Virgilian (Late Pennsylvanian) coiled nautiloids from the Finis Shale Member of the Graham Formation in Texas, southern Midcontinent North America

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Virgilian (Late Pennsylvanian) coiled nautiloids from the Finis Shale Member of the Graham Formation in Texas, southern Midcontinent North America

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Abstract: Nine species of Virgilian (Late Pennsylvanian) coiled nautiloids are described from the Finis Shale Member of the Graham Formation in north-central Texas, southern Midcontinent of North America. They include *Tainoceras monilifer* Miller, Dunbar and Condra, *Metacoceras quadratum* sp. nov., *Endolobus sturgeoni* sp. nov., *Domatoceras tuckeri* sp. nov., *Titanoceras* sp., *Solenochilus jackense* sp. nov., *Liroceras liratum* (Girty), *Peripetoceras bridgeportense* Tucker and Mapes, and *Ephippioceras ferratum* (Cox). The habitat of the nautiloid assemblage was the low latitudes in the Marginal Sea of the Panthalassic Ocean. Strong biotic linkage between the Marginal Sea and the southern Late Pennsylvanian Midcontinent Sea is confirmed.

Introduction

The Finis Shale Member, introduced by Plummer and Moore (1922), is an early Virgilian (Late Pennsylvanian = latest Carboniferous) unit in the Graham Formation, Cisco Group. It varies between 15−60 m in thickness and consists mainly of shale characterized by the abundant presence of ironstone concretions; it also contains sandstone and limestone in its basal part (Plummer and Hornberger, 1936). This member outcrops in north-central Texas near the Oklahoma border and west of Dallas on the southern Midcontinent of North America (McGowen *et al*., 1972; Barnes *et al*., 1987). A diverse marine fauna, including foraminifers, sponges, cnidarians and mollusks, is recorded from the member, and exceptionally well-preserved cephalopod specimens provide material for taxonomic (Miller *et al*., 1933; Plummer and Scott, 1937; Miller and Downs, 1950; Furnish *et al*., 1962; Hansman, 1965; Mapes, 1979; McKinzie and McLeod, 2003; Doguzhaeva *et al*., 1999, 2006; Niko and Mapes, 2010, 2011; Mutvei *et al*., 2012; Mutvei and Mapes, 2018), biostratigraphic (Boardman *et al*., 1994), and bionomic (Mapes, 1987; Mapes *et al*., 1995; Mapes and Chaffin, 2003; Wani *et al*., 2012) studies. Adding to these, the present paper analyzes coiled nautiloids as the third fascicle in our recent studies describing non-ammonoid cephalopods of the member and discusses their faunal significance.

Fossil material used in this serial project was recovered from dark gray (to brownish-yellowish in weathered parts) shales near Jacksboro, north-central Texas at 16 localities. These comprise exposures (Figure 1) at pond dams (TXV-34, 84), on hill sides (TXV-36, 78), at barren glades with grooves, gullies to ravines (TXV-40, 54, 55, 56, 61, 120), at road sites (TXV-60, 62), on the east slope of Lost Creek (TXV-63), at the Old Lake Jacksboro Dam and spillway (TXV-69), near an abandoned oil well pad excavation (TXV-92), and at the excavation that serves as emergency spillway for Lost Creek Lake (Lake Jacksboro; TXV-200).

Repository.—The specimens examined in the present paper are reposited in the paleontological collections of the American Museum of Natural History in New York City (prefixed AMNH) and the Tohoku University Museum in Sendai (prefixed IGPS).

Systematic Paleontology

Subclass Nautiloidea Agassiz, 1847
Order Nautilida Agassiz, 1847
Superfamily Tainoceratoidea Hyatt, 1883
Family Tainoceratidae Hyatt, 1883
Genus ***Tainoceras*** Hyatt, 1883
Type species.—*Nautilus quadrangulus* McChesney, 1859.

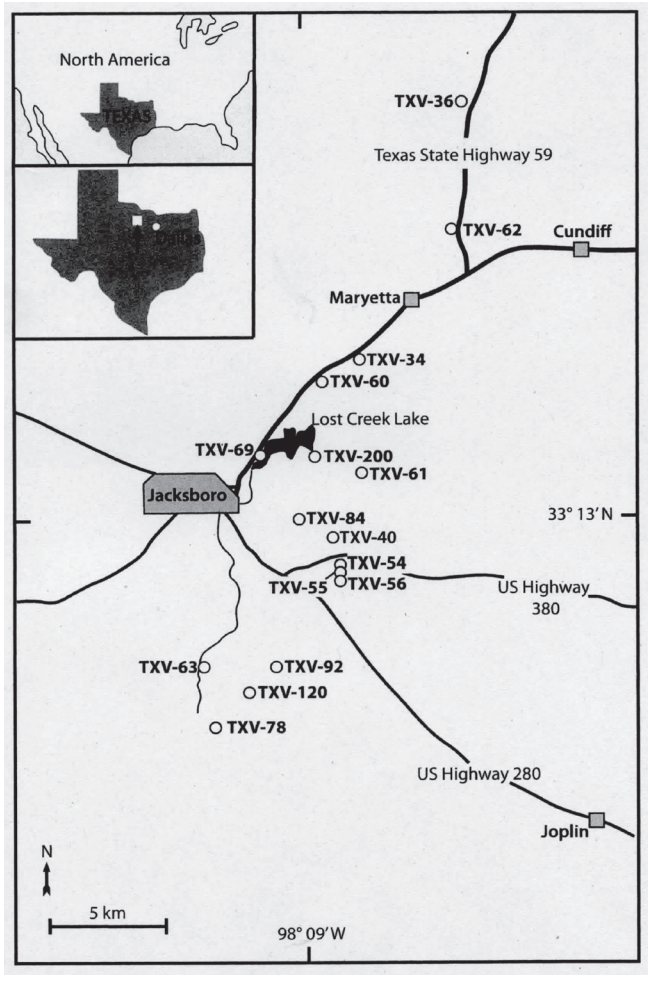

Figure 1. Map showing the geographic positions of non-ammonoid cephalopod localities in the Finis Shale Member near Jacksboro, north-central Texas.

Tainoceras monilifer Miller, Dunbar and Condra, 1933
Figure 2

Tainoceras monilifer Miller, Dunbar and Condra, 1933, p. 148–151, pl. 10, figs. 1–5, text-fig. 23; Unklesbay, 1962, p. 31–33, pl. 2, fig. 10; Tucker, 1976, p. 59, pl. 1, fig. 7, text-figs. 1a, b.

[not] *Tainoceras monilifer*; Miller and Unklesbay, 1942a, p. 142, 143, pl. 4, figs. 1–3 [figs. 1, 2 = *T. sexlineatum* Tucker, 1976; fig. 3 = *T*. sp. nov.]; 1947, p. 322, 323.

Tainoceras sp., Mapes and Chaffin, 2003, figs. 4A, 4D, 4F; McKinzie and McLeod, 2003, p. 88, fig. 4-32 top.

Description.—Conchs moderate in size, having 140 mm in reconstructed diameter, discoidal and evolute with gradual whorl expansion; umbilicus perforated; except for embryonic to juvenile shell indicating subcircular whorl sections, more adoral shells have dorsoventrally depressed and subquadrate whorl sections with width/height ratios of 1.3–2.1; profiles of adoral whorls consist of weakly inflated venter with a median groove, straight flanks, straight umbilical zone obtusely converging to dorsum and shallowly rounded impressed area; apex corn-shaped. Shell surface ornamented by oblique lirae in embryonic to juvenile shell, then these lirae become subdued and nodes are added on venter and at ventrolateral and umbilical angles; ventral nodes closely spaced, laterally elongated, forming two rows due to separation by a median groove; nodes at ventrolateral angles are strongly protruded. Septa shallow forming sutures with sub-triangular to broadly rounded ventral lobes, weak ventrolateral saddles, and relatively deep lateral lobes; siphuncle central to faintly subcentral in position.

Material examined.—AMNH 5998–6014, 6016–6080, 6474–6483.

Occurrence.—The holotype of *Tainoceras monilifer* was collected from the Finis Shale Member near Jacksboro, Texas (Miller *et al*., 1933). Specimens of this species are also known from the Upper Pennsylvanian of the Iatan Limestone in Nebraska (Miller *et al*., 1933), the Lawrence Shale, the Kereford and Burlingame Limestones in Kansas, and the Vamoosa Formation in Oklahoma (Unklesbay, 1962).

Localities of each examined specimen in this study are as follows; TXV-34 (AMNH 5998–6010, 6474–6483), TXV-55 (AMNH 6011), TXV-56 (AMNH 6012–6014, 6016–6022), TXV-120 (AMNH 6023–6025), TXV-200 (AMNH 6026–6080).

Discussion.—Miller and Unklesbay (1942a) assigned three specimens, Carnegie Museum cat. nos. 149, 10.434, and 22.299, from the Upper Pennsylvanian Conemaugh Formation of Pennsylvania to *Tainoceras monilifer*. Tucker (1976) reexamined them and concluded that 1) the former one is undoubtedly assignable to *T. monilifer* and 2) the latter two need to be separated from the species and designated as the types of a new species, *T. sexlineatum* Tucker, 1976. Although his second opinion is reasonable, we cannot agree with his first decision because the ventral nodes of specimen no. 149 vanish in the adoral shell; this diagnosis is not known from any previously named species of *Tainoceras*. Thus, this specimen (Carnegie Museum cat. no. 149) probably represents a new species. In addition, Tucker (1976) synonymized *T. murrayi* Miller and Unklesbay, 1942b, with *T. monilifer*. This taxonomic treatment is also unacceptable. *Tainoceras murrayi* is well differentiated from *T. monilifer* by the absence of nodes at umbilical angles.

