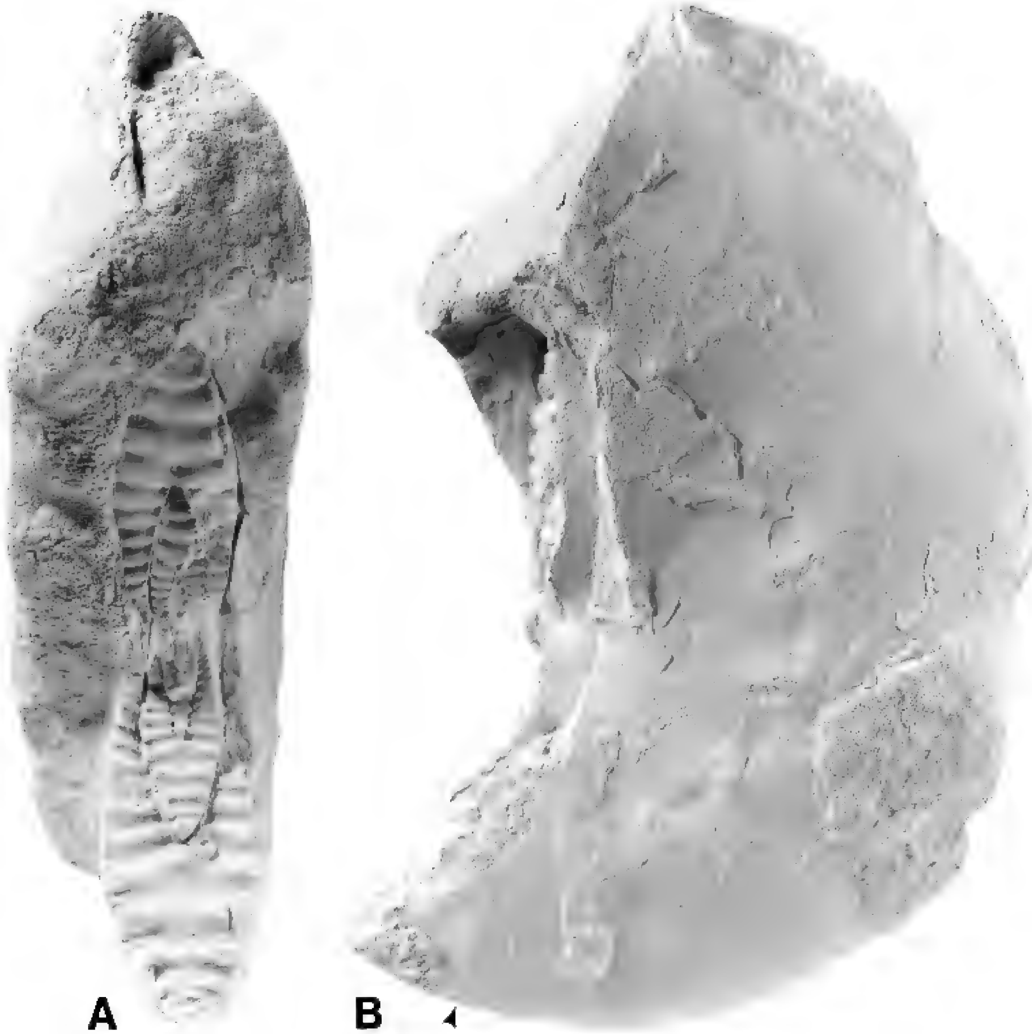


Fig. 10. *Coahuilites sheltoni* Böse, 1928. **A, B.** USNM 519520, base of the upper transition member of the Pierre Shale, NW¼, SW¼ sec. 5, T5S, R69W, Jefferson County, Colorado. **A,** Apertural; **B,** right lateral. All figures are ×1.

covers the umbilical wall and extends onto the inner one-quarter of the flanks. The scar is approximately 27 mm wide at its widest point. The scar is demarcated by a slight groove on its adapical side and a faint ridge on its adoral side. It is covered in part with a thin layer of nacre. An impression of the inner whorls occurs on the left side of the specimen. The impression reveals a row of sharp tubercles on the inner flanks and another row of low swellings on the outer flanks.

USNM 519507 is an internal mold about one-half whorl long consisting of the adoral part of the phragmocone and adapical part of the body chamber (fig. 15). The whorl height at the adoral end of the specimen is approximately 74 mm. The whorl section is oxyconic with the maximum width at midwhorl height; the ratio of whorl width to whorl height is 0.29. There is a row of sharp tubercles at approximately one-third whorl height and a row of low nodate swellings on the outer flanks.

USNM 77358 (not illustrated) is from approximately the same locality as USNM

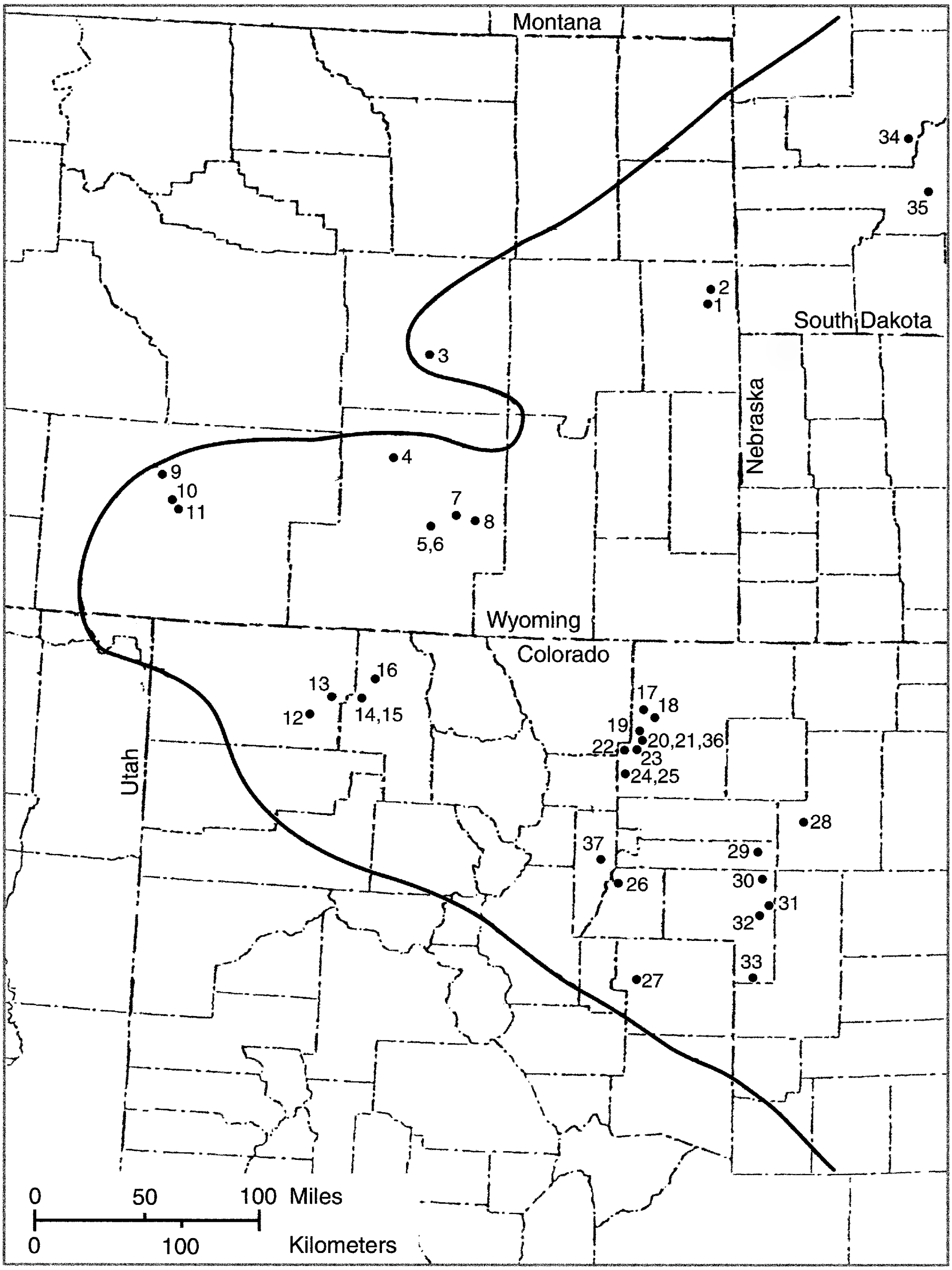


Fig. 11. Occurrences of *Sphenodiscus pleurisepta* (Conrad, 1857) or *Coahuilites sheltoni* Böse, 1928, or both, in Colorado, Wyoming, and South Dakota shown on a map of the Western Interior Seaway during the time of the *Baculites clinolobatus* Zone. The localities are listed in the appendix and the numbers do not correspond to those on figure 1.

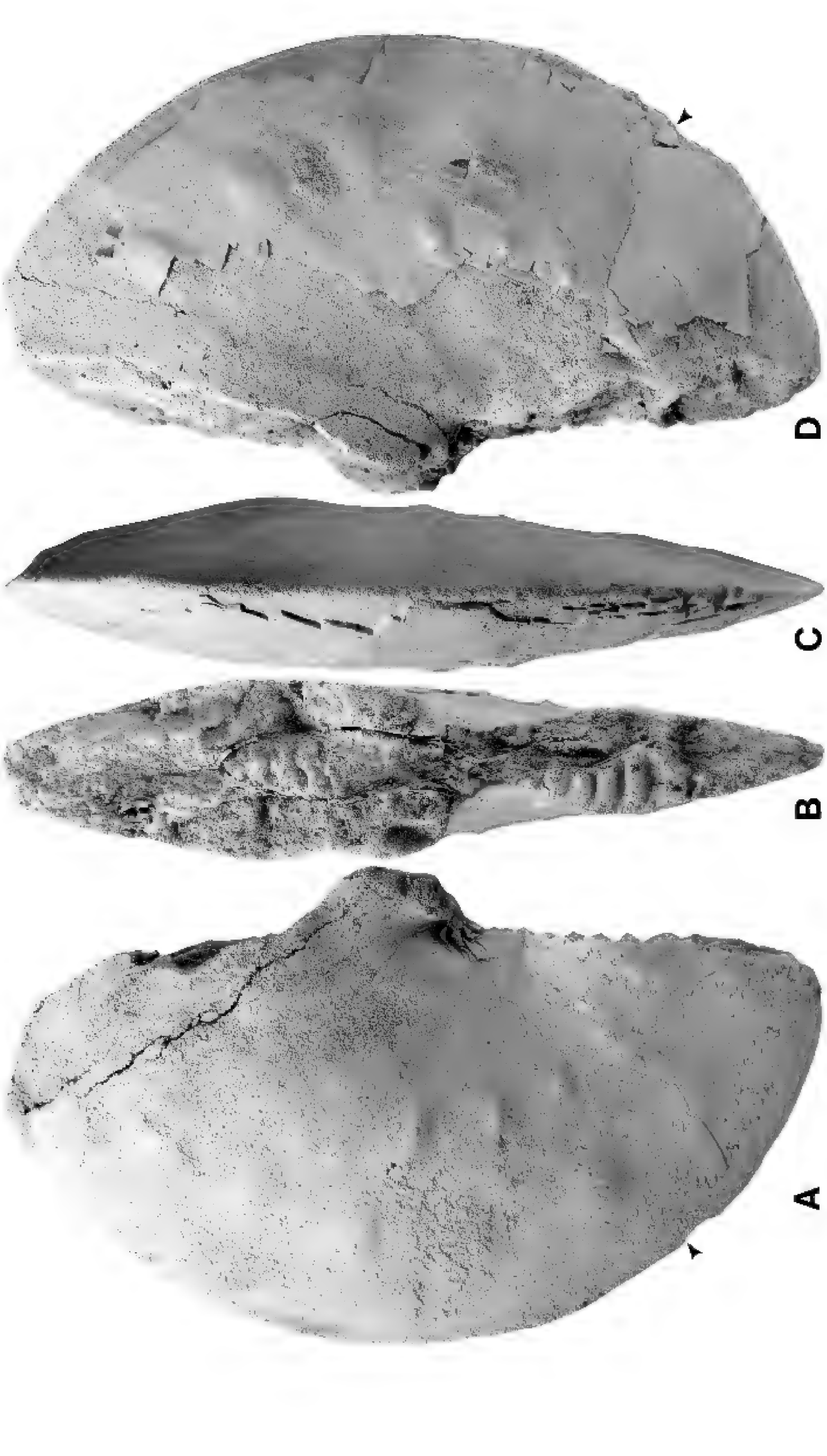


Fig. 12. *Sphenodiscus pleurisepta* (Conrad, 1857). **A–D.** USNM 519506, Fox Hills Formation, 5 mi (8.0 km) west and 2.5 mi (4.0 km) north of Ault, Weld County, Colorado. **A,** Left lateral; **B,** apertural; **C,** ventral; **D,** right lateral. All figures are ×0.94.

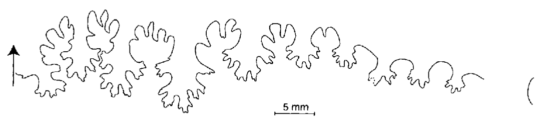


Fig. 13. Composite suture (last suture plus parts of fourth from last suture) of *Sphenodiscus pleurisepta* (Conrad, 1857), USNM 519506, Fox Hills Formation, 5 mi (8 km) west and 2.5 mi (4 km) north of Ault, Weld County, Colorado. Suture is drawn at a whorl height of 61.8 mm.