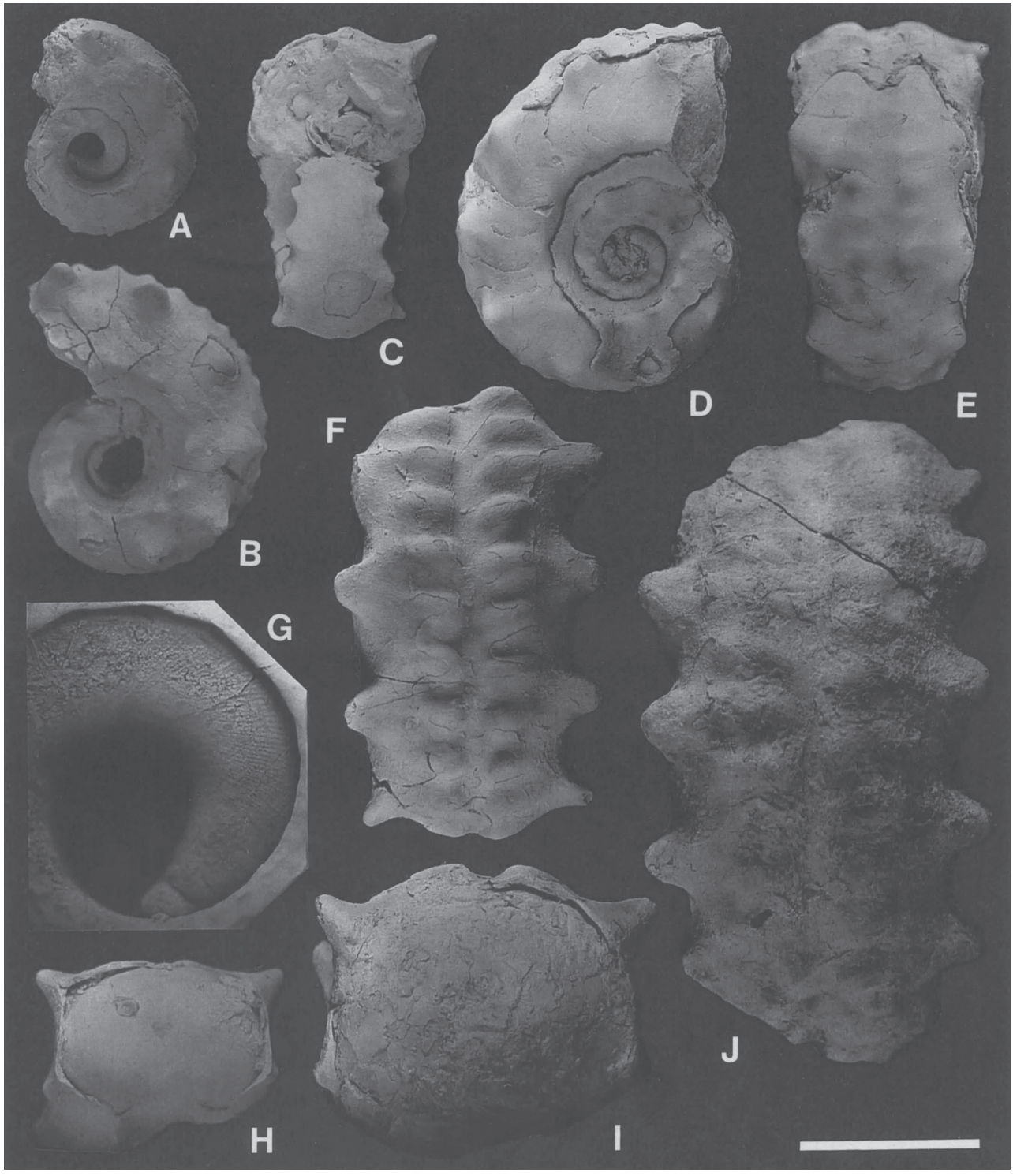

Figure 2. *Tainoceras monilifer* Miller, Dunbar and Condra, 1933. **A, G.** AMNH 6023: A, lateral view; G, partial enlargement of A to show embryonic to early juvenile shell morphologies. **B, C.** AMNH 6038: B, lateral view; C, ventral-apertural view. **D, E.** AMNH 6068, shell wall mostly exfoliated: D, lateral view; E, ventral view. **F, I.** AMNH 6007: F, ventral view; I, septal view, venter up. **H.** AMNH 6060, septal view, venter up. **J.** AMNH 6077, ventral view. Scale bar is 30 mm in A–F, J; 6 mm in G; 20 mm in H, I.

Genus ***Metacoceras*** Hyatt, 1883

Type species.—*Nautilus* (*Discus*) *sangamonensis* Meek and Worthen, 1860.

Metacoceras quadratum sp. nov.
Figure 3

Metacoceras sp., Mapes and Chaffin, 2003, fig. 4E; McKinzie and McLeod, 2003, p. 88, fig. 4-31.

Diagnosis.—Small species of *Metacoceras* with whorl sections of depressed subtrapezoidal in adoral phragmocones and depressed subquadrate shape in body chamber; width/height ratios of whorls usually 1.4–1.9; concavities of impressed area shallow to very shallow; nodes strongly protruded, possess weak bulla-like extension.

Description.—Conchs small, discoidal and evolute with gradual whorl expansion; umbilicus perforated; the holotype (largest specimen) represents an imperfect body chamber with the last septum and is 40 mm in length, 24 mm in maximum whorl width and 16 mm in maximum whorl height; reconstructed conch diameter from the holotype is approximately 60 mm; apex and peristome are not preserved; whorl sections in juvenile shells facing umbilical perforation are subcircular with a very shallow median groove at venter, then their profiles shift towards depressed subtrapezoidal shape with weakly inflated venter, rounded ventrolateral shoulders, nearly straight flanks that acutely converse to dorsum, nearly straight umbilical zones that obtusely converse to dorsum, and shallowly rounded impressed area; furthermore, shapes of whorl sections in body chamber shift to depressed subquadrate, where venter becomes nearly flat, flanks weakly inflated, and concavity of impressed area becomes very shallow; umbilical angles rounded; median ventral groove disappears in adoral phragmocone and body chamber; width/height ratios of whorls are 1.4–1.9 in adoral phragmocone and 1.4–1.5 in body chamber. Juvenile shell surface ornamented by distinct lirae that form V-shaped sinueses at venter, carinae at ventrolateral shoulders and rounded sinueses at dorsum; in more adoral shells, lirae become accentuated growth lines and strongly protruded and spine-like nodes develope on the position of ventrolateral shoulders; nodes possess weak bulla-like extension on their dorsal side; peristome shape can be reconstructed by growth lines as lingulate ventral (hyponomic) and shallow lateral (ocular) sinuses. Septa very shallow; sutures composed by broadly rounded ventral lobes, rounded ventrolateral saddles, shallow lateral lobes, and subtriangular dorsal lobes; siphuncle situates near halfway between conch center and ventral margin in juvenile, and subcentral position in more adoral shells; ratios of distance between ventral shell surface and central axis of siphuncle per whorl height at dorsoventral plane are 0.31–0.44.

Material examined.—Holotype, AMNH 6159. Paratypes, AMNH 6102, 6108–6111, 6118, 6130, 6134, 6147–6149, 6472. In addition, 61 specimens (AMNH 6091–6101, 6103–6107, 6112, 6115–6117, 6119–6129, 6131–6133, 6135–6146, 6150–6158, 6160–6163, 6473) are assigned to *Metacoceras quadratum* sp. nov.

Occurrence.—TXV-34 (AMNH 6092–6099), TXV-56 (AMNH 6091, 6100–6112, 6473), TXV-120 (AMNH 6115), TXV-200 (AMNH 6116–6163, 6472). All previous records of the new species as *Metacoceras* sp. by Mapes and Chaffin (2003) and McKinzie and McLeod (2003) are from the Finis Shale Member in Texas.

Etymology.—The specific name is derived from the Latin, *quadratus* (= quadrangular), referring to its whorl section shapes in the body chamber.

Discussion.—In its gross conch form of the adoral shells and ornament, *Metacoceras quadratum* sp. nov. is most similar to *M. cornutum* Girty (1911, p. 145, 146; 1915, p. 240–242, pl. 29, figs. 4, 4a, 4b, 5, 5a, 5b), which was described from the Desmoinesian (Middle Pennsylvanian) of Oklahoma. However, the impressed area of this new species is shallower than that of *M. cornutum* and the subtrapezoidal profiles developed in the phragmocones are not recognized in *M. cornutum*. A Virgilian species, *Metacoceras copei* Tucker (1976, p. 61, 62, pl. 1, fig. 6, pl. 3, figs. 1, 2, pl. 4. fig. 3) from the Mattoon Formation of Illinois, also resembles *M. quadratum*, but it possesses a median ventral groove in the adoral shells and the knob-like distal ends of nodes exclude it from *M. quadratum. Metacoceras clinocostatum* Sturgeon, Windle, Mapes and Hoare (1982, p. 1455, 1457, 1458, pl. 1, figs. 4, 8; 1997, p. 34, 35, pl. 1-8, figs. 4–9), from the Desmoinesian Allegheny Group and the Missourian (Late Pennsylvanian) part of the Conemaugh Group of Ohio, differs from *M. quadratum* by having strongly elongated nodes attaining the umbilical angles.

Family Koninckioceratidae Hyatt *in* Zittle, 1900

Genus ***Endolobus*** Meek and Worthen, 1865

Type species.—*Nautilus spectabilis* Meek and Worthen, 1860.

Endolobus sturgeoni sp. nov.
Figure 4

Diagnosis.—Species of *Endolobus* with 1.4–2.0 in width/height ratios of adoral whorls; flanks narrowly rounded; impressed area deeply concaved; nodes low and dorsoventrally elongated.

Description.—Conchs thick discoidal, evolute; whorl expansion rapid in phragmocone, but it becomes gradual in

Figure 3. *Metacoceras quadratum* sp. nov. **A, B, E–G.** paratype, AMNH 6118: A, lateral view of juvenile shell; B, septal view of juvenile shell, venter up; E, ventral view; F, lateral view; G, septal view, venter up. **C, D.** paratype, AMNH 6472, juvenile shell: C, ventral view; D, lateral view. **H.** paratype, AMNH 6130, septal view, venter up. **I.** paratype, AMNH 6134, dorsal view. **J.** paratype, AMNH 6102, lateral view. **K.** paratype, AMNH 6147, septal view, venter up. **L, M, P, Q.** holotype, AMNH 6159: L, lateral view; M, cross sectional view, venter up; P, ventral view; Q, dorsal view. **N.** paratype, AMNH 6110, ventral view, showing details of surface ornamentation. **O.** paratype, AMNH 6111, lateral view. Scale bar is 6 mm in A–D; 12 mm in E–H, J, N; 15 mm in I, K–M, O–Q.

Figure 4. *Endolobus sturgeoni* sp. nov. **A–C.** paratype, AMNH 6081, shell wall mostly exfoliated: A, lateral view; B, cross sectional view, venter up; C, partial enlargement of A to show details of juvenile shell. **D.** paratype, AMNH 6082, septal view, venter up. **E, F, L.** paratype, AMNH 6085: E, lateral view; F, dorsal view; L, ventral view. **G.** paratype, AMNH 6087, shell wall mostly exfoliated, lateral view. **H, J, M, N.** holotype, AMNH 6086: H, lateral view; J, cross sectional view, venter up; M, ventral view; N, dorsal view. **I, K.** paratype, AMNH 6084, shell wall mostly exfoliated: I, lateral view; K, cross sectional view, venter up. Scale bar is 15 mm in A, B; 6 mm in C; 20 mm in D–N.

body chamber; umbilicus perforated; the holotype represents an imperfect body chamber with the last septum and is 47 mm in length, 34 mm in maximum whorl width, and 18 mm in maximum whorl height; the largest specimen (paratype, AMNH 6089) has 41 mm in whorl width and 21 mm (imperfect) in whorl height; reconstructed conch diameter of the holotype is approximately 60 mm; apex not preserved; whorl sections are circular in juvenile shells facing umbilical perforation, then they shift towards depressed subelliptical shapes, whose profiles consist of broadly rounded venter to ventrolateral shoulders, narrowly rounded flanks (= umbilical angles), weakly inflated umbilical zones and rounded impressed area; width/height ratios of whorls are 1.4–1.6 in adoral phragmocone, these ratios increase to 2.0 in body chamber. Shell surface marked by dorsoventrally elongated low nodes on flanks; except for nodes, surface ornamentation absent; no peristome is preserved, but presence of deep lingulate ventral (hyponomic) and very shallow lateral (ocular) sinuses can be reconstructed by growth line shapes. Septal curvature moderate; sutures roughly straight, but some sutures have shallow lateral lobes, directly transverse in juvenile shell and strongly incline towards venter in adoral shell; siphuncle supracentral with weak to moderate dorsum wards shifting; ratios of distance between ventral shell surface and central axis of siphuncle per whorl height at dorsoventral plane are 0.54–0.72.

Material examined.—Holotype, AMNH 6086. Paratypes, AMNH 6081–6085, 6087–6089.

Occurrence.—TXV-34 (AMNH 6081–6086), TXV-200 (AMNH 6087–6089).

Etymology.—The specific name is in honor of the late Myron T. Sturgeon in recognition of his contributions to paleontological studies of Pennsylvanian nautiloids and conodonts.

Discussion.—*Endolobus schucherti* Miller (1932, p. 64–66, pl. 12, figs. 12, 13) from the Upper Pennsylvanian sandstone of New Mexico has similar node shapes as *E. sturgeoni* sp. nov., but it differs in its shallower impressed area. In addition, a median longitudinal ridge on the venter of *E. schucherti* is not developed in the new species.