519506. It is a fragment of a body chamber about one-quarter whorl long missing most of the left side. The whorl section is oxyconic with maximum whorl width at midwhorl height. A row of swellings occurs on the outer flanks. The row of tubercles on the midflanks is mostly absent, perhaps due to preservation—there is one small tubercle on the adapical end of the specimen. We provisionally include this specimen in *Sphenodiscus pleurisepta*, although the absence of midflank tubercles is suspicious.

DISCUSSION: The presence of two rows of tubercles or nodes distinguishes *Sphenodiscus pleurisepta* from *Sphenodiscus lobatus* (Tuomey, 1856). *Sphenodiscus pleurisepta* differs from *Coahuilites sheltoni* Böse, 1928, in its compressed, oxyconic whorl section.

OCCURRENCE: USNM 519510 and 519519 are in the same lot as USNM 519516, a microconch of *Jeletzkytes dorfi*. *Sphenodiscus pleurisepta* occurs in the *Hoploscaphites birkelundae* Zone of the Pierre Shale in Meade and Pennington counties, South Dakota (Kennedy et al., 1996; Larson et al., 1997), the Fox Hills Formation in Niobrara County, Wyoming (Kennedy et al., 1996), and the upper part of the Pierre Shale and Fox Hills Formation in Weld County, Colorado (Kennedy et al., 1996) (fig. 11, appendix). This species has also been reported from the Escondido Formation in Trans-Pecos Texas and northern Mexico (Stephenson, 1941, 1955), the Corsicana Formation in northern Texas (Kennedy and Cobban, 1993), the Owl Creek Formation in Tennessee, Mississippi, and Missouri (Kennedy and Cobban, 2000), the Prairie Bluff Chalk in Alabama and Mississippi (Cobban and Kennedy, 1995), and the Severn Formation in Maryland (Kennedy et al., 1997).

SUBORDER ANCYLOCERATINA WIEDMANN, 1966

SUPERFAMILY TURRILITACEAE GILL, 1871

FAMILY BACULITIDAE GILL, 1871

Genus *Trachybaculites* Cobban and Kennedy, 1995

TYPE SPECIES: *Baculites columna* Morton, 1834: 44, pl. 19, fig. 8, by subsequent designation by Cobban and Kennedy, 1995: 29.

Trachybaculites sp. cf. *T. columna* (Morton, 1834)

Figure 16

Compare: *Trachybaculites columna* (Morton, 1834). Cobban and Kennedy, 1995: 29, figs. 10.1, 10.3, 13.4–13.6, 14.3, 14.9, 17.1–17.14, 17.17–17.31 (with complete synonymy).

Trachybaculites columna (Morton, 1834). Kennedy and Jagt, 1998: 161, pl. 2, figs. 1–6.

Trachybaculites columna (Morton, 1834). Klinger and Kennedy, 2001: 267, fig. 191.

MATERIAL: CSM 5612 from the Fox Hills Formation near Wellington, Larimer County, Colorado.

DESCRIPTION: The specimen is 63 mm long and is embedded in a sandstone block with the dorsum, right side, and part of the venter exposed. No sutures are visible and the specimen is presumably all body chamber. The specimen is slightly crushed and twisted but the original whorl section appears to have been compressed ovoid. Ribs are sharp, straight, and prorsiradiate on the flanks. There are four ribs in a distance equivalent to the whorl height (rib index = 4). Ribs are strong and slightly convex on the venter and weak on the dorsum.

DISCUSSION: The rib index of this specimen, which equals 4, is higher than that in other specimens of *Trachybaculites columna*, in which the rib index is 2 or 3 (Cobban and Kennedy, 1995; see especially fig. 13.4–6 with a rib index of 3). The lectotype (ANSP 72867a) and paralectotypes (ANSP 72867b–f) all have a rib index of 3 (Klinger and Kennedy, 2001: fig. 191). BHI 2035 from the Fox Hills Formation of north-central South Dakota also has a rib index of 3 (Cobban and Kennedy, 1992:683, fig. 1.7–9). Nevertheless, the size of our specimen and its coarse ribbing suggest that it is closely related to *Trachybaculites columna*.

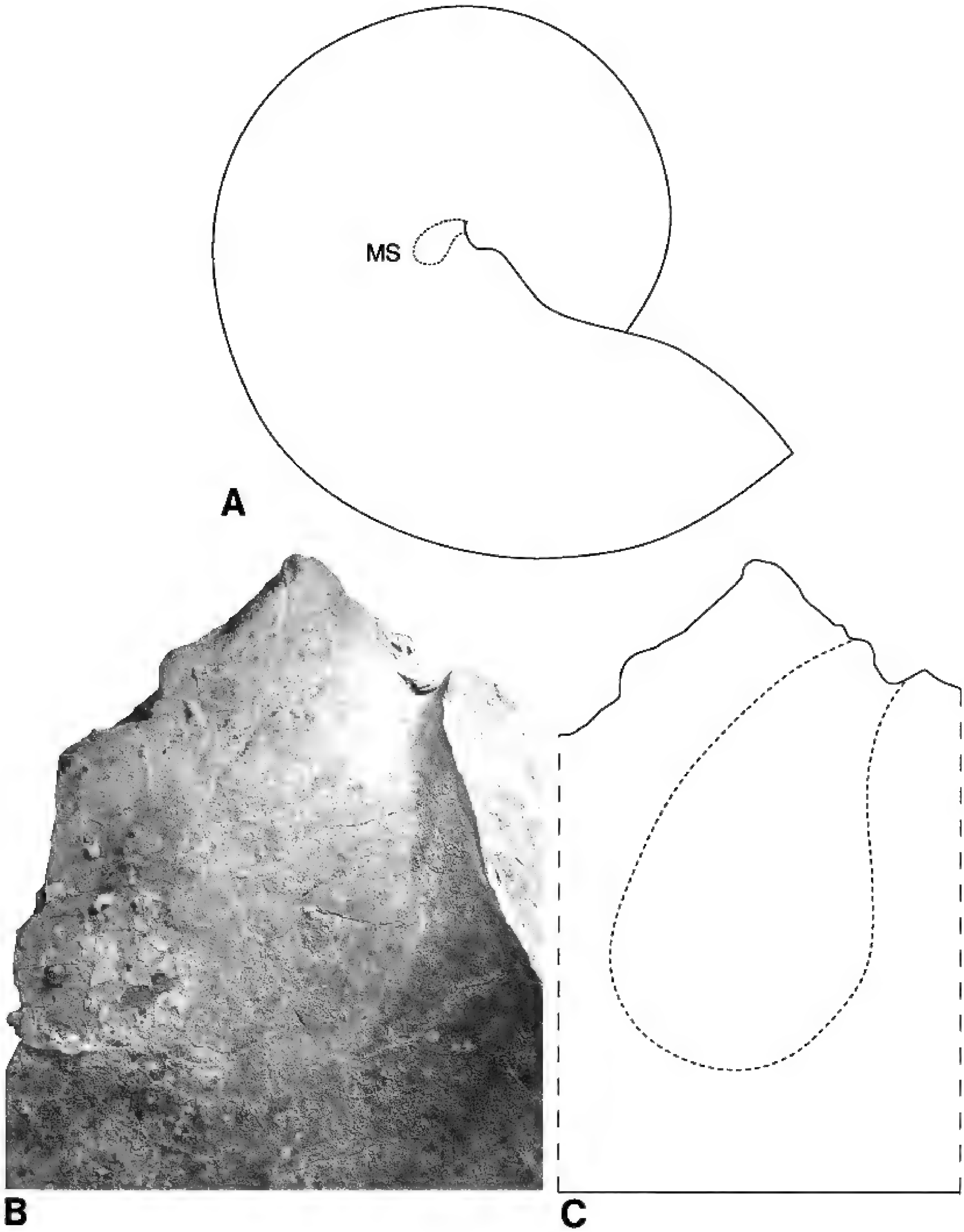


Fig. 14. *Sphenodiscus pleurisepta* (Conrad, 1857). **A–C.** USNM 519510, top of Pierre Shale or lower Fox Hills Formation, SW¼, SE¼ sec. 35, T6N, R67W, Weld County, Colorado. **A,** Sketch of reconstructed specimen showing the location of the muscle scar; **B,** close-up of the muscle scar, ×1.5; **C,** sketch of the muscle scar shown in B, ×1.5.

OCCURRENCE: This specimen is from the Fox Hills Formation near Wellington, Colorado. The only recorded specimens of *Trachybaculites columna* from the Western Interior are from the *Hoploscaphites nicolletii* and *Jeletzkytes nebrascensis* zones of the Fox Hills Formation in north-central South Dakota (Cobban and Kennedy, 1992). The species is also reported from the Prairie Bluff Chalk of Alabama and Mississippi (Cobban and Kennedy, 1995), the Corsicana Formation in Guadalupe County, Texas (Stephenson, 1941), and the Garzas Formation in the San Joaquin Valley, California (Matsumoto, 1959).

SUPERFAMILY SCAPHITACEAE GILL, 1871

FAMILY SCAPHITIDAE GILL, 1871

SUBFAMILY SCAPHITINAE GILL, 1871

GENUS HOPLOSCAPHITES NOWAK, 1911

TYPE SPECIES: *Ammonites constrictus* J. Sowerby, 1817: 189, pl. A, fig. 1, by original designation.

Hoploscaphites birkelundae

Landman and Waage, 1993

Figures 17–19, 20E–K

Hoploscaphites birkelundi Landman and Waage, 1993: 119, figs. 60, 85–90 (incorrect original spelling).

TYPE: The holotype is YPM 27172, a macroconch, as originally designated by Landman and Waage, 1993: 119, fig. 85G–K, from 50 to 60 ft (15.2 to 18.3 m) below the top of a bluff-forming bioturbated sandstone in the lower Fox Hills Formation, E½, NE¼ sec. 11, T38N, R62W, Niobrara County, Wyoming.

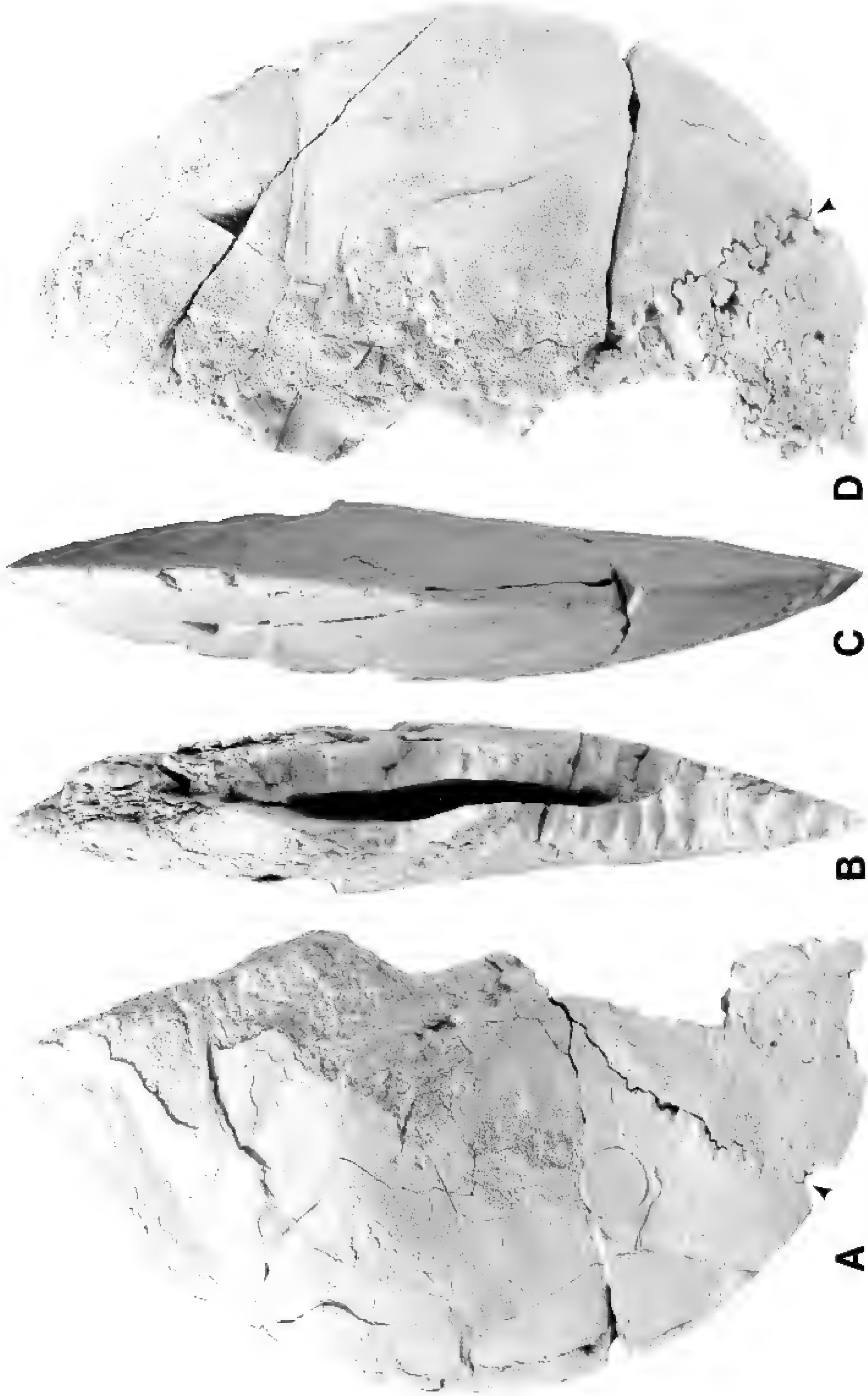
ETYMOLOGY: This species is named after Dr. Tove Birkelund who worked on Late Cretaceous scaphites from Greenland. The species name was incorrectly spelled in the original description (Dr. Birkelund was female) and is revised here, as per the rules in the International Code of Zoological Nomenclature pertaining to incorrect original spellings (article 32c).

MATERIAL: There are seven macroconchs and two microconchs: YPM 35505, a macroconch, from the Fox Hills Formation, SW¼, NE¼ sec. 31, T6N, R58W, Morgan County, Colorado (fig. 1, loc. 13); CSM 3517, a macroconch, from the Fox Hills Formation, 13 mi (20.9 km) north of Wellington, Larimer County, Colorado (fig. 1, loc. 2); CSM 7798–1, 7798–2 and 7796, all macroconchs, from the Fox Hills Formation, 4 mi (6.4 km) north and 7 mi (11.3 km) east of Fort Collins, Larimer County, Colorado (fig. 1, loc. 1); CSM 5225, a macroconch, from the Fox Hills Formation at Deadman Gulch near Golden, Jefferson County, Colorado; USNM 519503, a microconch, from the upper transition member of the Pierre Shale, NE¼, SE¼ sec. 31, T4N, R68W, Weld County, Colorado (fig. 1, loc. 12); and USNM 519504 and 519505, a microconch and macroconch, respectively, from the upper transition member of the Pierre Shale, NE¼, NW¼ sec. 30, T6N, R67W, Weld County, Colorado (fig. 1, loc. 11). There is also a scrap of a phragmocone YPM 35506 from the Fox Hills Formation, SW¼, NE¼ sec. 31, T6N, R58W, Morgan County, Colorado (fig. 1, loc. 26).

MACROCONCH DESCRIPTION: The best specimen is CSM 7796, a nearly complete macroconch (fig. 17A–D). It is missing the venter on the middle of the body chamber on the left side and nearly all of the body chamber on the right side. It is 63.0 mm in maximum length with a slightly elliptical shape in side view. The exposed phragmocone is very involute and 0.58 whorl long, ending slightly below the line of maximum length. The maximum diameter of the exposed phragmocone is 41.6 mm. The umbilicus is small with a diameter of 2.2 mm; the percentage of umbilical diameter to shell diameter is 3.5.

The body chamber is 0.54 whorl in angular length and consists of a relatively short shaft and slightly reflected hook. The shaft is straight along the dorsal margin, although there is some postmortem distortion in passing from the phragmocone to the body chamber. Most of the ventral margin of the middle of the shaft is missing; the adoral portion of the shaft and hook are tightly curved. The body chamber is only slightly extended beyond the coiled portion, leaving a very small gap. The hook is weakly reflected with an apertural angle of 50°. The apertural margin is flexuous with a slight adoral projection.

The whorl section on the middle of the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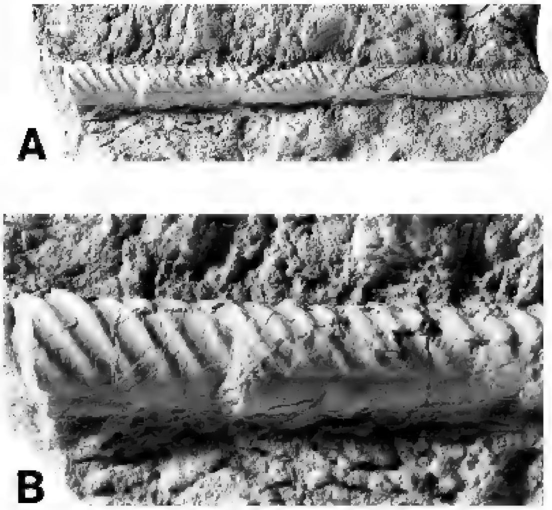

Fig. 16. *Trachybaculites* sp. cf. *T. columna* (Morton, 1834). **A, B.** CSM 5612, Fox Hills Formation, near Wellington, Larimer County, Colorado. **A,** Right lateral, ×1; **B,** close-up of adoral end, ×2.8.

exposed phragmocone is compressed ovoid; the ratio of whorl width to whorl height is 0.62. The whorl section on the adoral end of the phragmocone is also compressed ovoid with maximum width at midwhorl height; the ratio of whorl width to whorl height is 0.56. The flanks are very broadly rounded and gently slope toward the venter. The ventrolateral shoulder is sharply rounded, and the venter is very broadly rounded. Initially, the umbilical wall of the phragmocone is inclined outward and the umbilical shoulder is smoothly rounded. At the adoral end of the phragmocone, the umbilical wall is subvertical and the umbilical shoulder is abruptly rounded.

It is difficult to determine the dimensions of the body chamber because of postmortem breakage. However, the best estimate is at the point of recurvature where the whorl width and height are 18.6 mm and 24.0 mm, respectively; the ratio of whorl width to whorl height is 0.78. The whorl section is compressed ovoid with maximum width at the umbilical shoulder. Flanks are very broadly rounded to nearly flat and gently slope toward the venter. The ventrolateral shoulder is sharply rounded and the venter is very broadly rounded. Aside from the crushing of the umbilical shoulder on the adapical part of the body chamber, the umbilical wall of the shaft is steep and convex and the umbilical shoulder is sharply rounded, becoming more gently rounded toward the aperture.

The ornament consists of primary and secondary ribs that are more closely spaced on the body chamber than on the exposed phragmocone. There are tiny ventrolateral tubercles on the phragmocone and adapical part of the body chamber.

On the exposed phragmocone primary ribs are present on the umbilical shoulder. They were also undoubtedly present on the umbilical wall but are not preserved. Ribs are prorsiradiate and moderately widely spaced on the flanks. They increase by branching and intercalation at approximately one-third whorl height. Ribs swing backward on the inner one-third of the flanks, forward on the outer two-thirds, and slightly backward again near the ventrolateral shoulder. They cross the venter with a slight forward projection; there are 8 ribs/cm on the venter on the middle of the exposed phragmocone. These ribs are evenly spaced and weaken toward the adoral end of the phragmocone.

A row of tiny ventrolateral tubercles occurs on the exposed phragmocone. They become more closely spaced adorally. There are eight nontuberculate ribs between tuberculate ones on the adapical portion of the exposed phragmocone, whereas there are one or two nontuberculate ribs between tuberculate ones on the middle of the phragmocone. At the adoral end of the phragmocone, where the ventral ribs are weakest, tuberculate ribs occur at intervals of 3–4 mm, with one to three nontuberculate ribs between them. Most tubercles occur as matched pairs on either side of the venter.

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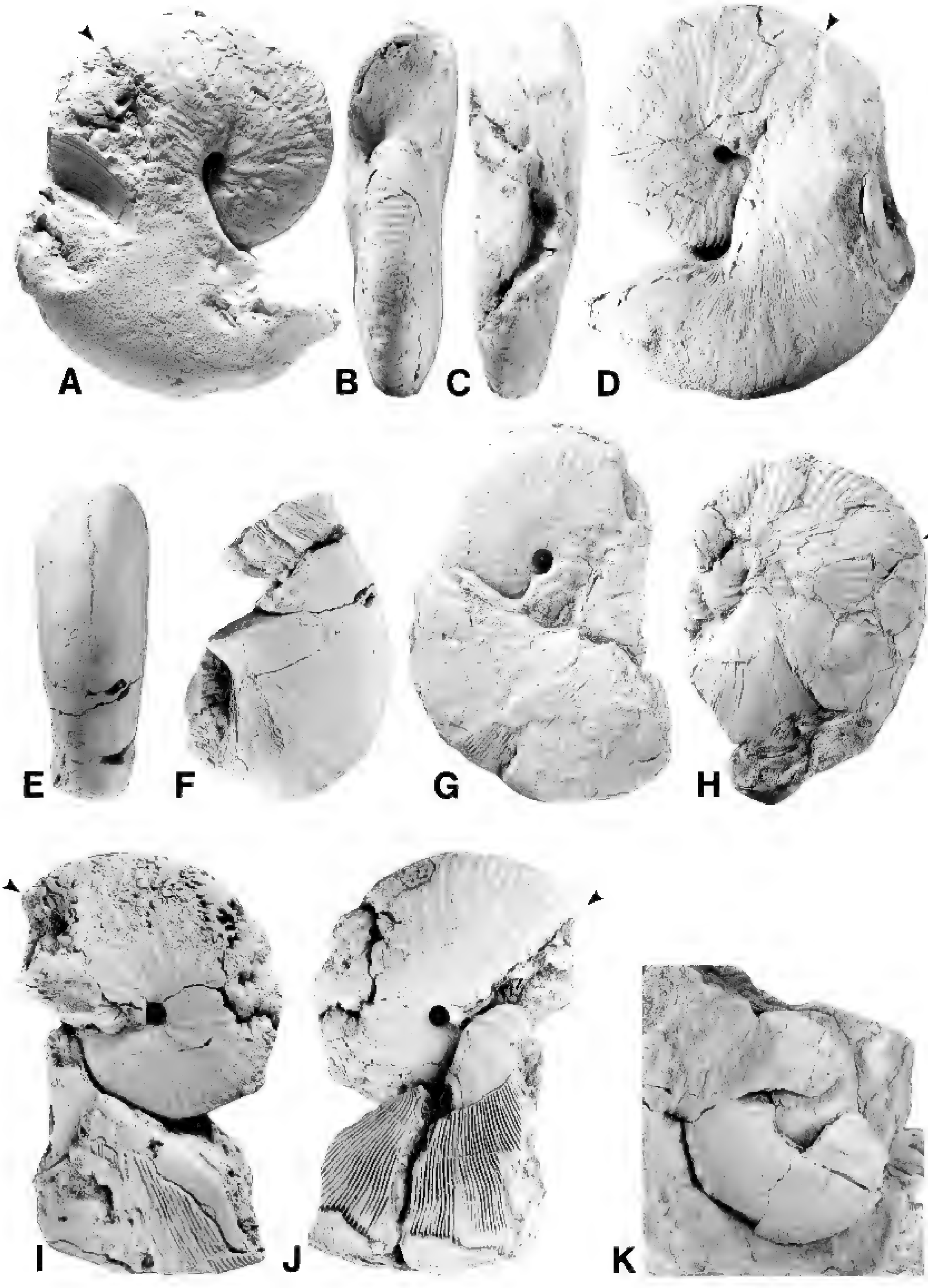
Fig. 15. *Sphenodiscus pleurisepta* (Conrad, 1857). **A–D.** USNM 519507, upper part of the Pierre Shale, NW¼ sec. 3, T2N, R68W, Weld County, Colorado. **A,** Left lateral; **B,** apertural; **C,** ventral; **D,** right lateral. All figures are ×1.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The base of the body chamber is damaged, and most of the shell except for the inner flanks is missing from the adapical half of the body chamber, so detecting the point at which the ribs become more closely spaced is difficult. However, the preserved part of the body chamber is covered with dense, fine ribbing whose appearance must be abrupt.

Ribs are closely spaced and bend backward on the umbilical wall and shoulder of the body chamber and form a concave arch on the inner one-third of the flanks. This concavity is most pronounced near the point of recurvature. Ribs are strong and widely spaced on the inner flanks on the adapical part of the shaft. They branch and intercalate at one-quarter whorl height. Where the outer shell is still retained on the adoral part of the shaft and hook, ribs are closely and evenly spaced. They are sharp, thin, prorsiradiate, and cross the flanks with a broad convexity. They bend slightly backward or straighten out on the outermost flanks, where they increase in number due to branching and intercalation. Ribs bend forward at the ventrolateral shoulder and cross the venter with a broad adoral projection; there are 14 ribs/cm on the venter on the adoral part of the shaft (table 1). Two small ventrolateral tubercles 2.5 mm apart occur on the adapical part of the body chamber.

There are several macroconchs similar to CSM 7796, although they are more fragmentary. CSM 3517 (fig. 17I, J) consists of two pieces: the adult phragmocone (internal mold) and most of the hook short of the aperture (internal mold plus some outer shell). The middle part of the body chamber is missing except for the straight umbilical shoulder. The specimen is 68.2 mm in maximum length, and the exposed phragmocone is 47.4 mm in maximum diameter. The umbilicus is small, 3.3 mm in diameter. The whorl section of the phragmocone is compressed ovoid. At the adoral end of the septate portion (presumed to be the base of the body chamber), the whorl width and height are 15.3 mm and 28.1 mm, respectively; the ratio is 0.54. The umbilical wall is steep, convex, and subvertical and the umbilical shoulder is sharply rounded. The inner flanks are nearly flat and inclined slightly outward; they reach maximum width at one-third whorl height and then converge in a broad convexity to the venter. The ventrolateral shoulder is abruptly rounded and the narrow venter is very broadly rounded. The whorl section of the body chamber at the point of recurvature is also compressed ovoid, but less compressed than that of the phragmocone, with a ratio of whorl width to whorl height of 0.61.