Superfamily Trigonoceratoidea Hyatt, 1884
Family Grypoceratidae Hyatt *in* Zittle, 1900
Genus ***Domatoceras*** Hyatt, 1891
Type species.—*Domatoceras umbilicatum* Hyatt, 1891.

Domatoceras tuckeri sp. nov.
Figure 5

Domatoceras sp., Mapes and Chaffin, 2003, figs. 4C, 4G, 4I; McKinzie and McLeod, 2003, p. 88, fig. 4-29.

Diagnosis.—Species of *Domatoceras* having whorl sections of compressed subtrapezoidal with concave venter in adoral phragmocone and compressed subrectangular in body chamber; width/height ratios of whorls 0.8–1.1; weakly waved carinae developed at ventral angles.

Description.—Conchs moderate in size, lenticular and evolute with relatively rapid whorl expansion; umbilicus perforated; the holotype of fragmentary phragmocone consisting of three volutions is 67 mm in maximum length, 37 mm in maximum whorl width, and 41 mm in maximum whorl height; the largest specimen (paratype, AMNH 6227) of imperfect body chamber attains 42 mm in whorl width (reconstructed from half width), 51 mm in whorl height and approximately 160 mm in reconstructed conch diameter; apex and peristome are not preserved; whorl sections are subcircular in juvenile shell facing umbilical perforation, subtrapezoidal to compressed subtrapezoidal in more adoral phragmocone, and compressed subrectangular in body chamber; profiles of whorl sections in adoral phragmocones consist of shallowly concave venter as ventral groove, nearly straight ventrolateral shoulders that acutely converge to venter, straight flanks that very acutely converge to venter, straight umbilical zones that obtusely converge to dorsum, and quadrate impressed area; in body chamber, venter becomes flat, shoulders and flanks integrate; umbilical angles bluntly pointed; width/height ratios of whorls are 0.9–1.1 in adoral phragmocone and 0.8–0.9 in body chamber. Surface of juvenile shell marked by sinuous lirae that persist in body chamber at ventral side, but are replaced by growth lines in other parts of more adoral shells; strong carina having weakly waved margin and frill-like appearance developed at ventral angle with bilateral symmetry in adoral shells; lirae and growth lines suggest peristome shape with V-shaped ventral (hyponomic) and shallow lateral (ocular) sinuses. Septal curvatures are relatively weak; sutures indicate shallow ventral and broadly rounded lateral lobes. Siphuncle is subcentral in position; ratios of distance between ventral shell surface and central axis of siphuncle per whorl height at dorsoventral plane are 0.48–0.52.

Material examined.—Holotype, AMNH 6278. Paratypes, AMNH 6181, 6186, 6208, 6209, 6227–6230, 6255, 6256, 6279–6281. In addition, 95 specimens (AMNH 6173–6180, 6182–6185, 6187–6207, 6210–6226, 6231–6254, 6257–6277) are assigned to *Domatoceras tuckeri* sp. nov.

Occurrence.—TXV-34 (AMNH 6173–6185), TXV-55 (AMNH 6186), TXV-56 (AMNH 6187–6227), TXV-200 (AMNH 6228–6281). All previous records of the new species as *Domatoceras* sp. by Mapes and Chaffin (2003) and McKinzie and McLeod (2003) are from the Finis Shale Member in Texas.

Etymology.—The specific name is to honor the late John K. Tucker in recognition of his contributions to paleontological

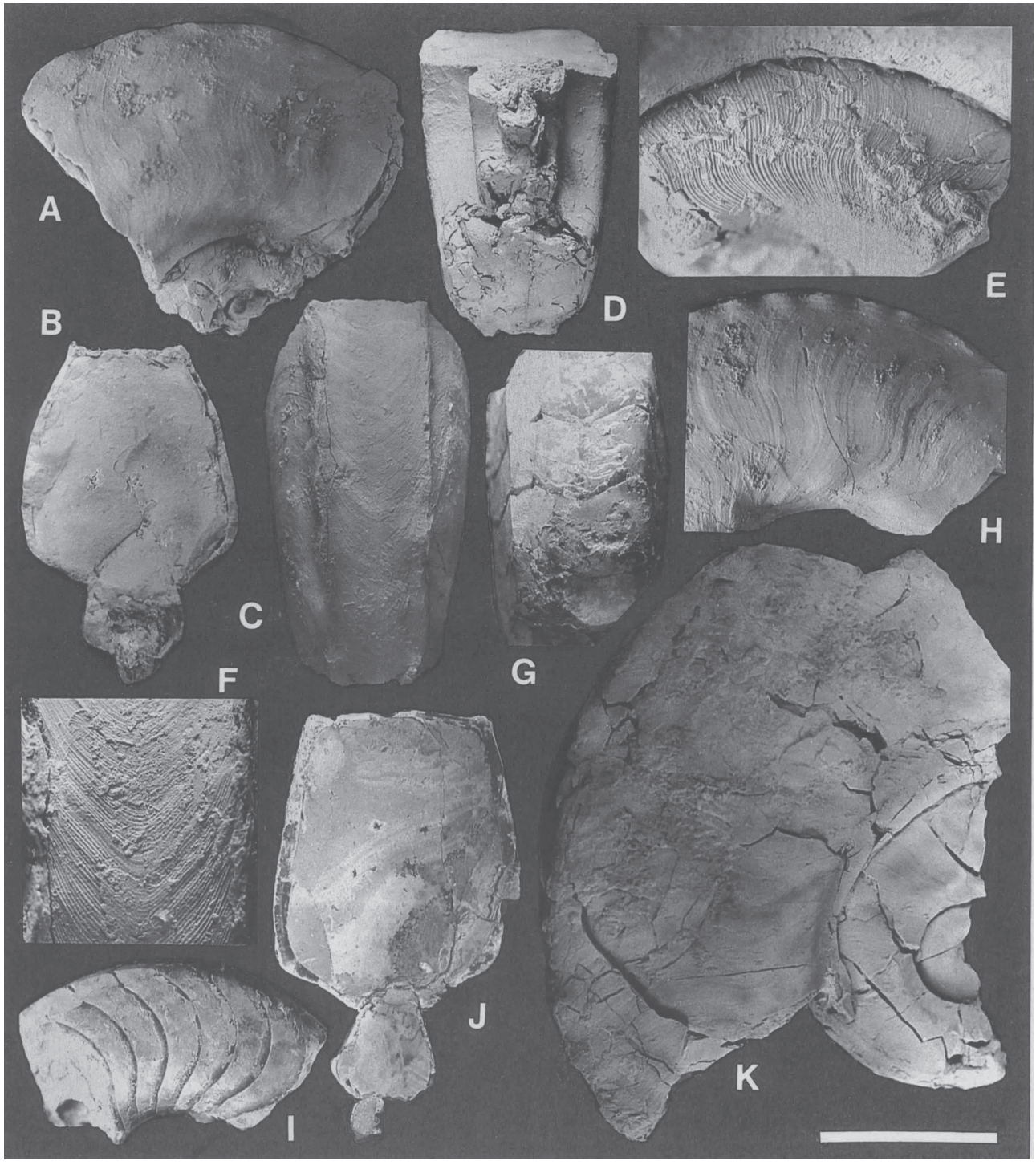

Figure 5. *Domatoceras tuckeri* sp. nov. **A–F.** holotype, AMNH 6278: A, lateral view; B, cross sectional view, venter up; C, ventral view; D, dorsal view; E, lateral view of juvenile shell; F, partial enlargement of C to shew details of surface ornamentation. **H.** paratype, AMNH 6281, lateral view. **G, I.** paratype, AMNH 6208, shell wall exfoliated: G, ventral view; I, lateral view. **J, K.** paratype, AMNH 6227: J, cross sectional view, venter up; K, lateral view. Scale bar is 30 mm in A–D, I–K; 6 mm in E; 10 mm in F; 20 mm in G; 37.5 mm in H.

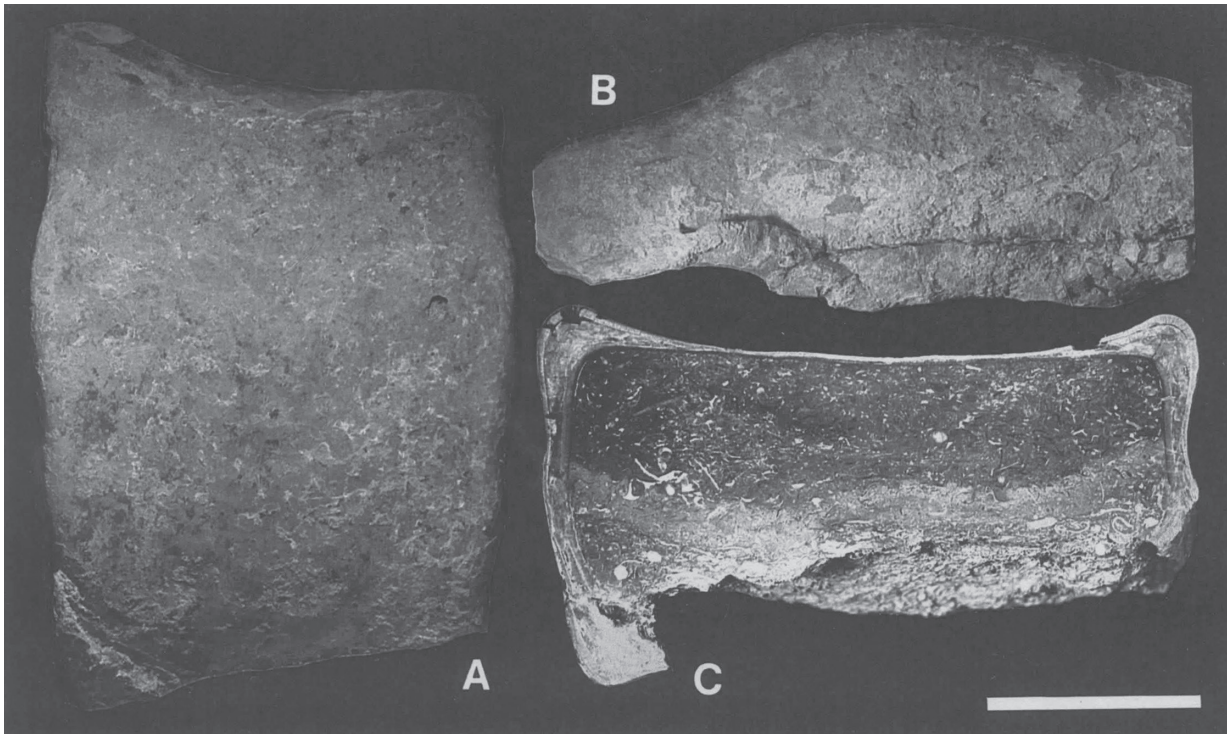

Figure 6. *Titanoceras* sp., IGPS coll. cat. no. 112545. **A.** ventral view. **B.** lateral view. **C.** cross sectional view, venter up. Scale bar is 100 mm in A, B; 75 mm in C.

studies of Pennsylvanian nautiloids.