Ornamentation on the adoral part of the phragmocone of CSM 3517 is similar to that on CSM 7796. Ribs are broad, prorsiradiate, and moderately widely spaced. Intercalation and branching occur on the inner and outer thirds of the flanks. Ribs sweep backward on the inner one-third of the flanks and then cross the middle of the flanks with a broad convexity. They sweep forward again on the outermost flanks and cross the venter with a weak adoral projection. There are 7 ribs/cm on the venter. Only two small ventrolateral tubercles are visible at the adoral end of the phragmocone. In addition, two ribs are bullate or slightly tuberculate just below the ventrolateral shoulder. In contrast to the phragmocone, the body chamber fragment is densely and evenly covered with fine, sharp, prorsiradiate, flexuous ribs. These ribs cross the venter with a weak adoral projection; there are 14 ribs/cm on the venter (table 1).

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Fig. 17. *Hoploscaphites birkelundae* Landman and Waage, 1993. **A–D.** CSM 7796, macroconch, Fox Hills Formation, 4 mi (6.4 km) north and 7 mi (11.3 km) east of Fort Collins, Larimer County, Colorado. **A,** Right lateral; **B,** apertural; **C,** ventral; **D,** left lateral. **E, F.** CSM 5225, macroconch, Fox Hills Formation, near Golden, Jefferson County, Colorado. **E,** Ventral; **F,** left lateral. **G.** CSM 7798–1, macroconch, left lateral, same locality as A–D. **H.** CSM 7798–2, macroconch, left lateral, same locality as A–D. **I, J.** CSM 3517, macroconch, Fox Hills Formation, 13 mi (20.9 km) north of Wellington, Larimer County, Colorado. **I,** Right lateral; **J,** left lateral. **K.** USNM 519503, microconch, right lateral, upper transition member of the Pierre Shale, NE¼, SE¼ sec. 31, T4N, R68W, Weld County, Colorado. All figures are ×1.

TABLE 1
Density of Ribbing on the Body Chamber of *Hoploscaphites birkelundae* Landman and Waage, 1993

Specimen	Macroconch/ microconch	Locality	Rib density[a]
YPM 27172 (holotype)	M	Wyoming	10
YPM 27180	M	Wyoming	11
AMNH 44225	M	Wyoming	17
AMNH 47113	M	Wyoming	14
AMNH 47115	M	Wyoming	14
YPM 35505	M	Colorado	13
CSM 7796	M	Colorado	14
CSM 3517	M	Colorado	14
CSM 5225	M	Colorado	15
CSM 7798-1	M	Colorado	16/17
USNM 519505	M	Colorado	13
YPM 27210 (allotype)	m	Wyoming	19
YPM 27209	m	Wyoming	19
USNM 519504	m	Colorado	13
USMN 519503	m	Colorado	16

[a] Number of ribs/cm on the venter of the hook.

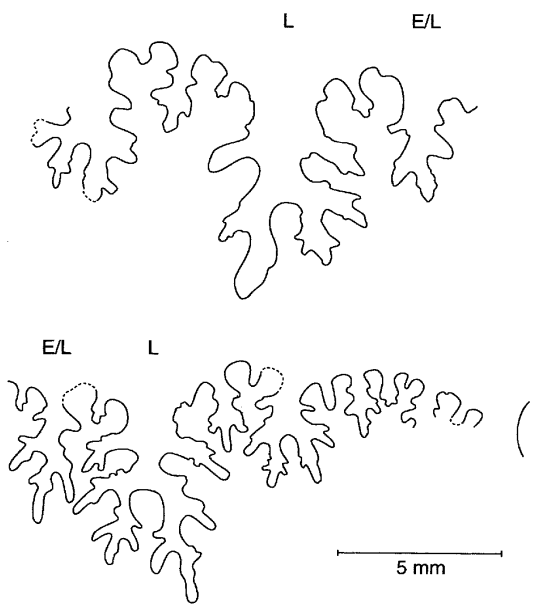


Fig. 18. Parts of two sutures of *Hoploscaphites birkelundae* Landman and Waage, 1993, CSM 3517, Fox Hills Formation, 13 mi (20.9 km) north of Wellington, Larimer County, Colorado. The sutures are drawn at whorl heights of 26.0 mm (above) and 18.7 mm (below).

On the inner flanks where the outer shell is missing, the fine ribs are extremely faint, but the swollen primary ribs are conspicuous.

Two partial sutures of CSM 3517 are illustrated in figure 18. The sutures are very similar to those of *Hoploscaphites birkelundae* published in Landman and Waage (1993: fig. 90). The first lateral lobe is narrow, bilobate, and asymmetric.

CSM 5225 is a small fragment of the hook of a body chamber (fig. 17E, F). It is notable because it retains most of its outer shell although the outermost layers have spalled off. It is densely and finely ribbed with 15 ribs/cm on the venter (table 1), all showing a slight adoral projection. There are no ventrolateral tubercles.

CSM 7798–1 is a crushed specimen with part of the phragmocone and adoral part of the body chamber preserved (fig. 17G). It is very similar to CSM 7796. The umbilicus is 3.2 mm in diameter. The phragmocone is compressed ovoid at its preserved adoral end (not the base of the body chamber) with a ratio of whorl width to whorl height of 0.50.

The umbilical wall is steep and the umbilical shoulder is sharply rounded. Flanks are very broadly rounded, converging to the venter. The ventrolateral shoulder is sharply rounded and the narrow venter is very broadly rounded. As in the other specimens, the phragmocone is covered with moderately widely spaced, prorsiradiate, flexuous ribs. The ribs swing backward on the inner one-third of the flanks and then forward, crossing the midflanks with a broad convexity. They swing slightly backward again near the ventrolateral shoulder and cross the venter with a slight adoral projection. There are 6 ribs/cm on the venter, all of which are sharp and of equal strength. In contrast, the preserved part of the body chamber is covered with dense, fine ribbing with 16 or 17 ribs/cm on the venter (table 1; no part of the venter is well enough preserved for a complete count). Ventrolateral tubercles are absent.

CSM 7798–2 is a crushed specimen showing part of the phragmocone and adapical part of the body chamber (fig. 17H). Some of the original outer shell is preserved. One feature worth noting is the presence of three small ventrolateral tubercles near the base of the body chamber.

USNM 519505 is a body chamber fragment, mostly the shaft, although the inner flanks are missing on the right side (fig. 19C, D). The broken adapical end of the specimen is assumed to be the base of the body chamber. There is crackled nacreous shell on the specimen. It is laterally crushed but was probably originally compressed with whorl height much greater than whorl width. It is ornamented with fairly large ventrolateral tubercles, umbilicolateral bullae, and prorsiradiate ribs. The estimated maximum diameter is 70.6 mm. The ribs are moderately widely spaced and weakly prorsiradiate on the adapical part of the shaft. They show a gentle convexity across the flanks. Intercalation and branching occur at the umbilicolateral bullae and on the outer one-quarter of the flanks. There are approximately 11 ribs/cm on the venter on the middle of the shaft, all of which show a slight adoral projection. Ribs become more closely spaced, prorsiradiate, and nearly straight slightly adoral of midshaft. This pattern continues to the adoral end of the specimen. There are 13 ribs/cm on the venter on the adoral part of the shaft and hook (table 1). A row of 13 fairly large ventrolateral tubercles is present (counted on the left side; the right side of the specimen is partly damaged); the tubercles increase in size adorally until the adoral end of the shaft, after which they diminish in size. They are evenly and closely spaced at distances of approximately 3.5 mm on the adapical part of the specimen. They become increasingly more widely spaced adorally so that the distance between the two most adoral tubercles is 12.5 mm. The largest tubercles are clavate in form with a steep adapical and more gradually inclined adoral side. The tubercles are paired on either side of the venter. Six weak umbilicolateral bullae are evenly spaced at distances of approximately 3–4 mm. They are slightly concave and occur on swollen primary ribs.

YPM 35505 is the smallest macroconch of *Hoploscaphites birkelundae* in our collection, with a maximum length of 47 mm (fig. 19E–H). It occurs at approximately the same locality as YPM 35506, a fragment of *H. birkelundae*, and AMNH 47400 and USNM 519515, fragments of *Jeletzkytes dorfi*. Most of the specimen is an impression in a yellowish sandy matrix, but part of the shaft and hook are preserved as three-dimensional casts. The umbilical shoulder of the shaft is straight, indicating that the specimen is a macroconch. The apertural margin is well preserved although crushed and is slightly flexuous. There is a constriction on both sides of the flanks a few millimeters adapical of the aperture, which may represent a healed injury. The whorl section of the aperture is compressed ovoid with broadly rounded flanks. The apertural angle is very low, approximately 35°. Examination of a latex peel of the impression reveals that the phragmocone is covered with moderately widely spaced ribs with broad interspaces between them. In contrast, the shaft and hook are covered with closely spaced ribs. The ribs on the shaft swing backward on the inner one-third of the flanks and then forward, crossing the outer two-thirds of the flanks with a broad convexity. Ribs become increasingly prorsiradiate toward the aperture. Intercalation and branching occur on the outer one-third of the flanks. There are 13 ribs/cm on the venter of

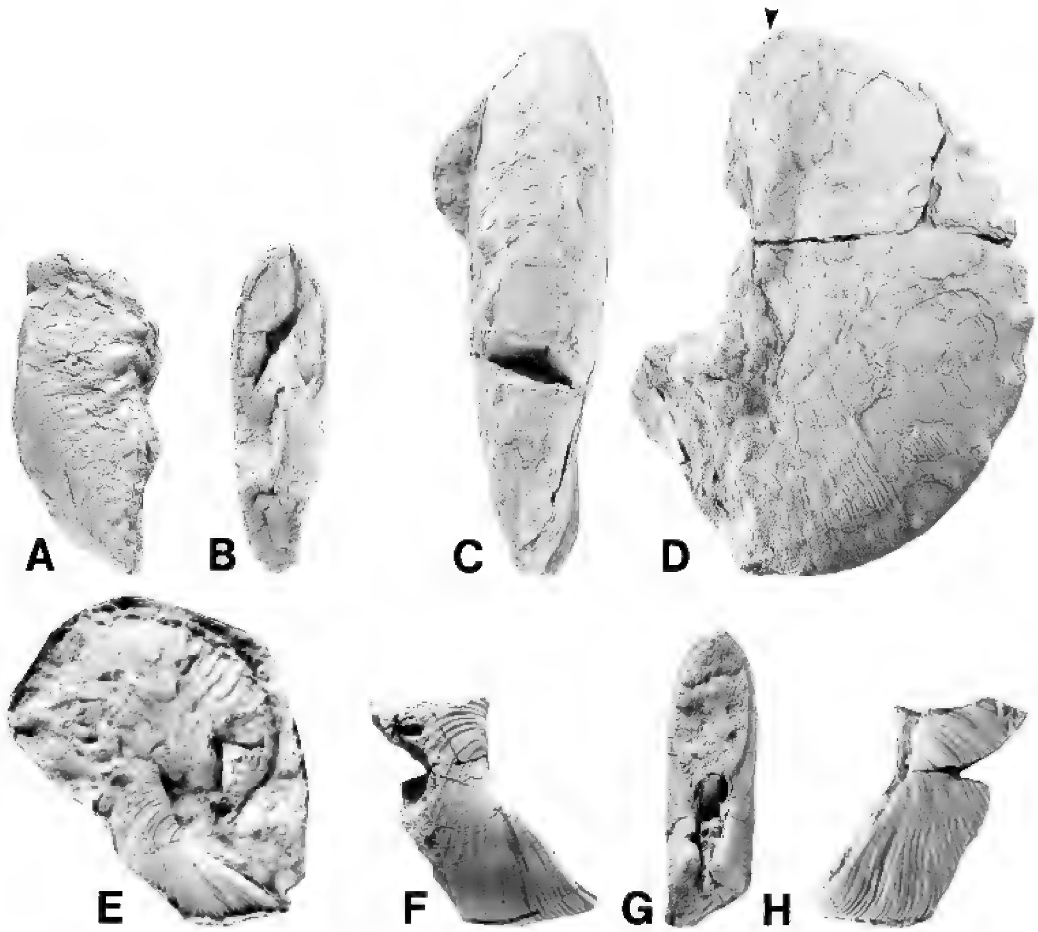


Fig. 19. *Hoploscaphites birkelundae* Landman and Waage, 1993. **A, B.** USNM 519504, microconch, upper transition member of the Pierre Shale, NE¼, NW¼ sec. 30, T6N, R67W, Weld County, Colorado. **A,** Right lateral; **B,** apertural. **C, D.** USNM 519505, macroconch, same locality as A, B. **C,** Ventral; **D,** left lateral. **E–H.** YPM 35505, small macroconch, Fox Hills Formation, SW¼, NE¼ sec. 31, T6N, R58W, Morgan County, Colorado. **E,** Right lateral of latex peel; **F,** right lateral; **G,** apertural; **H,** left lateral. All figures are ×1.

the hook (table 1). Ribs cross the venter with a moderately strong adoral projection, which strengthens toward the aperture.