Discussion.—This new species most closely resembles *Domatoceras oreskovichi* Sturgeon, Windle, Mapes and Hoare (1982, p. 1468, 1469, pl. 2, figs. 6, 7, 9, pl. 3, fig. 2; 1997, p. 60, 61, pl. 1-23, figs. 6, 7, pl. 1-24, figs. 2, 3, pl. 1-26, figs. 1, 2, pl. 1-27, figs. 1–6, text-fig. 1-8A), from the Desmoinesian Allegheny Group of Ohio, by having compressed subquadrate whorl sections with a concaved venter. However, larger amplitude of the waved carinae distinguishes it from *Domatoceras tuckeri* sp. nov. A concaved venter is also developed in *D. texanum* Tucker and Mapes (1978, p. 597, pl. 2, figs. 4, 5, pl. 3, fig. 6) from the Missourian Wolf Mountain Shale of Texas. The differences between *D. texanum* and *D. tuckeri* are its subtrapezoidal whorl sections remain in the body chambers and morphological shifting from carinae to nodes as shell grows.

Genus ***Titanoceras*** Hyatt**,** 1884

Type species.—*Nautilus ponderosus* Meek, 1872.

Titanoceras sp.

Figure 6

Titanoceras sp., McKinzie and McLeod, 2003, p. 91, fig. 4-33.

Description.—A single very large specimen of fragmentary body chamber is available for study; it is 352 mm in length, 225–232 mm in whorl width and 137 mm in whorl height; whorl sections are strongly depressed, subquadrate with width/height ratios of approximately 1.6 and consists of broadly concave venter and weakly inflated flanks; most of umbilical zone is missing, but preserved part indicates shallow concavity. Shell surface smooth; ventrolateral and umbilical angles are carinated; longitudinally elongated nodes occur on carina at ventrolateral angles.

Material examined.—IGPS coll. cat. no. 112545.

Occurrence.—TXV-200. Previous record of the species by McKinzie and McLeod (2003) is from the Finis Shale Member in Texas.

Discussion.—Its depressed subquadrate whorl sections with a broadly concaved venter suggest the generic assignment of this specimen to *Titanoceras* rather than *Latitemnocheilus* Sturgeon, Windle, Mapes and Hoare (1982; type species, *Nautilus* (*Temnocheilus*) *latus* Meek and Worthen, 1870) and *Temnocheilus* M'Coy (1844; type species, *Nautilus* (*Temnocheilus*) *coronatus* M'Coy, 1844).

General shape of the venter of *Latitemnocheilus* is weakly convex and the whorl section of *Temnocheilus* indicates subtrapezoidal profile.

The present *Titanoceras* sp. is well differentiated from other species assigned to the genus by having a larger width/height ratio of the whorl. However, erection of new species is not possible due to lacking information about the phragmocone.

Superfamily Aipoceratoidea Hyatt, 1883
Family Solenochilidae Hyatt, 1893
Genus ***Solenochilus*** Meek and Worthen, 1870

Type species.—*Nautilus* (*Cryptoceras*) *springeri* White and St. John, 1868.

Solenochilus jackense sp. nov.
Figure 7

Diagnosis.—Species of *Solenochilus* with subelliptical whorl sections, whose width/height ratios are 1.4–1.5; venter broadly rounded; ventrolateral shoulders rounded; flanks weakly inflated to straight; umbilical angles carinated; umbilical zones weakly concaved; impressed area moderately concaved; camerae relatively long; except for relatively deep ventral sinus, sutures roughly transverse.

Description.—Conchs large, subglobose with rapid whorl expansion; inner whorls are narrowly evolute with narrow umbilical area, then coiling becomes loose in more adoral phragmocone; apex not observable; the holotype (largest specimen) is fragmentary whorl of mature phragmocone having 58 mm in whorl length, 52 mm in maximum whorl width (reconstructed from half width, exfoliated lateral shall wall), and 36 mm in maximum whorl height (exfoliated ventral shall wall); a paratype (AMNH 6167) representing immature phragmocone is 45 mm in diameter, 40 mm in maximum whorl width (reconstructed from half width), 27 mm in maximum whorl height, and 0.2 in approximate ratio of umbilical diameter per conch diameter; whorl sections are depressed and subelliptical; profiles of whorl sections in immature phragmocone consist of broadly rounded venter, rounded ventrolateral shoulders, weakly inflated flanks, weakly concaved umbilical zones and shallowly rounded impressed area; in mature phragmocone, flanks become straight and acutely converge to venter; umbilical angles carinated; width/height ratios of whorls are 1.4–1.5; no body chamber preserved. Shell surface is mostly smooth except for umbilical carinae that are marked by longitudinal lirae; umbilical spine not preserved. Septa are shallowly concaved; sutures are roughly transverse with narrow but relatively deep ventral sinus, weak ventrolateral saddles, and nearly straight at lateral to dorsolateral portions; cameral lengths are relatively long for the genus, 17–20 mm at ventral margin in the holotype. Siphuncle is at the ventral margin; septal necks are suborthochoanitic in immature and orthochanitic in mature phragmocones.

Material examined.—Holotype, AMNH 6168. Paratypes, AMNH 6166, 6167. In addition, two specimens (AMNH 6164, 6165) are assigned to *Solenochilus jackense* sp. nov.

Occurrence.—TXV-34 (AMNH 6164), TXV-200 (AMNH 6165–6168).

Etymology.—The specific name is derived from Jack County, from which all examined specimens including the type series were collected.

Discussion.—*Solenochilus missouriensis* Miller, Lane and Unklesbay (1947, p. 10, pl. 4, figs. 3, 4), from the Middle Pennsylvanian Winterset Limestone of Missouri, most closely resembles the new species, by its subelliptical whorl sections with a width/height ratio of approximately 1.5 and relatively long camerae. However, this species has more strongly fluted sutures especially at the lateral to dorsolateral portions than those of *S. jackense* sp. nov. *Solenochilus greenensis* Sturgeon (1946, p. 33–35, pl. 8, fig. 6, pl. 9, fig. 3, text-fig. 3A; Sturgeon *et al*., 1997, p. 71, 72, pl. 1-31, figs. 1, 2, pl. 1-32, fig. 2, pl. 1-33, fig. 3, pl. 1-34, figs. 1–3, text-fig. 1-11B), described from the Desmoinesian Hamden Limestone, Ohio also resembles *S. jackense*, but its dorsal part of the flanks is strongly concave. *Solenochilus mcfarlandi* Sturgeon, Windle, Mapes and Hoare (1982, p. 1469, 1471, 1472, pl. 5, figs. 3, 4; 1997, p. 73, 74, pl. 1-35, fig. 2, pl. 1-37, figs. 2, 3, text-fig. 1-12A) from the Missourian part of the Conemaugh Group of Ohio differs from *S. jackense* in having more depressed whorl sections exceeding 1.8 in a width/height ratio and shorter camerae. Other comparable species, including *S. brammeri* Miller, Dunbar and Condra (1933, p. 234–236, pl. 22, figs. 6, 7, pl. 23, fig. 1, pl. 24. fig. 1) from the Missourian Argentine Limestone of Nebraska and *S. springeri* (White and St. John, 1868, p. 124, 125, fig. 10; Kummel, 1964, figs. 319, 320,1, 321; Mikesh and Glenister, 1966, p. 273–277, figs. 1A, 1B) from the Middle Pennsylvanian of Iowa and Arkansas, are well differentiated from *S. jackense* by the presence of a mid-ventral groove in their mature phragmocones.

Superfamily Clydonautiloidea Hyatt *in* Zittel, 1900
Family Liroceratidae Miller and Youngquist, 1949
Genus ***Liroceras*** Teichert, 1940

Type species.—*Coloceras liratum* Girty, 1911.

Liroceras liratum (Girty, 1911)
Figure 8

Coloceras liratum Girty, 1911, p. 144, 145; 1915, p. 237, 238, pl. 28, figs. 2, 2a, b, 3, 3a, b, 4, 4a, 5, 6, 6a; Miller *et al*., 1933, p. 132–134, pl. 6, figs. 1–8.

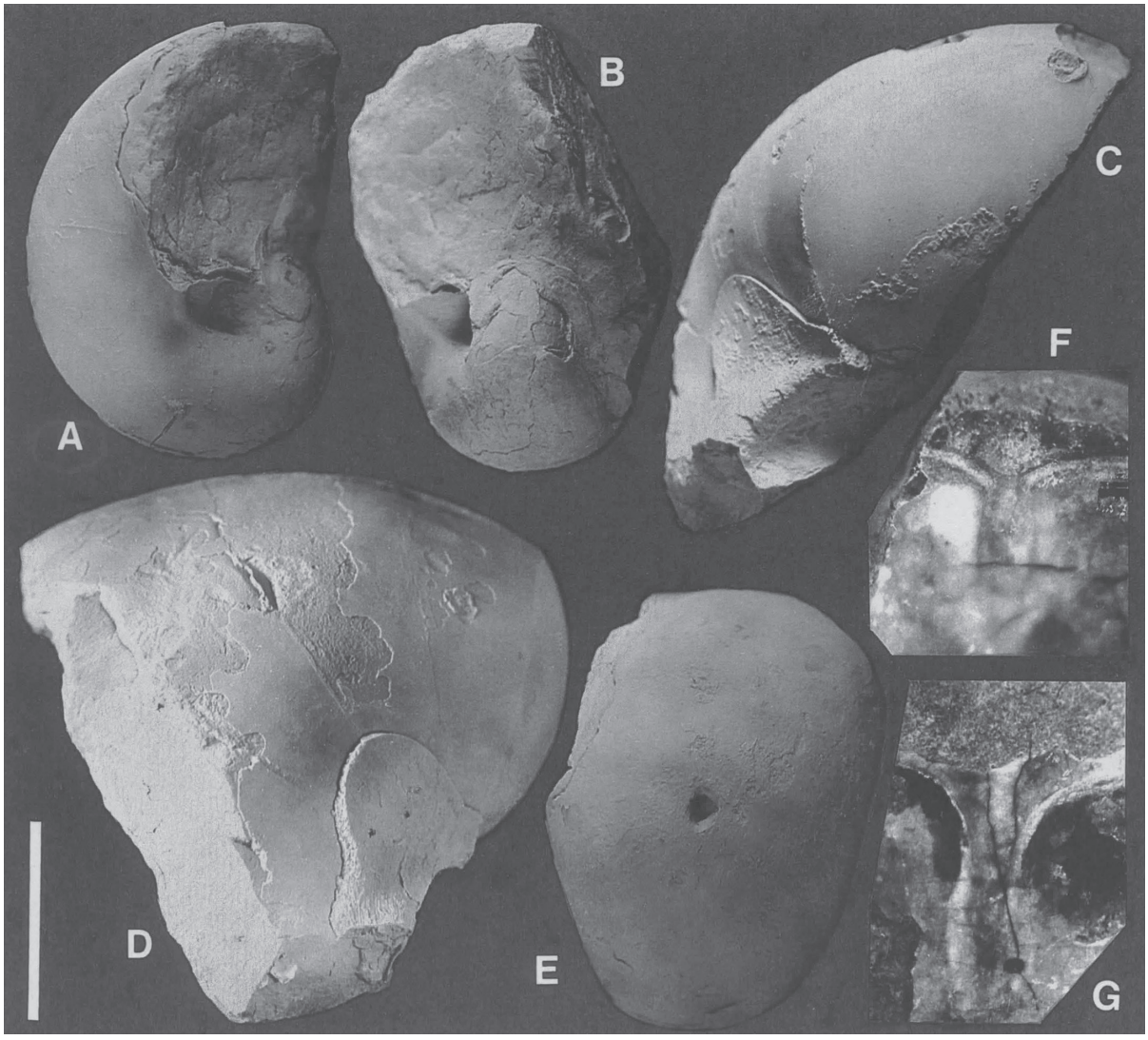

Figure 7. *Solenochilus jackense* sp. nov. **A, B, E, F.** paratype, AMNH 6167: A lateral view; B, ventral-apertural view; E, ventral view; F, ventral view, showing details of siphuncle. **C, D, G.** holotype, AMNH 6168, shell wall mostly exfoliated: C, septal view, venter up; D, lateral view; G, ventral view, showing details of siphuncle. Scale bar is 20 mm in A–E; 6 mm in F, G.

Coloceras liratum obsoletum Girty, 1911, p. 145; 1915, p. 238, 239, pl. 29, figs. 1, 1a, b, 2, 2a, 3, 3a.

Coloceras obsoletum Girty. Miller *et al*., 1933, p. 134–136, pl. 7, figs. 4–7.

Coloceras liratum? Girty. Miller and Cline, 1934, p. 173–175, pl. 28, figs. 24–26.

Liroceras liratum (Girty). Teichert, 1940, p. 590; Young, 1942, p. 122; Sturgeon, 1946, p. 19–21, pl. 4, figs. 6–9; Miller and Youngquist, 1949, pl. 53, figs. 3–6; Unklesbay and Palmer, 1958, p. 1073, pl. 138, figs. 1–3; Unklesbay, 1962, p. 45–47, pl. 5, figs. 6–8, pl. 6, figs. 5, 6, text-fig. 1; Kummel, 1964, figs. 324,3a, b; Murphy, 1970, p. 203, 204, pl. 36, fig. 9; Tucker, 1976, p. 67, 68, pl. 3, fig. 4; Sturgeon *et al*., 1997, p. 78, 79, pl. 1-44, figs. 1, 3–12; Seuß *et al*, 2009, p. 627.

Liroceras cf. *liratum* (Girty). Young, 1942, p. 122.

Liroceras sp., Miller and Unklesbay, 1942a, p. 137, 138, pl. 1, fig. 13, text-fig. 1A; Sturgeon and Miller, 1948, p. 76, 77; Mapes and Chaffin, 2003, fig. 4B; McKinzie and McLeod, 2003, p. 88, fig. 4-30.

Description.—Conchs small, having 70 mm in reconstructed diameter, subglobose, involute with moderate whorl expansion; whorl sections are depressed and reniform

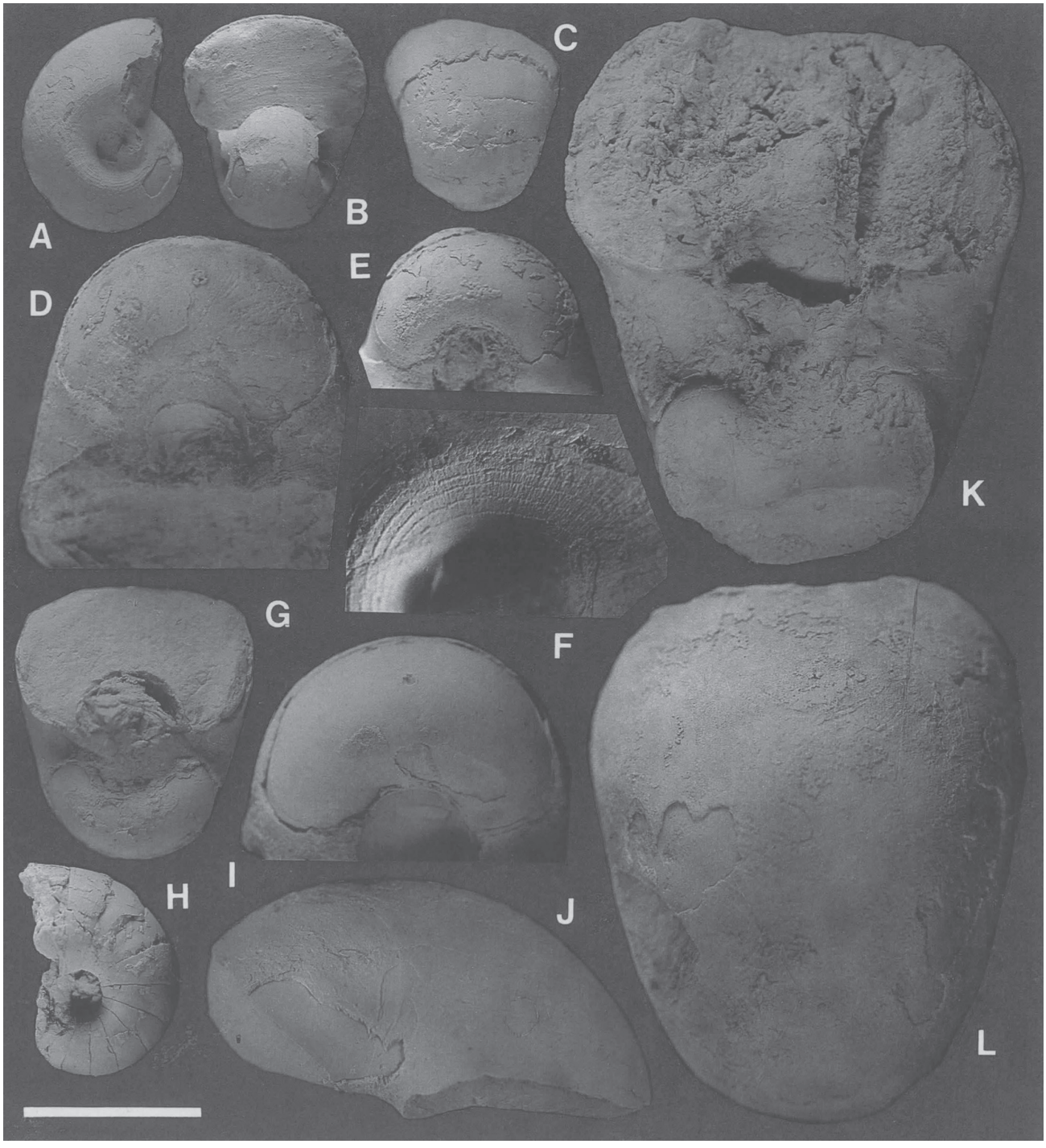

Figure 8. *Liroceras liratum* (Girty, 1911). **A, B, F.** AMNH 6305: A, lateral view; B, ventral-apertural view; F, lateral view, showing details of surface ornamentation. **C.** AMNH 6348, shell wall mostly exfoliated, ventral view. **D.** AMNH 6310, septal view, venter up. **E.** AMNH 6354, septal view, venter up. **G.** AMNH 6352, dorsal view. **H.** AMNH 6345, shell wall exfoliated, lateral view. **I.** AMNH 6360, septal view, venter up. **J.** AMNH 6355, lateral view. **K, L.** AMNH 6357: K, dorsal view; L, ventral view. Scale bar is 20 mm in A–E, G–L; 6 mm in F.

consisting of rounded venter, ventrolateral shoulders to flanks, broadly rounded umbilical zones and rounded impressed area; umbilical angles narrowly rounded; width/height ratios of whorls are 1.2–1.7. Shell surface is smooth, except for portion of umbilical angles to umbilical zones in inner volutions, where reticulate ornamentation is developed; growth lines exhibit shallow ventral (hyponomic) and lateral (ocular) sinuses. Septa relatively deep; sutures are directly transverse. Siphuncle is subcentral.

Material examined.—AMNH 6298–6471.

Occurrence.—The syntypes were collected from the Desmoinesian Wewoka Formation of Oklahoma (Girty, 1911). Except for the type stratum, specimens of this species are widely known from the Middle to Upper Pennsylvanian of the North American Midcontinent including the Allegheny and Conemaugh Formations in Pennsylvania (Miller and Unklesbay, 1942a), the Pottsville, Allegheny and Conemaugh Formations in Ohio (Sturgeon, 1946), the Mattoon Formation in Illinois (Tucker, 1976), the Burgner Formation in Missouri (Unklesbay and Palmer, 1958), the Weston Shale in Kansas (Miller *et al*., 1933), the Atoka, Pumpkin Creek, Boggy, Stuart, Senora, Wetumka, Holdenville, Nellie Bly, Wann, Vamoosa and Kanwaka Formations in Oklahoma (Miller *et al*., 1933), the Jacksboro Limestone and the Finis Shale Member in Texas (Miller *et al*., 1933), and the Magdalena Group in New Mexico (Young, 1942).

Localities of each examined specimen in this study are as follows; TXV-34 (AMNH 6298–6302), TXV-36 (AMNH 6303), TXV-54, (AMNH 6304), TXV-56 (AMNH 6305–6341), TXV-120 (AMNH 6342–6347), TXV-200 (AMNH 6348–6471).

Discussion.—Unklesbay (1962) considered that differences between *Liroceras liratum* and *L. obsoletum*, especially in their surface ornamentations are intraspecific variations and synonymized them. We agree with his proposal. *Liroceras liratum* is the most abundant nautiloid species in the Finis Shale Member.

Genus ***Peripetoceras*** Hyatt, 1894

Type species.—*Nautilus freieslebeni* Geinitz, 1843.

Peripetoceras bridgeportense Tucker and Mapes, 1978
Figure 9

Peripetoceras bridgeportense Tucker and Mapes, 1978, p. 598, 600, 603, pl. 1, figs. 1–3, pl. 2, figs. 1, 2, pl. 3, fig. 7.
Peripetoceras sp., Wani *et al*., 2012, fig. 3D.

Description.—Conchs small, having 50 mm in reconstructed diameter, subglobose, involute with rapid whorl expansion; whorl sections depressed, reniform in apical and subtrapezoidal in adoral shells; profiles of apical whorls consist of rounded venter, ventrolateral shoulders to flanks, narrowly rounded umbilical zones and rounded impressed zone; in adoral whorls, subquadrate ventral angles appear and following profiles indicate nearly flat venter, nearly flat ventrolateral shoulders to flanks converging acutely to venter, narrowly rounded umbilical zones, and deeply rounded and wide impressed zone; umbilical angles broadly rounded throughout; width/height rations of whorls range from 1.5 to1.7. Shell surface is smooth; growth lines exhibit narrowly rounded ventral (=hyponomic) sinus, broadly rounded ventrolateral lobes, very shallow lateral (= ocular) sinus; sutures are transverse and roughly straight; siphuncle is supracentral in position and slightly off to dorsum.

Material examined.—AMNH 6282–6297.

Occurrence.—The holotype and all paratypes of *Peripetoceras bridgeportense* were collected from the Missourian (early Late Pennsylvanian) Wolf Mountain Shale, Texas (Tucker and Mapes, 1978).

Localities of each examined specimen in this study are as follows; TXV-34 (AMNH 6282–6287), TXV-54 (AMNH 6288), TXV-56 (AMNH 6289–6292), TXV-200 (AMNH 6293–6297). Previous record of the species by Wani *et al*. (2012) is from the Finis Shale Member in Texas.

Discussion.—We assign the present specimens to *Peripetoceras bridgeportense* on the basis of similarities with the holotype in their whorl section shapes, ratios of conch expansion, and siphuncular position. It is possible that an unfigured species, *Peripetoceras* sp., recorded from the Finis Shale Member by McKinzie and McLeod (2003) also is conspecific with *P. bridgeportense*.

Family Ephippioceratidae Miller and Youngquist, 1949

Genus ***Ephippioceras*** Hyatt, 1884

Type species.—*Nautilus ferratus* Cox, 1858.