MICROCONCH DESCRIPTION: USNM 519503 is a small microconch 37 mm in maximum length (fig. 17K). It is laterally crushed but was probably originally compressed. Only the right side (and an impression of it) are visible. The specimen is slightly elongate. The umbilical shoulder of the shaft is curved in side view and the umbilical wall is inclined outward. The apertural margin is slightly flexuous and bordered by a constriction. The phragmocone and shaft are covered with moderately widely spaced ribs with broad interspaces between them. Ribs are prorsiradiate and broadly convex on the shaft; they become more prorsiradiate and closely spaced on the hook, where intercalation and branching occur on the outer flanks. Ribs cross the venter with a weak adoral projection. There are 16 ribs/cm on the venter of the hook (table 1). Four umbilicolateral tubercles, somewhat bullate, are perched on the umbilical shoulder of the shaft. A row of small, closely spaced ventrolateral tubercles seems to occur on the phragmocone, but this is unclear due to crushing.

Four sharp, tiny ventrolateral tubercles are preserved on the adapical part of the shaft, where they are evenly spaced at distances of approximately 3 mm. The venter of the adoral part of the shaft is broken off, but at least one or even two ventrolateral tubercles appear adoral of the break.

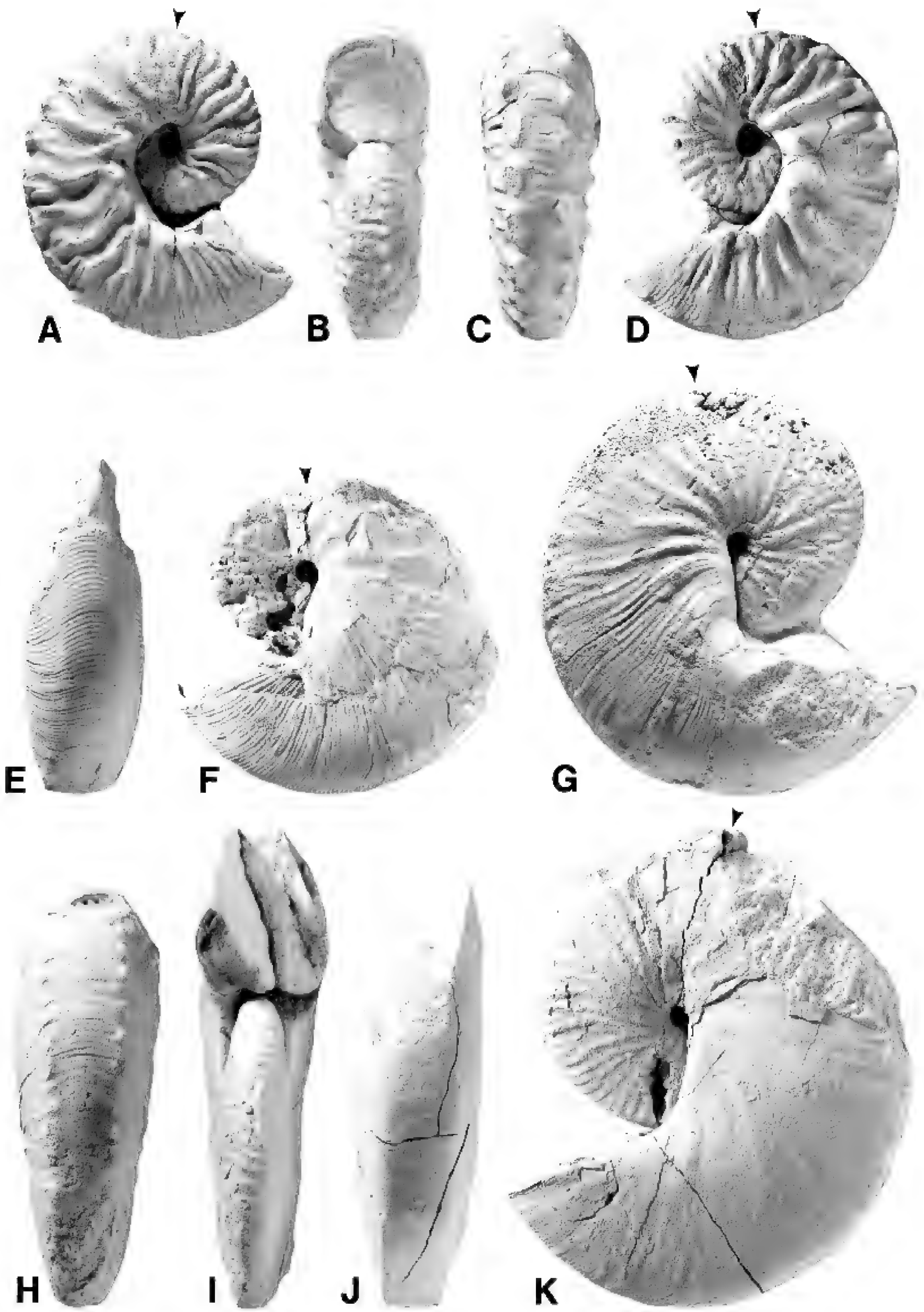
USNM 519504 is a body chamber fragment of a small microconch (fig. 19A, B) in the same collection as USNM 519505, a macroconch (fig. 19C, D). It extends from midshaft to the aperture and has some original outer shell. Although it is crushed laterally, it was probably originally compressed. The umbilical wall is broad and inclined outward. The aperture is slightly flexuous and has a moderately projected venter. There are five umbilicolateral bullae (counted on the right side) perched on the umbilical shoulder, spaced at approximately equal distances of 4–5 mm. The ribs branch and intercalate at the bullae and at two-thirds whorl height. Ribs are moderately well spaced and nearly rectiradiate on the most adapical part of the specimen, but become more closely spaced and prorsiradiate adorally. They are broadly convex on the inner two-thirds of the flanks and concave on the outer one-third and bend forward crossing the venter with a moderately strong adoral projection. There are 13 ribs/cm on the venter of the hook (table 1). A row of four ventrolateral tubercles is present (counted on the left side), the largest of which is on the adapical part of the specimen. The two most adapical tubercles are spaced 9 mm apart.

DISCUSSION: *Hoploscaphites birkelundae* is similar in appearance to *Hoploscaphites nicolletii* (Morton, 1842) and *Hoploscaphites melloi* Landman and Waage, 1993. However, there are important differences. In *H. nicolletii*, the apertural margin at maturity shows a pronounced adoral projection, whereas in *H. birkelundae*, the adoral projection is much weaker. In *H. melloi*, the pattern of fine, closely spaced ribbing first appears on the adoral part of the phragmocone, whereas in *H. birkelundae* it first appears on the middle of the shaft.

All of the specimens in our collection resemble specimens of *Hoploscaphites birkelundae* from the Fox Hills Formation in Niobrara County, Wyoming (fig. 20E–K). The phragmocone and adapical part of the body chamber are covered with moderately widely spaced prorsiradiate ribs. The ribs become finer and more closely spaced at approximately midshaft. Small ventrolateral tubercles appear on the phragmocone and extend onto the adapical part of the body chamber.

There are minor differences between the Colorado and Wyoming specimens. CSM 7796 has a low apertural angle (50°), less than the lowest value (56°) reported by Landman and Waage (1993: 125). This angle is closer to the average value of *Hoploscaphites melloi*. This specimen is also slightly more robust and less pancakelike than most of the specimens from Wyoming (fig. 20 I–K; ibid.: figs. 85F, 86E–G, 87D, E). The density of ribs on the venter of the hook (14 ribs/cm) is slightly less than the average of 17 ribs/cm reported in Landman and Waage (1993: 123) but matches the rib density on AMNH 47115 (fig. 20E, F) and AMNH 47113 (fig. 20G, H), both from Wyoming. An analysis of 11 macroconchs from Wyoming and Colorado indicates that the density of ribbing on the hook ranges from 10 to 17 ribs/cm and averages approximately 14 ribs/cm (table 1). In USNM 519505, the ventrolateral tubercles on the shaft are unusually large but are similar to those on YPM 27177 from Wyoming (ibid.: fig. 87A–C). YPM 35505 is a very small macroconch but is the same size as the smallest macroconch from Wyoming (AMNH 44225) illustrated by Landman and Waage (1993: fig. 86A). However, the apertural angle of YPM 35505 (36°) is much lower than that of AMNH 44225 (65°). Presumably all these differences reflect the range of variation within the species.

OCCURRENCE: USNM 519504 and 519505 are in the same lot as a very small fragment of *Sphenodiscus*, presumably *S. pleurisepta*. *Hoploscaphites birkelundae* occurs in the upper transition member of the Pierre Shale and Fox Hills Formation in Larimer, Weld, Morgan, and Jefferson counties, Colorado, and in the Fox Hills Formation in Niobrara County, Wyoming (Landman and Waage, 1993). The species defines a zone above *Baculites clinolobatus*, which represents the lower part of the upper Maastrichtian in the Western Interior. This species commonly co-occurs with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the ammonites *Jeletzkytes dorfi*, *Coahuilites sheltoni*, and *Sphenodiscus pleurisepta*.

Hoploscaphites sp. cf. *H. birkelundae* Landman and Waage, 1993

Figures 21, 22

Compare: *Hoploscaphites birkelundi* Landman and Waage, 1993: 119, figs. 60, 85–90 (incorrect original spelling).

MATERIAL: CSM 5209, a macroconch, from the upper transition member of the Pierre Shale, Green Mountain, near Golden, Jefferson County, Colorado (fig. 1, loc. 4).

DESCRIPTION: CSM 5209 is a large, compressed macroconch 106.8 mm in maximum length (fig. 21). It is somewhat crushed producing a slight offset from one side to the other. The specimen is an internal mold with most of the outer shell missing. The adapical part of the phragmocone and part of the venter and flanks of the body chamber are missing on the left side. The specimen is nearly circular in side view. The umbilicus is tiny but due to postmortem breakage, it is not measurable. The exposed phragmocone is 81.4 mm in maximum diameter, compressed, and very involute. It is 0.67 whorl long and terminates well below the line of maximum length. The angle between the last septum and the line of maximum length is approximately 60°.

The body chamber consists of a short shaft and slightly reflected hook. The body chamber is tightly curved in side view and is 0.44 whorl in angular length. There is very little gap, if any, between the phragmocone and reflected hook. The umbilical shoulder shows a slight bulge, especially on the left side. The apertural angle is 53.5° and the apertural margin is fairly straight with a constriction on the right side.

Despite the poor preservation, it is clear that the whorl section of the phragmocone was compressed ovoid with very broadly rounded flanks. The whorl height at the base of the body chamber is 50.4 mm. The whorl section of the body chamber is also compressed ovoid. The ratio of whorl width to whorl height at midshaft is 0.54. The umbilical wall is steep and convex and the umbilical shoulder is sharply rounded. The inner one-half of the flanks is nearly flat or inclined very slightly outward with maximum width at midwhorl height. The outer flanks converge in a broad convexity toward the ventrolateral shoulder, which is sharply rounded. The venter is very broadly rounded. At the point of recurvature, the whorl section is slightly more depressed because of a reduction in whorl height; the ratio of whorl width to whorl height is 0.68. The umbilical wall is steep and slightly convex and the umbilical shoulder is fairly sharply rounded. The flanks are very broadly rounded and converge to the ventrolateral shoulder, which is fairly sharply rounded; the venter is very broadly rounded.

Ornamentation on the exposed phragmocone consists of moderately widely spaced, broad prorsiradiate ribs. They appear swollen (or even bullate) on the adapical part of the phragmocone. They cross the venter with a slight adoral projection; there are 4 ribs/cm on the venter. Ventrolateral tubercles are preserved on the middle and adoral end of the exposed phragmocone and are evenly spaced at distances of approximately 6 mm. A row of three flank tubercles is also preserved on the middle of the phragmocone near the ventrolateral margin. Each tubercle occurs on a single rib separated by a nontuberculate rib.

The ribs on the body chamber are low and broad with wide interspaces. On the adapical part of the shaft, the ribs bend backward across the umbilical shoulder and form a weak concavity on the inner flanks. They then become broadly convex and weakly

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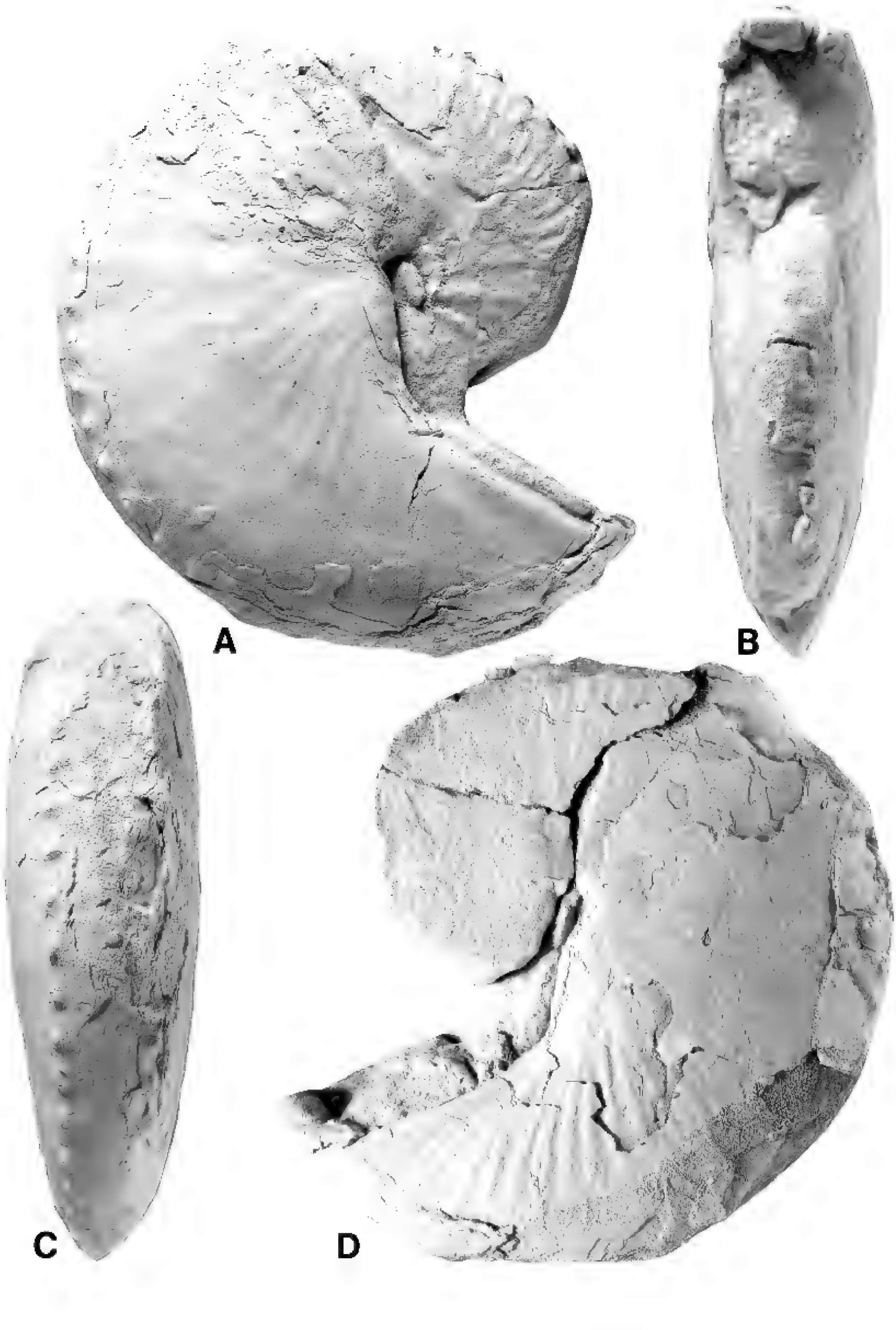
Fig. 20. **A–D.** *Jeletzkytes dorfi* Landman and Waage, 1993, AMNH 47128, microconch, lower Fox Hills Formation, near Redbird, Niobrara County, Wyoming. **A,** Right lateral; **B,** apertural; **C,** ventral; **D,** left lateral. **E–K.** *Hoploscaphites birkelundae* Landman and Waage, 1993, macroconchs, lower Fox Hills Formation, near Redbird, Niobrara County, Wyoming. **E, F.** AMNH 47115. **E,** Ventral view of hook; **F,** left lateral. **G, H.** AMNH 47113. **G,** Right lateral; **H,** ventral. **I–K.** AMNH 47114. **I,** Apertural, **J,** ventral; **K,** left lateral. All figures are ×1.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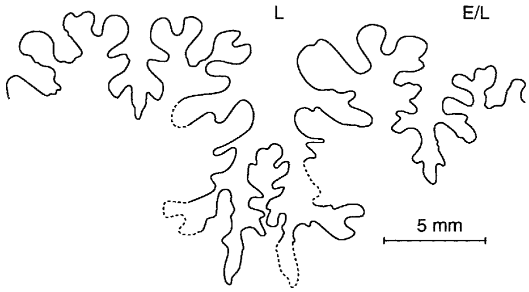

Fig. 22. Last suture of *Hoploscaphites* sp. cf. *H. birkelundae* Landman and Waage, 1993, CSM 5209, Fox Hills Formation, Green Mountain, near Golden, Jefferson County, Colorado. The suture is drawn at a whorl height of 49.2 mm.

prorsiradiate on the outer flanks. There is a patch of adapically pointed chevrons on the middle of the flanks on the left side, indicating a healed injury. On the adoral part of the shaft and hook (as shown on the left side), the ribs become increasingly prorsiradiate. They are slightly concave on the umbilical shoulder and innermost flanks but then bend markedly forward and cross the middle and outer flanks in a weak convexity. The spacing between rib crests at midflank at the point of recurvature is approximately 4.5 mm. Ribs are not preserved on the venter of the body chamber. Even where shell is present on the adapical part of the shaft, there are no ventral ribs. Ventrolateral tubercles occur on the entire body chamber nearly to the aperture; they may indeed extend to the aperture, but the outer shell is not preserved there. The tubercles are more or less evenly spaced at intervals of 6–8 mm and are paired across the venter.

The last few sutures are preserved but they are strongly approximated and difficult to draw. A portion of the last suture, including parts of the first and second lateral saddles and the first lateral lobe, is illustrated in figure 22. The suture is similar to that of *Hoploscaphites birkelundae* except that the first lateral lobe is unusually narrow and the second lateral saddle is unusually wide.

DISCUSSION: This specimen is very similar to *Hoploscaphites birkelundae* in its ornamentation and proportions (see Landman and Waage, 1993: figs. 85F, 86E–G, 87D, E). However, it is much larger than any previously described specimen of this species. It is 106.8 mm in maximum length whereas the largest specimen of *H. birkelundae* described by Landman and Waage (1993: 125) is 76.5 mm in maximum length. As we develop a better understanding of the intraspecific variation within *H. birkelundae*, we may discover that this large specimen represents the upper size limit of the species. Indeed, in other species of *Hoploscaphites*, macroconchs show a broad variation in size (see Landman and Waage, 1993: figs. 58, 75). We presently refer this specimen to *Hoploscaphites* sp. cf. *H. birkelundae*.

OCCURRENCE: Upper transition member of the Pierre Shale, Jefferson County, Colorado.

Genus *Jeletzkytes* Riccardi, 1983

TYPE SPECIES: *Scaphites nodusus* Owen, 1852: 481, pl. 18, fig. 4, by original designation.

Jeletzkytes dorfi Landman and Waage, 1993
Figures 20A–D, 23

Jeletzkytes dorfi Landman and Waage, 1993: 184, figs. 141–148.
Jeletzkytes dorfi Landman and Waage, 1993. Jagt and Kennedy, 1994: 242, fig. 3A–E.

TYPE: The holotype is YPM 23175, a macroconch, as originally designated by Landman and Waage, 1993: 184, fig. 141A–E, from a bluff-forming bioturbated sandstone in the lower Fox Hills Formation, SE¼, SW¼ to SE¼, SE¼ sec. 18, T37N, R62W, Niobrara County, Wyoming.

MATERIAL: There are six microconchs: USNM 519513 from the Fox Hills Formation, NE¼, SW¼ sec. 2, T9S, R76W, Park County, Colorado; USNM 519514 from the Fox Hills Formation near Round Butte, Larimer County, Colorado (fig. 1, loc. 6);

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Fig. 21. *Hoploscaphites* sp. cf. *H. birkelundae* Landman and Waage, 1993. **A–D.** CSM 5209, upper transition member of the Pierre Shale, Green Mountain, near Golden, Jefferson County, Colorado. **A,** Right lateral; **B,** apertural; **C,** ventral; **D,** left lateral. All figures are ×1.

USNM 519512 from the Fox Hills Formation just south of the Wyoming border and east of Round Butte, Larimer County, Colorado (fig. 1, loc. 9); USNM 519515 from the Fox Hills Formation, center sec. 31, T6N, R58W, Morgan County, Colorado (fig. 1, loc. 8); CSM 7797 from the Fox Hills Formation, 4 mi (6.4 km) north and 7 mi (11.3 km) east of Fort Collins, Larimer County, Colorado (fig. 1, loc. 1); and USNM 519516 from near the top of the Pierre Shale or lower part of the Fox Hills Formation, SW¼, SE¼ sec. 35, T6N, R67W, Weld County, Colorado (fig. 1, loc. 20). There are also four specimens too fragmentary to determine the dimorph: CSM 7799 from the Fox Hills Formation, 11 mi (17.7 km) north of Wellington, Larimer County, Colorado (fig. 1, loc. 3); AMNH 47399 from the upper transition member of the Pierre Shale, sec. 11, T4N, R70W, Jefferson County, Colorado (fig. 1, loc. 22); AMNH 47400 from the Fox Hills Formation, SW¼, NE¼ sec. 31, T6N, R58W, Morgan County, Colorado (fig. 1, loc. 23); and AMNH 47398 from the Milliken Sandstone Member of the Fox Hills Formation, SE¼, NE¼ sec. 7, T2N, R68W, Boulder County, Colorado (fig. 1, loc. 24).

MICROCONCH DESCRIPTION: USNM 519512 is an internal mold with part of the phragmocone and aperture missing (fig. 23E–G). The base of the body chamber is not apparent. The umbilical shoulder of the shaft of the body chamber is curved in side view. The cross section at midshaft is subquadrate to trapezoidal with maximum width at the umbilical shoulder in both costal and intercostal section. The umbilical wall is broad and inclined outward and the umbilical shoulder is sharply rounded. The flanks are nearly flat and converge toward the venter. The ventrolateral shoulder is sharply rounded and the venter is very broadly rounded to flat.

The specimen is characterized by coarse ribbing and large umbilicolateral and ventrolateral tubercles, in addition to small flank tubercles on the adoral part of the phragmocone. Ribs on the phragmocone are coarse and widely spaced. Near the adoral end of the phragmocone, they swing slightly backward across the umbilical wall and shoulder, then forward, increasing in strength and crossing the flanks with a weak convexity. They bifurcate or intercalate at midwhorl height. Ribs are broad and weak on the venter, which they cross with a very slight adoral projection. There are 5 ribs/cm on the venter at the adoral end of the phragmocone/adapical end of the body chamber. Ribs are barlike on the umbilical wall of the shaft. They are weakly convex on the flanks with broad interspaces between them; the distance between successive rib crests at midflank is 3–4 mm. The venter is smooth but undulose, with swellings joining pairs of ventrolateral clavi on either side of the venter. Primary ribs swell into fairly massive umbilicolateral clavi, which are especially noticeable on the right side, where there are four of them. The two most adoral clavi are spaced approximately 9 mm apart. Ventrolateral tubercles are also very prominent and are projected outward and backward and become more widely spaced and larger toward the adoral end of the specimen. They are spaced at distances of 3–5 mm on the adapical end of the specimen and 9 mm on the adoral end. The tubercles are clavate in shape with steep adapical sides and more gently sloping adoral sides. Tubercles are generally paired across the venter. Two short rows of flank tubercles occur on the adapical end of the specimen. On the left side, there are two pairs of tubercles, one pair on each of two ribs; on the right side, there is a pair of tubercles on one rib and single tubercles on each of two ribs.

USNM 519513 is a microconch still embedded in the matrix with most of the phragmocone missing (fig. 23O, P). It is an internal mold 53.8 mm in maximum length. The umbilical shoulder is curved in side view and follows the curvature of the venter. The whorl section at midshaft is compressed subquadrate with maximum width at the umbilical shoulder in costal section and at one-third whorl height in intercostal section. The umbilical wall is broad and inclined outward and the umbilical shoulder is sharply rounded. Flanks are very broadly rounded, and the ventrolateral shoulder is sharply rounded. The venter is very broadly rounded to nearly flat.