Ephippioceras ferratum (Cox, 1858)
Figure 10

Nautilus ferratus Cox, 1858, p. 574, 575, pl. 10, figs. 2, 2a.
Ephippioceras ferratum (Cox). Hyatt, 1884, p. 290; 1894, p. 539, pl. 10, figs. 23–26; Miller *et al*., 1933, p. 114–118, pl. 3, figs. 14–17; Miller and Owen, 1934, p. 209–211, pl. 12, figs. 3, 4, text-figs. 1A, B; Smith, 1938, p. 10, 11, pl. 1, fig. 17; Miller and Unklesbay, 1942a, p. 136, pl. 1, figs. 14, 15; Sturgeon, 1946, p. 18, 19, pl. 4, figs. 2–4; Miller and Unklesbay, 1947, p. 320, pl. 1, figs. 7, 8; Miller *et al*., 1947, p. 6, pl. 2, figs. 7–10; Miller and Youngquist, 1949, p. 129, pl. 53, figs. 7, 8; Unklesbay, 1962, p. 50–52, pl. 4, fig. 3; Kummel, 1963, p. 357, pl. 15, figs. 4–7; 1964, fig. 326, 2; Sturgeon *et al*., 1997, p. 81, 82, pl. 1-46, figs. 1–5, 7, 9.
Ephippioceras (*Nautilus*) *ferratum* (Cox). Hyatt, 1891, p. 352.
[not] *Ephippioceras ferratum* (Cox). Gordon, 1964, p. 162,

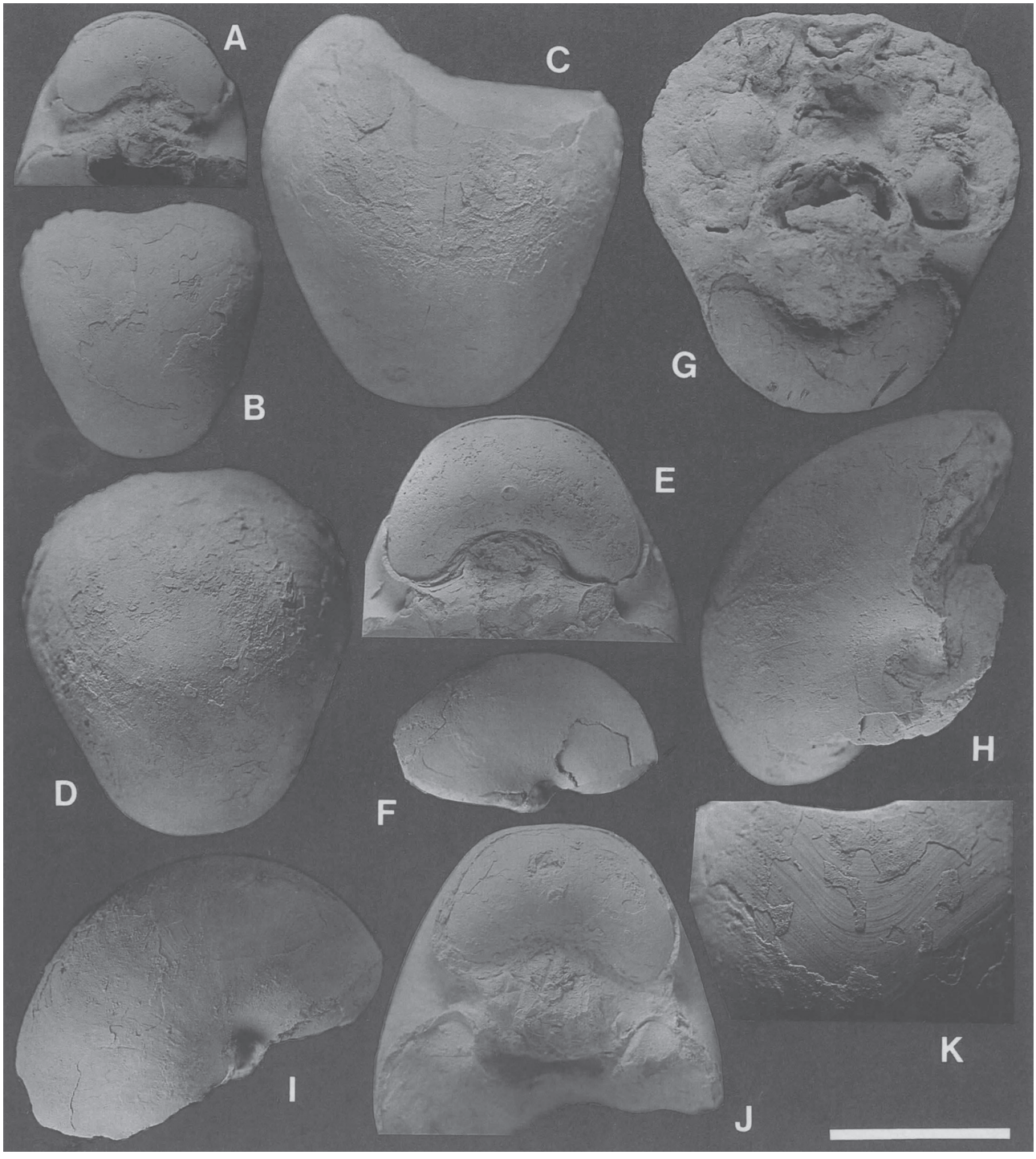

Figure 9. *Peripetoceras bridgeportense* Tucker and Mapes, 1978. **A, B, F, K.** AMNH 6289: A, septal view, venter up; B, ventral view; F, lateral view; K, partial enlargement of B to show details of surface ornamentation. **C, I, J.** AMNH 6283: C, ventral view; I, lateral view; J, septal view, venter up. **D, G.** AMNH 6292: D, ventral view; G, dorsal view. **E.** AMNH 6295, septal view, venter up. **H.** AMNH 6297, lateral view. Scale bar is 20 mm in A–J; 12 mm in K.

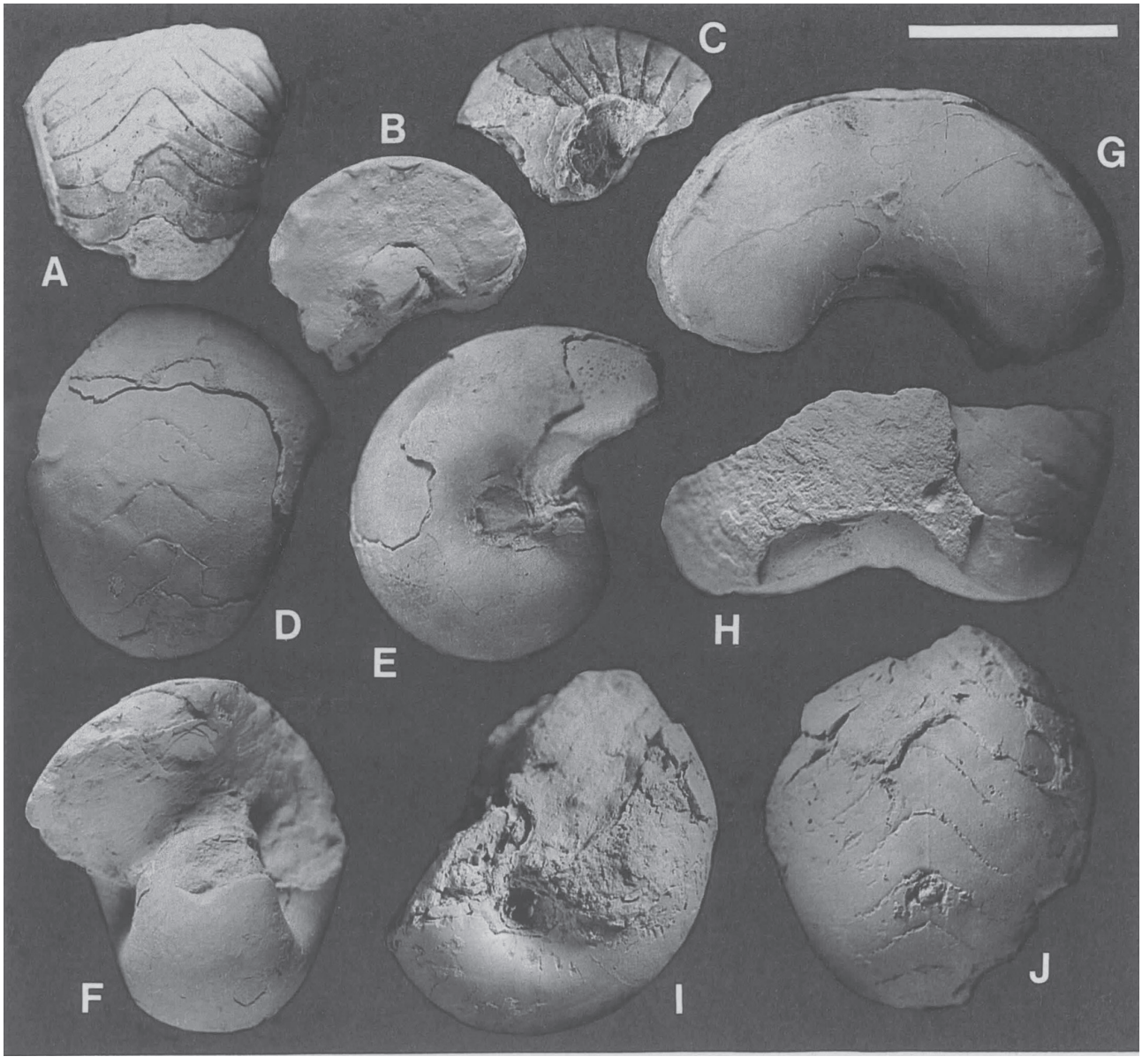

Figure 10. *Ephippioceras ferratum* (Cox, 1858). **A–C.** AMNH 6169, shell wall mostly exfoliated: A, ventral view; B, cross sectional view, venter up; C, lateral view. **D–F.** AMNH 6170, shell wall mostly exfoliated: D, ventral view; E, lateral view; F, ventral-apertural view. **G, H.** AMNH 6171: G, septal view, venter up; H, ventral view. **I, J.** AMNH 6172, shell wall mostly exfoliated: I, lateral view; J, ventral view. Scale bar is 15 mm.

163, pl. 16, figs. 1–3, text-fig. 31 [= *E*. sp. nov.].

Eohippioceras [sic.] *ferratum* (Cox). Seuß *et al*, 2009, p. 627.

Description.—Conchs small, subglobose and involute with relatively rapid whorl expansion; a well-preserved specimen (AMNH 6172) has 29 mm in conch diameter; whorl sections are strongly depressed, reniform consisting of rounded venter, ventrolateral shoulders to franks, weakly inflated umbilical zones and deeply rounded impressed area; umbilical angles bluntly pointed; width/height ratios of whorls are 1.6–1.8; mid-ventral conchal furrow developed. Shell surface smooth. Cameral length short; sutures exhibit distinct flutings indicating V-shaped and very prominent