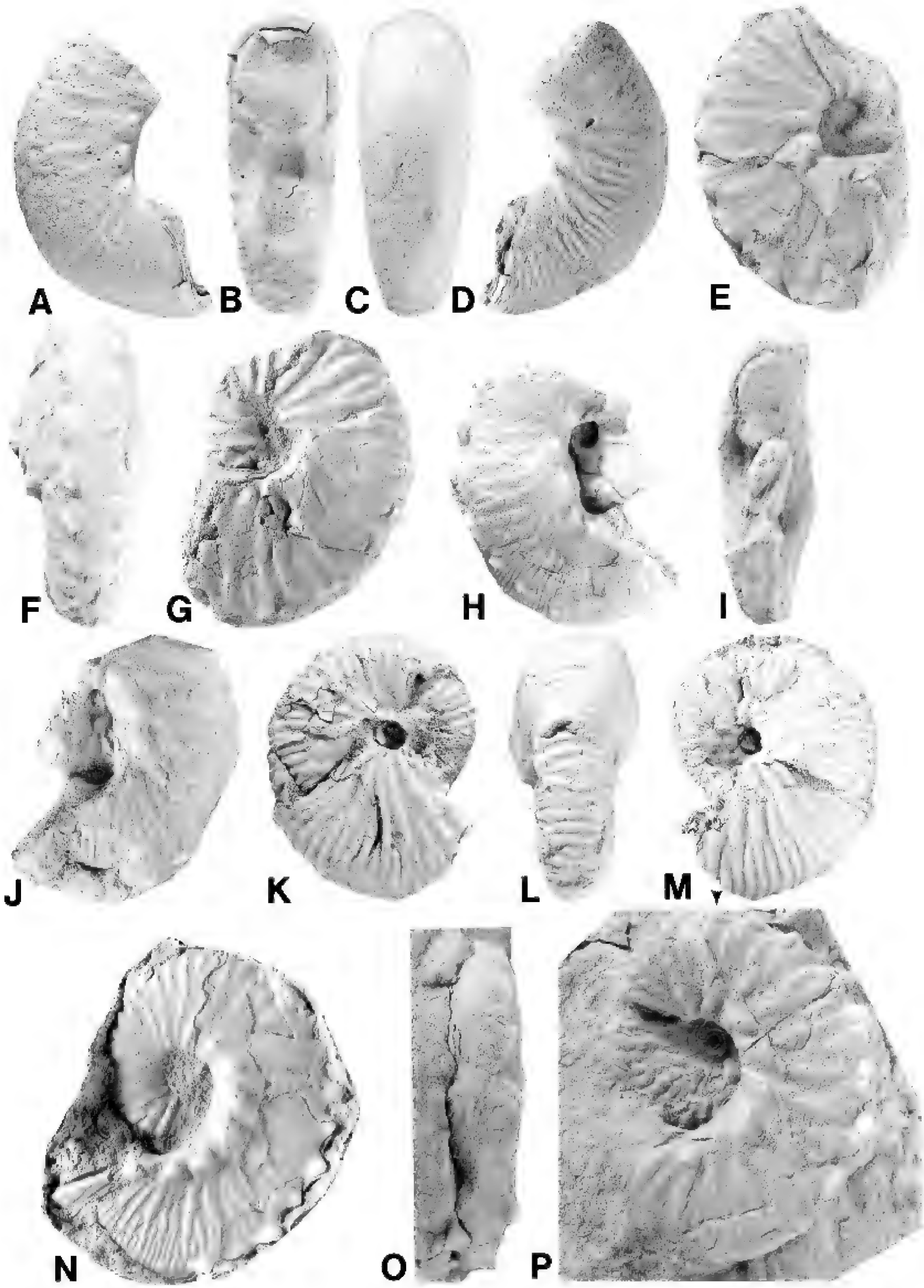
As in other microconchs of *Jelezkytes dorfi*, this specimen is characterized by coarse ribbing, prominent umbilicolateral and ventrolateral clavi, and partial rows of flank tubercles on the adoral portion of the phragmocone. Ribs are strong, prorsiradiate, and straight on the preserved part of the phragmocone, with intercalation at one-third whorl height. Several ribs bear one or two small flank tubercles, and all ribs, at least those preserved, bear ventrolateral tubercles. The ribs cross the venter with a weak adoral projection, and there are 7 to 8 ribs/cm on the venter on the adoral part of the phragmocone. Primary ribs are straight, prorsiradiate, and barlike on the umbilical wall of the shaft. They merge into prominent umbilicolateral clavi that are fairly uniformly spaced at distances of 4–5 mm. One clavus clearly shows a steep, concave adapical side and more gradually sloping adoral side. Two prorsiradiate ribs branch from each clavus, the more adoral one of which is more prorsiradiate and convex. These ribs are separated by broad interspaces. Branching and intercalation occur on the outer one-third of the flanks, especially on the adoral part of the shaft and hook. As a consequence, the ribbing is denser on the ventrad part of the shell. Large clavi occur on the ventrolateral margin. They increase in size adorally, reaching their largest size (3.5 mm in height) at midshaft, after which they diminish in size. They also gradually become more widely spaced adorally; the distance between successive clavi at midshaft is 9–10 mm. The clavi are sharp and projected backward and outward. Each shows a steep adapical side and more gently sloping adoral side. Two clavi show small grooves along their midlines. There are no ribs on the venter but it is slightly undulose, with swellings joining pairs of ventrolateral clavi on either side of the venter.

USNM 519514 is an impression of a microconch in a chunk of sandstone (fig. 23N). The specimen is approximately 56 mm in maximum length. Like the other microconchs, it is characterized by coarse ribbing and prominent umbilicolateral and ventrolateral tubercles/clavi, in addition to a partial row of flank tubercles on what is presumably the adoral part of the phragmocone. Ribs are widely spaced and rectiradiate or prorsiradiate on the midshaft. Ribs become more closely spaced and prorsiradiate on the adoral part of the shaft and hook. Intercalation and branching occur on the outer one-third of the flanks on the midshaft and nearer the middle of the flanks on the hook. Approximately 9 ribs/cm are present on the flanks on the adoral part of the shaft. Eight more or less evenly spaced umbilicolateral tubercles occur at distances of 5–6 mm; they attain their maximum height at midshaft. Ventrolateral clavi are also approximately evenly spaced on the shaft at distances of 7 mm. They disappear abruptly (or diminish to a tiny tubercle) at the adoral end of the shaft.

USNM 519515 is a small body chamber fragment, mostly an internal mold, part of which is worn away (fig. 23A–D). The umbilical shoulder is curved in side view. The apertural margin is slightly flexuous with a weak adoral projection at the venter; the dorsal lappet is not preserved. The whorl section at midshaft is subquadrate. The umbilical wall is broad and slanted outward and the umbilical shoulder is sharply rounded. Flanks are very broadly rounded with maximum width at the umbilicolateral tubercles in costal section and at one-third whorl height in intercostal section. Flanks gradually converge toward the venter. The ventrolateral shoulder curves gently into a moderately well-rounded venter. The ratio of whorl width to whorl height in intercostal section at midshaft is 0.83. The aperture is more ovoid in cross section, with an intercostal ratio of whorl width to whorl height of 0.91.

The body chamber is covered with ribs and umbilicolateral tubercles. Ribs on the shaft are broad and slightly prorsiradiate with wide interspaces between them, becoming more prorsiradiate and closely spaced on the hook. Intercalation and branching occur on the middle and outer flanks. Ribs cross the venter with a moderately strong adoral projection; there are 10 ribs/cm on the venter of the hook. The body chamber bears five umbilicolateral tubercles, which are sites of branching and intercalation. These tubercles occur at equal distances of approximately 5 mm. Ventrolateral tubercles are worn off but there are still swellings on the shaft.

CSM 7797 is a small slightly distorted microconch with half of the phragmocone missing (fig. 23H–J). It is approximately 47.4 mm in maximum length and is elongate in outline with only a slight gap between the hook and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phragmocone. The umbilicus is large, 3.9 mm in diameter, and the umbilical shoulder is curved in side view. The aperture is slightly flexuous with part of the dorsal lappet exposed. The right side of the midshaft is inflated, possibly due to a healed injury. The whorl section at midshaft, based on the left side of the specimen, is nearly quadrate, with maximum width at the umbilical shoulder in costal section and at one-third whorl height in intercostal section. The umbilical wall is broad, convex, and inclined outward. The umbilical shoulder is sharply rounded and the flanks are broadly rounded, converging toward the venter. The ventrolateral shoulder is sharply rounded and the venter is very broadly rounded. The ratio of whorl width to whorl height at mid-shaft is approximately 0.76.

Ribs on the adapical part of the phragmocone are coarse and widely spaced. They are equally widely spaced on the middle of the shaft, but become more closely spaced and prorsiradiate on the adoral part of the shaft and hook, with intercalation and branching occurring on the middle and outer flanks. Ribs cross the venter with a weak adoral projection; there are 9 ribs/cm on the venter of the hook. Six umbilicolateral tubercles are perched on the umbilical shoulder. They are spaced at equal distances of approximately 5 mm at midshaft. There are nine ventrolateral tubercles on the body chamber, which are more or less evenly spaced at distances of 6–8 mm. The largest and most clavate tubercles occur at midshaft.

DISCUSSION: *Jeletzkytes dorfi* is characterized by moderately widely spaced ribbing, which becomes more closely spaced on the hook, umbilicolateral and ventrolateral tubercles/clavi, and partial rows of flank tubercles on the adoral part of the phragmocone. These features are well illustrated in specimens from Niobrara County, Wyoming (fig. 20A–D; Landman and Waage, 1993: figs. 141–146). The specimens in our collection match those from Wyoming with two exceptions. USNM 519515 lacks ventrolateral tubercles. However, this is a worn specimen and the tubercles have probably eroded away. CSM 7797 is a very small specimen with an estimated maximum length of 47.4 mm. However, it is only slightly smaller than the smallest specimen from Wyoming (48.9 mm) recorded by Landman and Waage (1993: 192).

OCCURRENCE: AMNH 47400 occurs at the same locality as YPM 202272, a small belemnite. USNM 519516 is in the same lot as USNM 519510 and 519519, both specimens of *Sphenodiscus pleurisepta*. *Jeletzkytes dorfi* occurs in the upper part of the Pierre Shale and Fox Hills Formation in Larimer, Weld, Morgan, Park, Boulder, and Jefferson counties, Colorado, and in the Fox Hills Formation in Niobrara County, Wyoming (Landman and Waage, 1993). It occurs in the *Hoploscaphites birkelundae* Zone and is commonly associated with the ammonites *Hoploscaphites birkelundae*, *Coahuilites sheltoni*, and *Sphenodiscus pleurisepta*. *Jeletzkytes dorfi* has also been reported from the lower upper Maastrichtian of Belgium (Jagt and Kennedy, 1994).

Jeletzkytes sp. cf. *J. dorfi* Landman and Waage, 1993

Figure 24

Compare: *Jeletzkytes dorfi* Landman and Waage, 1993: 184, figs. 141–148.

←

Fig. 23. *Jeletzkytes dorfi* Landman and Waage, 1993, microconchs. **A–D.** USNM 519515, Fox Hills Formation, center sec. 31, T6N, R58W, Morgan County, Colorado. **A,** Right lateral; **B,** apertural; **C,** ventral; **D,** left lateral. **E–G.** USNM 519512, Fox Hills Formation, just south of the Wyoming border and east of Round Butte, Larimer County, Colorado. **E,** Right lateral; **F,** ventral; **G,** left lateral. **H–J.** CSM 7797, Fox Hills Formation, 4 mi (6.4 km) north and 7 mi (11.3 km) east of Fort Collins, Larimer County, Colorado. **H,** Right lateral; **I,** apertural; **J,** left lateral. **K–M.** CSM 7799, Fox Hills Formation, 11 mi (17.7 km) north of Wellington, Larimer County, Colorado. **K,** Right lateral; **L,** ventral; **M,** left lateral. **N.** USNM 519514, left lateral of latex peel, Fox Hills Formation, near Round Butte, Larimer County, Colorado. **O, P.** USNM 519513, Fox Hills Formation, NE¼, SW¼ sec. 2, T9S, R76W, Park County, Colorado. **O,** Ventral; **P,** left lateral. All figures are ×1.

MATERIAL: USNM 519511 from near the base of the upper transition member of the Pierre Shale, SW¼, SE¼ sec. 2, T1N, R70W, Boulder County, Colorado (fig. 1, loc. 7).

DESCRIPTION: USNM 519511 is a large, robust, elongate macroconch (fig. 24). It is an internal mold; a portion of the phragmocone and the midflanks of the body chamber are crushed, so that the elongate form of the specimen may be due in part to postmortem distortion. The left side of the specimen and most of the venter are not preserved. It is difficult to pinpoint the position of the base of the body chamber but it is probably near the line of maximum length. The specimen is 117.7 mm in length. It is clearly a macroconch because the umbilical shoulder of the body chamber is straight in side view and shows a slight bulge. The hook is only slightly separated from the phragmocone; the apertural angle is estimated at 47°, to the extent that it can be measured at all, given that the tip of the aperture is missing. The umbilicus is 6.5 mm in diameter.

The whorl section of the adapical part of the phragmocone is compressed subquadrate. The umbilical wall is inclined outward, the umbilical shoulder is moderately well rounded, and the flanks are broadly rounded. The ventrolateral shoulder is sharply rounded and the venter is very broadly rounded to flat. The whorl section becomes more compressed with an increase in whorl height toward the line of maximum length, but it is unclear how much of this change is due to crushing. The umbilical wall is steep and subvertical, and the umbilical shoulder is sharply rounded. The flanks are very broadly rounded and gently slope toward the ventrolateral shoulder. The ventrolateral shoulder is sharply rounded and the venter is nearly flat. The whorl section at midshaft is compressed subquadrate; the ratio of whorl width to whorl height is 0.84. The umbilical wall is strongly convex and the umbilical shoulder is fairly sharply rounded. The flanks are very broadly rounded with maximum width at midwhorl height. The ventrolateral shoulder is fairly sharply rounded, and the venter is very broadly rounded. The whorl section becomes equidimensional at the point of recurvature because of a reduction in whorl height; the ratio of whorl width to whorl height is 1.00.

Ornament on the phragmocone is visible on the adapical part on the right side. Ribs are prorsiradiate, coarse, and widely spaced, with intercalation and branching on the outer flanks. Each long rib bears three or four flank tubercles and each short rib bears one or two tubercles, so that there are four rows of flank tubercles, with the outermost row being the most persistent. The innermost row probably represents a continuation of the row of umbilicolateral tubercles on the body chamber, but because of postmortem crushing, it is difficult to trace these tubercles onto the body chamber. The ribs bend forward near the ventrolateral margin and cross the venter with a very weak adoral projection; there are 5 ribs/cm on the venter. Ventrolateral tubercles are evenly spaced at distances of approximately 5 mm and are paired on either side of the venter. They are larger and more widely spaced than the outermost flank tubercles.

The body chamber is also covered with strong, widely spaced ribs with broad interspaces between them. Intercalation and branching occur on the outermost flanks. On the adapical part of the shaft, the ribs are rectiradiate and cross the flanks with a broad convexity. At midshaft, the ribs are rectiradiate on the umbilical wall and recti- or slightly prorsiradiate on the flanks. They form a slight concavity on the innermost flanks and a broad convexity on the middle and outer flanks. They are widely spaced on the outer flanks with interspaces of approximately 5 mm between them at midshaft. Ribs become progressively more prorsiradiate toward the aperture. The ribs bend forward on the hook near the ventrolateral margin, accompanied by branching and intercalation. No ribs are preserved on the venter. Umbilicolateral tubercles occur on the entire body chamber and form a broad arc along the inner flanks although, in general, only the bases of the tubercles are preserved. They attain maximum size and spacing (approximately every 8 mm) at midshaft. Ventrolateral tubercles are preserved on the adapicalmost and adoralmost parts of the body chamber (they are absent on the middle part but were no doubt worn away). These tubercles are evenly spaced on the hook at distances of approximately 6–7 mm and are slightly offset from one side of the venter to the other. A row of tubercles

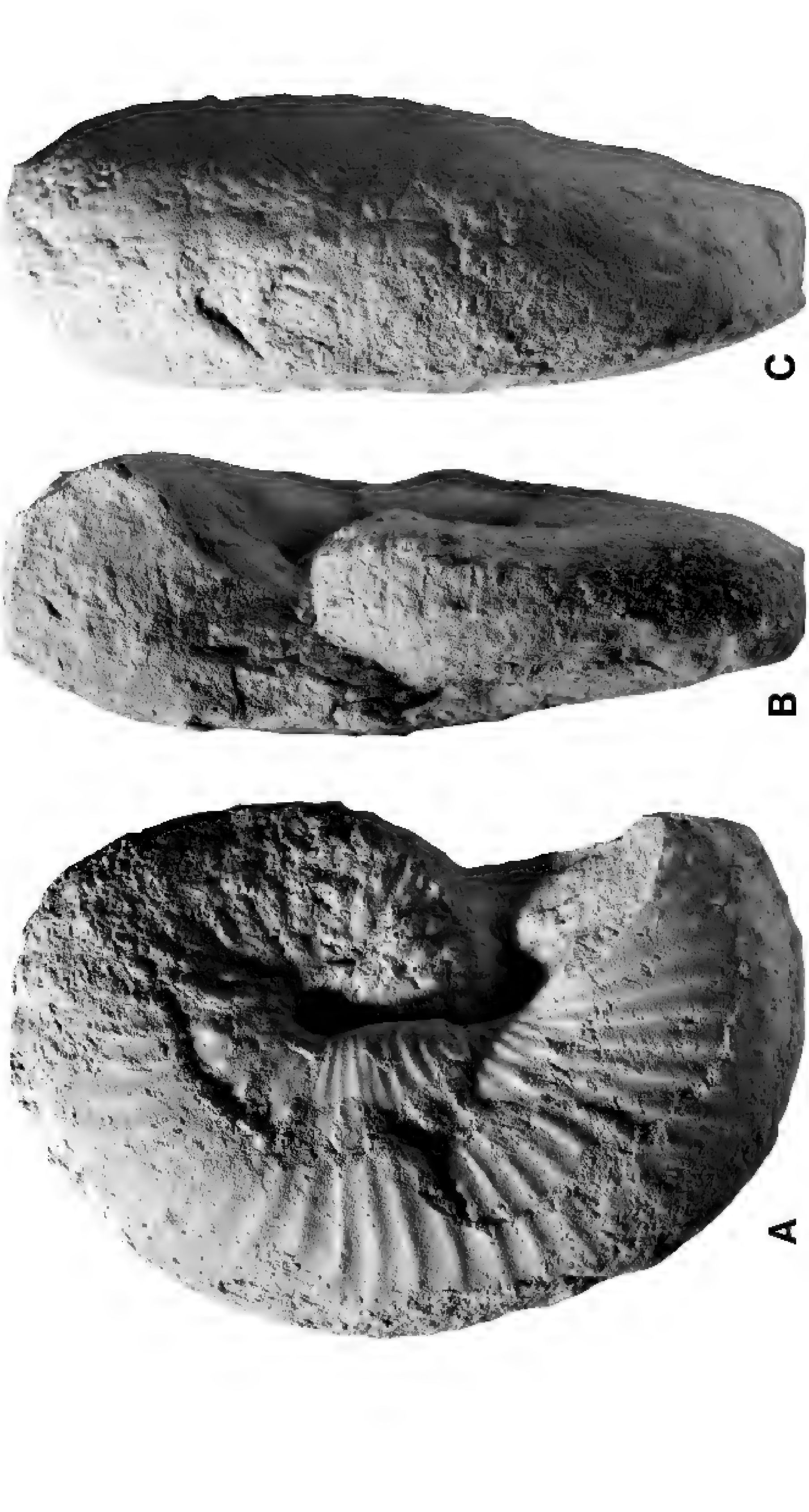

Fig. 24. *Jeletzkytes* sp. cf. *J. dorfi* Landman and Waage, 1993. **A–C.** USNM 519511, macroconch, base of upper transition member of the Pierre Shale, SW¼, SE¼ sec. 2, T1N, R70W, Boulder County, Colorado. **A,** Right lateral; **B,** apertural; **C,** ventral. All figures are ×1.

occurs on the outermost flanks of the hook. These tubercles are evenly spaced at distances of approximately 5 mm and are the sites of intercalation and branching. Another tiny tubercle is visible near the aperture on the middle of the flanks.

DISCUSSION: This is a very robust specimen characterized by coarse ribbing, umbilico- and ventrolateral tubercles, multiple rows of flank tubercles on the adapical part of the phragmocone, and a single row of flank tubercles on the hook. In these respects, it matches the description of *Jeletzkytes dorfi* Landman and Waage, 1993. In terms of shell shape and coarseness of ribbing, it most closely resembles YPM 23176 from Wyoming (Landman and Waage, 1993: fig. 142A–D). However, our specimen differs from *J. dorfi* in its large size. It is 117.7 mm in maximum length, whereas the largest specimen of *J. dorfi* recorded by Landman and Waage (1993: 192) is 104.6 mm in maximum length. It also differs in its low apertural angle (47°). In contrast, the lowest apertural angle reported by Landman and Waage (1993: 192) is 53°.

OCCURRENCE: This specimen was collected near the base of the upper transition member of the Pierre Shale, Boulder County, Colorado. The label refers to impressions of *Baculites clinolobatus* 20 ft (6.1 m) below this specimen, suggesting that this specimen is in or just above the *B. clinolobatus* Zone, in the *Hoploscaphites birkelundae* Zone.

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APPENDIX

Occurrences of *Sphenodiscus pleurisepta* (Conrad, 1857) or *Coahuilites sheltoni* Böse, 1928, or both, in Colorado, Wyoming, and South Dakota, as indicated on figure 11.

1. USGS loc. D2121. NE¼ sec. 14, T38N, R62W, Niobrara County, Wyoming, Pierre Shale, 93–104 ft (28.4–31.7 m) below top, *Baculities clinolobatus* Zone.
2. USGS loc. D1049. NW¼ sec. 25, T39N, R62W, Niobrara County, Wyoming, Fox Hills Formation, 145 ft (44.2 m) above base, *Hoploscaphites birkelundae* Zone.
3. USGS loc. 10707. Sec. 24, T33N, R83W, Natrona County, Wyoming, Fox Hills Formation.
4. USGS loc. D5474. SE¼ sec. 24, T25N, R86W, Carbon County, Wyoming, Lewis Shale, lower part.
5. USGS loc. D6295. SW¼ sec. 10, T20N, R83W, Carbon County, Wyoming, Lewis Shale, upper part.
6. USGS loc. D6276. NW¼ sec. 14, T20N, R83W, Carbon County, Wyoming, Fox Hills Formation, 30 ft (9.1 m) above base, *Baculites clinolobatus* Zone.

7. USGS loc. 9363. NW¼ sec. 18, T21N, R80W, Carbon County, Wyoming, Lewis Shale, upper part.
8. USGS loc. D5540. NW¼ sec. 11, T21N, R79W, Carbon County, Wyoming, Fox Hills Formation, 30 ft (9.1 m) above base, *Baculites clinolobatus* Zone.
9. USGS loc. 5199. Sec. 14, T23N, R103W, Sweetwater County, Wyoming.
10. USGS loc. D6871. Center sec. 3, T20N, R101W, Sweetwater County, Wyoming, Almond Formation, 100 ft (30.5 m) below top.
11. USGS loc. D10213. SW¼ sec. 17, T22N, R102W, Sweetwater County, Wyoming, Almond Formation, near top.
12. USGS loc. D8133. SW¼ sec. 9, T6N, R93W, Moffat County, Colorado, Lewis Shale, lower part of Dad Sandstone Member.
13. USGS loc. 8360. 1 mi east of Fortification Creek in Lay area, Moffat County, Colorado.
14. USGS loc. D6446. SW¼ sec. 13, T7N, R88W, Routt County, Colorado, Lewis Shale, *Baculites clinolobatus* Zone.
15. USGS loc. D6447. SW¼ sec. 13, T7N, R88W, Routt County, Colorado, Lewis Shale, *Baculites clinolobatus* Zone.
16. NW¼ sec. 22, T9N, R87W, Routt County, Colorado, Lewis Shale.
17. USGS loc. 5714. Sec. 31, T8N, R66W, 5 mi (8 km) west and 2.5 mi (4 km) north of Ault, Weld County, Colorado, Fox Hills Formation, *Hoploscaphites birkelundae* Zone.
18. Sec. 35, T7N, R66W, Weld County, Colorado, Milliken Sandstone Member of the Fox Hills Formation, *Hoploscaphites birkelundae* Zone.
19. USGS loc. D3726. SW¼, SE¼ sec. 35, T6N, R67W, Weld County, Colorado, Pierre Shale, near top, *Hoploscaphites birkelundae* Zone.
20. USGS loc. 5719. Bluff southwest of Wildcat Mound, NW¼, NE¼ sec. 34, T4N, R67W, Weld County, Colorado, Fox Hills Formation, about 40 ft (12.2 m) below the Milliken Sandstone Member, *Hoploscaphites birkelundae* Zone.
21. USGS loc. 9185. Sec. 6, T4N, R66W, Weld County, Colorado, Fox Hills Formation.
22. USGS loc. 9211. SE¼ sec. 22, T4N, R68W, Weld County, Colorado, Fox Hills Formation.
23. USGS loc. 9191. Center sec. 22, T4N, R67W, Weld County, Colorado, Fox Hills Formation.
24. USGS loc. 9202. North side of St. Vrain River, 1.5 mi (2.4 km) below mouth of Boulder Creek, NW¼ sec. 3, T2N, R68W, Weld County, Colorado, upper part of the Pierre Shale, *Hoploscaphites birkelundae* Zone.
25. USGS loc. D12236. NE¼ sec. 8, T2N, R68W, Weld County, Colorado, Fox Hills Formation.
26. USGS loc. D814. SW¼ sec. 29, T7S, R68W, Douglas County, Colorado, Pierre Shale, *Baculites clinolobatus* Zone.
27. USGS loc. 15749. Fountain Creek near Pikeview, El Paso County, Colorado, Fox Hills Formation.
28. USGS loc. 15825. E½ sec., T2S, R55W, Washington County, Colorado, upper transition member of the Pierre Shale.
29. USGS loc. 15835. NE¼ sec. 29, T4S, R58W, Arapahoe County, Colorado, top of Pierre Shale.
30. DMNH loc. 2304. NE¼ sec. 27, T6S, R58W, Elbert County, Colorado, upper transition member of the Pierre Shale, 140 ft (42.7 m) below the Fox Hills Formation, *Hoploscaphites birkelundae* Zone.
31. USGS loc. 15840. NE¼ sec. 13, T8S, R57W, Elbert County, Colorado, basal Fox Hills Formation.
32. USGS loc. D6729. SE¼ sec. 25, T8S, R58W, Elbert County, Colorado, Pierre Shale, upper part.
33. USGS loc. 16179. SW¼ sec. 34, T13S, R58W, Elbert County, Colorado, upper transition member of the Pierre Shale, *Hoploscaphites birkelundae* Zone.
34. 1 mi (1.6 km) north of the mouth of Elk Creek, N½ sec. 36, T4N, R14E, Meade County, South Dakota, upper part of the Pierre Shale, *Baculites clinolobatus* Zone.
35. Just west of Wall, Pennington County, South Dakota, top of Pierre Shale.
36. AMNH loc. 3325. Center, line between secs. 23 and 26, T4N, R67W, Wildcat Mound, ~2 mi (3.2 km) south of Milliken, Weld County, Colorado, sandstone about 40 ft (12.2 m) below the base of the Milliken Sandstone Member of the Fox Hills Formation, *Hoploscaphites birkelundae* Zone.
37. USGS loc. D1545. NE¼, SW¼ sec. 5, T5S, R69W, Jefferson County, Colorado, base of the upper transition member of the Pierre Shale, *Hoploscaphites birkelundae* Zone.

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