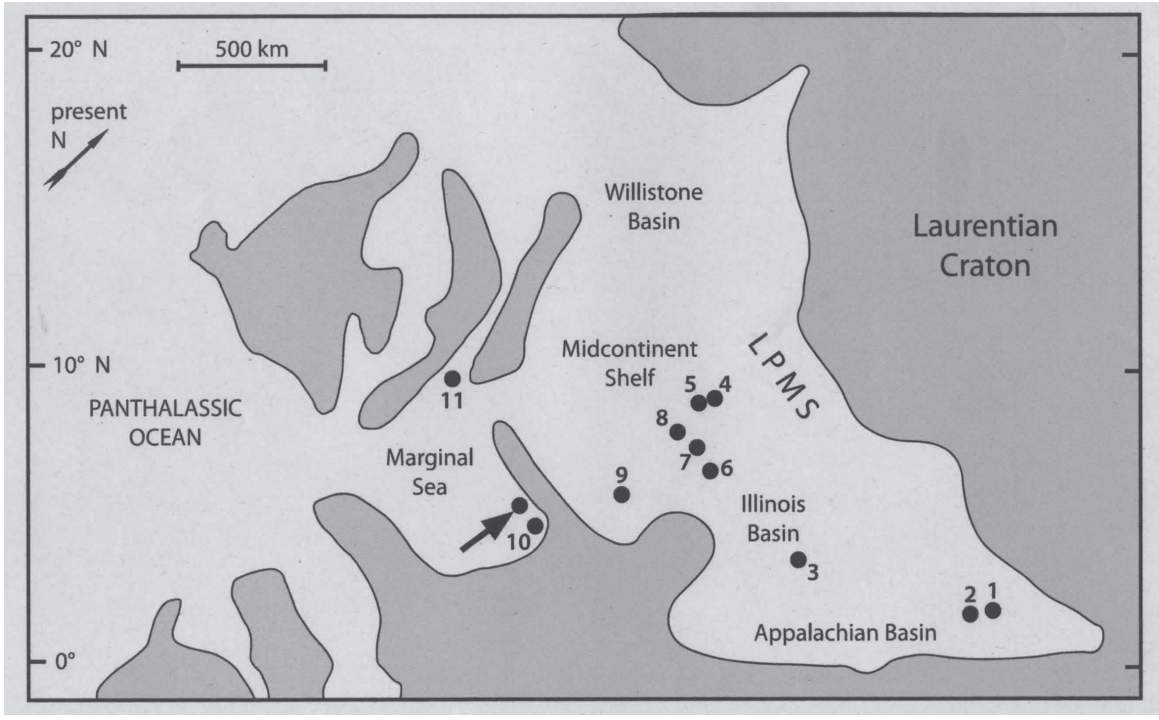

Figure 11. Paleogeographic reconstruction of the distribution of common Late Pennsylvanian coiled nautiloid species with the Finis Shale assemblage (arrow). Map based on and modified from Algeo and Heckel (2008). 1, *Liroceras liratum* and *Ephippioceras ferratum* in the Conemaugh Formation, Pennsylvania; 2, *L. liratum* and *E. ferratum* in the Conemaugh Formation, Ohio; 3, *L. liratum* in the Mattoon Formation, Illinois; 4, *E. ferratum* in the South Bend Formation, Nebraska; 5, *Tainoceras monilifer* in the Iatan Limestone, Nebraska; 6, *E. ferratum* in the Dennis and Westerville limestones, Missouri; 7, *L. liratum* in the Weston Shale, Kansas;8, *T. monilifer* in the Lawrence Shale and Kereford and Burlingame Limestones, Kansas; 9, *T. monilifer* in the Vamoosa Formation and *L. liratum* in the Nellie Bly, Wann, Vamoosa and Kanwaka Formations, Oklahoma; 10, *Peripetoceras bridgeportense* in the Wolf Mountain Shale, Texas; 11, *L. liratum* in the Magdalena Group, New Mexico.

ventral saddle, broadly rounded lateral lobes and low umbilical saddle. Siphuncle central to slightly supracentral in position.

Material examined.—AMNH 6169–6172.

Occurrence.—The holotype of *Ephippioceras ferratum* was collected from the Pennsylvanian (specific stratigraphic setting unknown) of Kentucky (Cox, 1858). Specimens of this species are also known from the Middle to Upper Pennsylvanian of the Conemaugh Formation in Pennsylvania (Miller and Unklesbay, 1942a), the Pottsville, Allegheny and Conemaugh Formations in Ohio (Sturgeon, 1946), the Cherokee Formation and the Dennis and Westerville Limestones in Missouri (Miller *et al*., 1933), the South Bend Formation in Nebraska (Miller *et al*., 1933), and the Boggy Formation in Oklahoma (Smith, 1938).

Localities of each examined specimen in this study are as follows; TXV-34 (AMNH 6169–6171), TXV-56 (AMNH 6172).

Discussion.—Gordon (1964) assigned a single Morrowan (Early Pennsylvanian) specimen from the Hale Formation, Arkansas to *Ephippioceras ferratum* and stated that it is the earliest record of this species. However, we cannot agree with his point of view because the ventral saddle in the suture of this Morrowan specimen is much lower than that of the typical ones of *E. ferratum*. We think that this specimen probably represents a new species and the chronological range of *E. ferratum* is, therefore, constrained exclusively in Middle to Late Pennsylvanian time.

Coiled Nautiloid Assemblage

The Late Pennsylvanian coiled nautiloid assemblage from the Finis Shale Member is composed by *Tainoceras monilifer* Miller, Dunbar and Condra, *Metacoceras quadratum* sp. nov., *Endolobus sturgeoni* sp. nov., *Domatoceras tuckeri* sp. nov., *Titanoceras* sp., *Solenochilus jackense* sp. nov., *Liroceras liratum* (Girty), *Peripetoceras bridgeportense* Tucker and Mapes, and *Ephippioceras ferratum* (Cox). In our previous studies concerning fossil cephalopods

in the Midcontinent of North America, Niko *et al*. (2018) examined the Middle Pennsylvanian orthoconic cephalopod assemblage in the Buckhorn Asphalt Quarry, located ca. 150 km northeast of Jacksboro, and concluded that it demonstrates provincialism. In contrast to this assemblage, the Finis Shale assemblage indicates cosmopolitanism and is characterized by the absence of endemic genera and presence of common, widely occurring species to high degree. Most of the area of Midcontinent North America, situated in the low latitudes at this time, was flooded due to the rise of the sea level forced by melting Gondwanan ice sheets and submergence in the shelf sea (i.e., the Late Pennsylvanian Midcontinent Sea (LPMS); Heckel, 1994). The LPMS included the Appalachian Basin, the Illinois Basin, the Midcontinent Shelf and the Willistone Basin, and was connected to the Panthalassic Ocean through the Marginal Sea (Algeo and Heckel, 2008; Algeo *et al*., 2008; Algeo and Herrmann, 2017).

As obvious from the proceeding systematic part, Late Pennsylvanian occurrences of the previously known four species from outside the Finis Shale Member are as follows: *T. monilifer* (Nebraska, Kansas, Oklahoma), *L. liratum* (Pennsylvania, Ohio, Illinois, Oklahoma, New Mexico), *P. bridgeportense* (Texas), and *E. ferratum* (Pennsylvania, Ohio, Missouri, Nebraska, Oklahoma). Among these, all localities in Texas (including the Finis Shale) and New Mexico belong to the Marginal Sea while others are in the LPMS; more particularly they belong to the Appalachian Basin (Pennsylvania, Ohio), the Illinois Basin (Illinois) and the Midcontinent Shelf (Missouri, Nebraska, Kansas, Oklahoma), whose areas represent the southern part of the sea (Figure 11). Niko *et al*. (2018) suggested that the Buckhorn Asphalt was deposited in the restricted epeiric sea during a cool episode. Differences of above-mentioned composition between these two assemblages can be referred to sea level change triggered by forming and melting of ice sheets. We can conclude that the coiled nautiloid assemblage from the Finis Shale inhabited the Marginal Sea that was open to the Panthalassic Ocean at that time and thus, had strong biotic linkage with the southern LPMS including the Appalachian Basin, the Illinois Basin, and the Midcontinent Shelf.

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References

Agassiz, L., 1847, *An Introduction to the Study of Natural History, in a Series of Lectures Delivered in the Hall of the College of Physicians and Surgeons*, 58 p. Greeley and McElrath, New York.

Algeo, T. J. and Heckel, P. H., 2008, The Late Pennsylvanian Midcontinent Sea of North America: A review. *Palaeogeography*, *Palaeoclimatology*, *Palaeoecology*, vol. 268, p. 205−221.

Algeo, T. J. and Herrmann, A. D., 2017, An ancient estuarine-circulation nutrient trap: The Late Pennsylvanian Midcontinent Sea of North America. *Geology*, vol. 46, p. 143−146.

Algeo, T. J., Rowe, H., Hower, J. C., Schwark, L., Herrmann, A. and Heckel, P. H., 2008, Changes in ocean denitrification during Late Carboniferous glacial-interglacial cycles. *Nature Geoscience*, vol. 1, p. 709−714.

Barnes, V. E., Hentz, T. F., Brown, L. F., Cleaves, A. W., Kier, R. S., McGowen, J. H., Parrish, W. C., Ramsey, J. W., Long, T. F., Reutinger, C. A., Caran, S. C., Henry, C. D. and Kaiser, W. R., 1987, *Geologic Atlas of Texas*, *Wichita Falls-Lawton Sheet*. Annual Report, Bureau of Economic Geology, The University of Texas at Austin.

Boardman, D. R. II, Work, D. M., Mapes, R. H. and Barrick, J. E., 1994, Biostratigraphy of Middle and Late Pennsylvanian (Desmoinesian-Virgilian) ammonoids. *Kansas Geological Survey, Bulletin*, no. 232, p. 1−121.

Cox, E. T., 1858, Palaeontological report of Coal Measure Mollusca. *Kentucky Geological Survey*, vol. 3, p. 557−576, pls. 7−10.

Doguzhaeva, L. A., Mapes, R. H. and Dunca, E., 2006, A Late Carboniferous adolescent cephalopod from Texas (USA), with a short rostrum and a long body chamber. *Acta Universitatis Carolinae*, *Geologica*, vol. 49, p. 55−68.

Doguzhaeva, L. A., Mapes, R. H. and Mutvei, H., 1999, A Late Carboniferous spirulid coleoid from the southern Mid-continent (USA), shell wall ultrastructure and evolutionary implications. *In*, Olóriz F. and Rodríguez-Tovar, F. J. *eds*., *Advancing Research on Living and Fossil Cephalopods*, p. 47−57. Kluwer Academic/Plenum Publishers, New York, Boston, Dordrecht, London and Moscow.

Furnish, W. M., Glenister, B. F. and Hansman, R. H., 1962, Brachycycloceratidae, *novum*, deciduous Pennsylvanian nautiloids. *Journal of Paleontology*, vol. 36, p. 1341–1356, pls. 176–180.

Geinitz, H. B., 1843, *Gäa von Sachsen. Einleitung in die Flora von Sachsen von Dr. und Prof. Ludwig Reichenbach*, 235 p. Dresden and Leipzig.

Girty, G. H., 1911, On some new genera and species of Pennsylvanian fossils from the Wewoka Formation of Oklahoma. *Annals of the New York Academy of Science*, vol. 21, p. 119–156.

Girty, G. H., 1915, Fauna of the Wewoka Formation of Oklahoma. *United States Geological Survey, Bulletin*, no. 544, p. 1–353.

Gordon, M. Jr., 1964, Carboniferous cephalopods of Arkansas. *United States Geological Survey Professional Paper*, no. 460, p. 1–322, pls. 1–30.

Hansman, R. H., 1965, *Brachycycloceras*? from the Pennsylvanian of Texas. *Journal of Paleontology,* vol. 39, p. 729−730.

Heckel, P. H., 1994, Evaluation of evidence for glacial-eustatic control over marine Pennsylvanian cyclothems in North America and consideration of possible tectonic effects. *In*, Dennison, J. M. and Ettensohn, F. R. *eds*., *Tectonic and Eustatic Controls on Sedimentary Cycles*, p. 65−87. SEPM

(Society for Sedimentary Geology), Concepts in Sedimentology and Paleontology, vol. 4, Tulsa.

Hyatt, A., 1883–1884, Genera of fossil cephalopods. *Proceedings of the Boston Society of Natural History*, vol. 22, p. 253–338.

Hyatt, A., 1891, Carboniferous cephalopods. *Geological Survey of Texas*, *Second Annual Report, 1890*, p. 327–356.

Hyatt, A., 1893, Carboniferous cephalopods. Second paper. *Geological Survey of Texas*, *Fourth Annual Report*, *1892*, p. 377–474.

Hyatt, A., 1894, Phylogeny of acquired characteristics. *Proceedings of the American Philosophical Society,* vol. 32, p. 349–647, pls. 1–14.

Kummel, B., 1963, Miscellaneous nautilid type species of Alpheus Hyatt. *Bulletin of the Museum of Comparative Zoology*, vol. 128, p. 325–368, pls. 1–30.

Kummel, B., 1964, Nautiloidea—Nautilida. *In*, Teichert, C., Kummel, B., Sweet, W. C., Stenzel, H. B., Furnish, W. M., Glenister, B. F., Erben, H. K., Moore, R. C. and Nodine Zeller, D. E. *eds.*, *Treatise on Invertebrate Paleontology, Part K*, *Mollusca 3 (Cephalopoda*. *General Features*, *Endoceratoidea–Actinoceratoidea, Nautiloidea*, *Bactritoidea)*, p. K383–K457. Geological Society of America, New York, and University of Kansas Press, Lawrence.

Mapes, R. H., 1979, Carboniferous and Permian Bactritoidea (Cephalopoda) in North America. *The University of Kansas Paleontological Contributions, Article 64*, p. 1–75, pls. 1–41.

Mapes, R. H., 1987, Upper Paleozoic cephalopod mandibles: Frequency of occurrence, modes of preservation, and paleoecological implications. *Journal of Paleontology*, vol. 61, p. 521–538.

Mapes, R. H. and Chaffin, D. T., 2003, Predation on cephalopods, a general overview with a case study from the Upper Carboniferous of Texas. *In*, Kelley, P. H., Kowalewski, M. and Hansen, T. A. *eds.*, *Predator-Prey Interactions in the Fossil Record*, p. 177–213. Kluwer Academic/Plenum Publishers, New York, Boston, Dordrecht, London and Moscow.

Mapes, R. H., Sims, M. S. and Boardman, D. R. II, 1995, Predation on the Pennsylvanian ammonoid *Goniloboceras* and its implications for allochthonous vs. autochthonous accumulations of Goniatites and other ammonoids. *Journal of Paleontology*, vol. 69, p. 441–446.

McChesney, J. H., 1859, Descriptions of new species of fossils, from the Palaeozoic rocks of the western states. *Extra Transactions*, *Chicago Academy of Sciences*, vol. 1, p. 1–76.

McKinzie, M. and McLeod, J., 2003, Pennsylvanian fossils of north Texas. *Occasional Papers of the Dallas Paleontological Society*, vol. 6, p. 1–145.

McGowen, J. H., Proctor, C. V., Haenggi, W. T., Reaser, D. F. and Barnes, V. E., 1972, *Geologic Atlas of Texas*, *Dallas Sheet*. Bureau of Economic Geology, The University of Texas at Austin.

M'Coy, F., 1844, *A Synopsis of the Characters of the Carboniferous Limestone Fossils of Ireland*, 274 p. Privately published. (reissued by Williams and Norgate, London, 1862)

Meek, F. B., 1872, Part II. Paleontology. Report on the paleontology of eastern Nebraska, with some remarks on the Carboniferous rocks of that district. *In*, *Final Report of the United States Geological Survey of Nebraska and Portions of the Adjacent Territories*, *Made Under the Direction of the Commissioner of the General Land Office*, p. 83–236, pls. 1–11. Government Printing Office, Washington, D.C.

Meek, F. B. and Worthen, A. H., 1860, Descriptions of new Carboniferous fossils from Illinois and other western states. *Proceedings of the Academy of Natural Sciences of Philadelphia*, *1860*, p. 447–472.

Meek, F. B. and Worthen, A. H., 1865, Contributions to the palaeontology of Illinois and other western states. *Proceedings of the Academy of Natural Sciences of Philadelphia*, *1865*, p. 245–273.

Meek, F. B. and Worthen, A. H., 1870, Descriptions of new species and genera of fossils from the Palaeozoic rocks of the western states. *Proceedings of the Academy of Natural Sciences of Philadelphia*, *1870*, p. 22–56.

Mikesh, D. L. and Glenister, B. F., 1966, *Solenochilus springeri* (White & St. John, 1868) from the Pennsylvanian of southern Iowa. *Proceedings of the Iowa Academy of Science*, vol. 73, p. 269–278.

Miller, A. K., 1932, A Pennsylvanian cephalopod fauna from south-central New Mexico. *Journal of Paleontology*, vol. 6, p. 59–93, pls. 12, 13.

Miller, A. K. and Cline, L. M., 1934, The cephalopod fauna of the Pennsylvanian Nellie Bly Formation of Oklahoma. *Journal of Paleontology*, vol. 8, p. 171–185, pl. 28.

Miller, A. K. and Downs, R. H., 1950, Ammonoids of the Pennsylvanian Finis Shale of Texas. *Journal of Paleontology*, vol. 24, p. 185–218, pls. 31–35.

Miller, A. K., Dunbar, C. O. and Condra, G. E., 1933, The nautiloid cephalopods of the Pennsylvanian System in the Mid-Continent region. *Nebraska Geological Survey, Bulletin*, no. 9, p. 1–240, pls. 1–24.

Miller, A. K., Lane, J. H. and Unklesbay, A. G., 1947, A nautiloid cephalopod fauna from the Pennsylvanian Winterset Limestone of Jackson County, Missouri. *University of Kansas Paleontological Contributions, Mollusca, Article 2*, p. 1–11, pls. 1–5.

Miller, A. K. and Owen, J. B., 1934, Cherokee nautiloids of the northern Mid-Continent region. *University of Iowa Studies in Natural History*, vol. 16, p. 185–272, pls. 8–19.

Miller, A. K. and Unklesbay, A. G., 1942a, The cephalopod fauna of the Conemaugh Series in western Pennsylvania. *Annals of the Carnegie Museum*, vol. 29, p. 127–174, pls. 1–8.

Miller, A. K. and Unklesbay, A. G., 1942b, Permian nautiloids from western United States. *Journal of Paleontology*, vol. 16, p. 719–738, pls. 111–117.

Miller, A. K. and Unklesbay, A. G., 1947, The cephalopod fauna of the Conemaugh Series in western Pennsylvania: Supplement. *Annals of the Carnegie Museum*, vol. 30, p. 319–330, pls. 1, 2.

Miller A. K. and Youngquist, W., 1949, American Permian nautiloids. *The Geological Society of America Memoir*, no. 41, p. 1–218, pls. 1–59.

Murphy, J. L., 1970, Coiled nautiloid cephalopods from the Brush Creek Limestone (Conemaugh) of eastern Ohio and western Pennsylvania. *Journal of Paleontology*, vol. 44, p. 195–205, pls. 35, 36.

Mutvei, H. and Mapes, R. H., 2018, Carboniferous coleoids with mixed coleoid-orthocerid characteristics: a new light on cephalopod evolution. *GFF*, *A Scandinavian Journal of Earth Science*, vol. 140, p. 11–24.

Mutvei, H., Mapes, R. H. and Doguzhaeva, L. A., 2012, Shell structure in Carboniferous bactritid-like coleoids (Cephalopoda) from South Central UAS. *GFF*, *A Scandinavian Journal of Earth Science*, vol. 134, p. 201–216.

Niko, S. and Mapes, R. H., 2010, Reevaluation of the Late Carboniferous cephalopod, *Brachycycloceras*? *spectrum*

Hansman, 1965 from Texas, USA. *Paleontological Research*, vol. 14, p. 227–232.

Niko, S. and Mapes, R. H., 2011, *Texanoceras*, a new neptunoceratid cephalopod genus from the Upper Pennsylvanian Graham and Caddo Creek formations in north-central Texas. *Journal of Paleontology*, vol. 85, p. 519–523.

Niko, S., Seuss, B. and Mapes, R. H., 2018, Desmoinesian (Middle Pennsylvanian) orthocerid cephalopods from the Buckhorn Asphalt Lagerstätte in Oklahoma, Midcontinent North America. *Paleontological Research*, vol. 22, p. 20–36.

Plummer F. B. and Hornberger, J. Jr., 1936, Geology of Palo Pinto County, Texas. *University of Texas Bulletin*, no. 3534, p. 1–240.

Plummer, F. B. and Moore, R. C., 1922, Stratigraphy of the Pennsylvanian formations of north-central Texas. *University of Texas Bulletin*, no. 2132, p. 1–237, pls. 1–27.

Plummer, F. B. and Scott, G., 1937, Upper Paleozoic ammonites in Texas. *The University of Texas Bulletin*, no. 3701, p. 1–516, pls. 1–41.

Seuß, B., Nützel, A., Mapes, R. H. and Yancey, T. E., 2009, Facies and fauna of the Pennsylvanian Buckhorn Asphalt Quarry deposits: A review and new data on an important Palaeozoic fossil *Lagerstätte* with aragonite preservation. *Facies*, vol. 55, p. 609–645.

Smith, H. J., 1938, *The cephalopod Fauna of the Buckhorn Asphalt*, 40 p. The University of Chicago Libraries, Chicago, Illinois.

Sturgeon, M. T., 1946, Allegheny fossil invertebrates from eastern Ohio— Nautiloidea. *Journal of Paleontology*, vol. 20, p. 8–37, pls. 3–9.

Sturgeon, M. T. and Miller, A. K., 1948, Some additional cephalopods from the Pennsylvanian of Ohio. *Journal of Paleontology*, vol. 22, p. 57–80, pls. 18, 19.

Sturgeon, M. T., Windle, D. L., Mapes, R. H. and Hoare, R. D., 1982, New and revised taxa of Pennsylvanian cephalopods in Ohio and west Virginia. *Journal of Paleontology*, vol. 56, p. 1453–1479, pls. 1–5.

Sturgeon, M. T., Windle, D. L., Mapes, R. H. and Hoare, R. D., 1997, Pennsylvanian cephalopods of Ohio. Part 1. Nautiloid and bactritoid cephalopods. *Ohio Division of Geological Survey, Bulletin*, no. 71, p. 1–191.

Teichert, C., 1940, Contributions to nautiloid nomenclature. *Journal of Paleontology*, vol. 14, p. 590–597.

Tucker, J. K., 1976, A coiled nautiloid fauna from the Mattoon Formation (Pennsylvanian) of Illinois. *Transactions of the Illinois State Academy of Sciences*, vol. 69, p. 57–77.

Tucker, J. K. and Mapes, R. H., 1978, Coiled nautiloid cephalopods from the Wolf Mountain Shale (Pennsylvanian), north-central Texas. *Journal of Paleontology*, vol. 52, p. 596–604, pls. 1–3.

Unklesbay, A. G., 1962, Pennsylvanian cephalopods of Oklahoma. *Oklahoma Geological Survey*, *Bulletin*, no. 96, p. 1–150, pls. 1–19.

Unklesbay, A. G. and Palmer, E. J., 1958, Cephalopods from the Burgner Formation in Missouri. *Journal of Paleontology*, vol. 32, p. 1071–1075, pl. 138.

Wani, R., Jenkins, R. G. and Mapes, R. H., 2012, Preferential predatory peeling: Ammonoid *vs*. nautiloid shells from the Upper Carboniferous of Texas, USA. *Geobios*, vol. 45, p. 129–137.

White, C. A. and St. John, O. H., 1868, Descriptions of new Subcarboniferous and Coal Measure fossils collected upon the Geological Survey of Iowa; together with a notice of new generic characters observed in two species of brachiopods. *Transactions of the Chicago Academy of Sciences*, vol. 1, p. 115–127.

Young, J. A. Jr., 1942, Pennsylvanian Scaphopoda and Cephalopoda from New Mexico. *Journal of Paleontology*, vol. 16, p. 120–125, pl. 20.

Zittel, K. A. von, 1900, *Text-book of Palaeontology* (translated and edited by Eastman, C. R.), vol. 1, 706 p. Macmillan, London and New York.