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Early Carboniferous trigonoceratid nautilids from the Pitkin Formation of Arkansas, Midcontinent North America

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Abstract. Two new species of trigonoceratid nautilids from the middle Chesterian (Early Carboniferous) Pitkin Formation of Arkansas, Midcontinent North America are described. *Epistroboceras pitkinense* sp. nov. is most similar to *E. caneyense* Niko and Mapes, 2004, but is distinguished mainly by its dorsally shifted umbilical angle. *Stroboceras gordoni* sp. nov. is characterized by the narrow lg 2 (second lateral groove) in the lateral grooves, the two bilaterally symmetrical lateral ridges, and the weak nodes at intersections of ridges and the growth lines. Species previously described or assigned to *Stroboceras* are re-examined. Similarities in the shell morphology between the trigonoceratid nautilid *Stroboceras* and the isochronous Early Carboniferous ammonoid *Eumorphoceras* probably provide an example of synchronized convergent evolution.

Key words: Arkansas, *Epistroboceras pitkinense* sp. nov., middle Chesterian (Early Carboniferous), Pitkin Formation, *Stroboceras gordoni* sp. nov., trigonoceratid nautilids

Introduction

The Pitkin Formation in northern Arkansas, Midcontinent North America (middle Chesterian, late Early Carboniferous) was named by Adams (1904, p. 27) and Ulrich (1904, p. 109). This formation mostly comprises fossiliferous marine carbonates deposited in high-energy oolitic and bioclastic grain shoals along the shoreface into a southward-deepening ramp (Handford, 1986). According to the lithofacies analysis by Jehn and Young (1976), grainstones and packstones are dominant with minor amounts of shale, wackestone and biohermal limestone. The thickness of this formation is 15 m at the type section just north of the town of Woolsey in Washington County, Arkansas, but to the east the formation attains a thickness of more than 120 m (Easton, 1942, 1943). Saunders *et al*. (1977) subdivided this formation into two informal members with correlative discussions based on ammonoids. "The Lower Pitkin Member" contains a rich ammonoid assemblage, including *Cravenoceras* sp., *Richardsonites richardsonianus*, *Eumorphoceras* sp., *Arcanoceras furnishi*, *Syngastrioceras* sp., *Metadimorphoceras* aff. *M. saleswheelense* and *Trizonoceras* sp., and is assigned to the E_1, upper Pendleian Stage (Saunders *et al.*, 1977; Saunders and Work, 1999; Titus, 1999). "The Upper Pitkin Member", known as the *Eumorphoceras bisulcatum-Cravenoceras richardsonianum* Zone, corresponds to the E_{2a}, lower Arnsbergian Stage.

The purpose of this report is to describe two new species of trigonoceratid nautilids recovered from the Pitkin Formation. The fossil localities are on Lick Mountain, Newton County, Arkansas (locality 1), and road cut on the southern side of Arkansas Highway 66, approximately 1 km northeast of Leslie, Searcy County, Arkansas (locality 2 = loc. M-28 in Mapes, 1979). Localities 1 and 2 belong to the informal "Lower" and "Upper" Pitkin members, respectively. The specimens studied are housed in the Ohio University Zoological Collection (OUZC), Ohio University at Athens, Ohio.

Systematic paleontology

Family Trigonoceratidae Hyatt, 1884
Genus **Epistroboceras** Turner, 1954

Remarks.—See Niko and Mapes (2004, p. 341, 342) for the current status of this genus.

Epistroboceras pitkinense sp. nov.

Figures 1, 2.1–2.8, 2.10, 2.11, 3.2, 3.4

Stroboceras (*Epistroboceras*) sp., Gordon, 1964, p. 147.
Epistroboceras sp., Niko and Mapes, 2004, p. 341.

Diagnosis.—Species of *Epistroboceras* with width/height ratios of 0.75–0.83 and dorsally shifted umbilical angle in adoral whorl with umbilical zone height per whorl height ratios of 0.17–0.25; ventral platform relatively wide; ventral (hyponomic) sinus U-shaped; siphuncular position ratios (see the description for its definition) are 0.23–0.25.

Description.—Compressed, evolute shells consisting of at least approximately two volutions with 31.4 mm in maximum observable diameter and 9.5 mm in maximum observable whorl width in holotype whose adoral termination is an incomplete body chamber; umbilicus perforate; whorls rapidly inflate during growth, thus umbilical area narrow for evolute form with ratios of umbilical area diameter per shell diameter of 0.34–0.36, and umbilical slope deeply concave; almost perfect body chamber (paratype, OUZC 5103) attains 38.2 mm in length, which represents approximately 4/9 of the last (third?) volution. Embryonic shell not preserved; juvenile whorl facing umbilical perforation and succeeding approximately 1/4 volution are *Stroboceras*-like with subtrapezoidal profiles; whorl sections of this *Stroboceras*-like portion have concave venter as ventral groove (vg), concave ventrolateral shoulders as ventrolateral grooves (v-lg), undulated flanks and subrounded dorsum; two bilaterally symmetrical lateral grooves (lg 1, 2) developed on flanks; dorsal (contact) groove present except for juvenile whorl; among these grooves, lg 1 forms widest concavity, where whorl section strongly constricted; whorl surface of this *Stroboceras*-like portion is ornamented by four longitudinal ridges with bilateral symmetry and distinct growth lines; ventral ridges (vr) at boundary between vg and v-lg, ventrolateral ridges (v-lr) at boundary between v-lg and lg 1, lateral ridges (lr) at boundary between lg 1 and lg 2, and dorsolateral ridges (d-lr) at boundary between lg 2 and umbilical wall. Adoral whorls shift to compressed suboctagonal in profiles with width/height ratios of 0.75–0.83; vg forms relatively wide ventral platform bordered by carinate ventrolateral angle (= vr) of 120° to 130° in internal mold; ratios of vg width per whorl width are 0.3–0.4; ventrolateral shoulders become obsolescent, and shift to concave ventral sides (v-lg) of converging flanks; angle on flank (= v-lr) obtuse, ranges from 155° to 170°; v-lg width represents approximately 1/3 of flank width; lg 1 became obsolescent; lg 2 disappeared as shell becomes flattened to weakly inflated; umbilical angle subround of about 125° to 130°, shifting to dorsum; ratios of umbilical zone height per whorl height are 0.17–0.25; umbilical wall indicates nearly linear profiles; except for vr and v-lr, surface ridges become subrounded; growth lirae also become subdued; ventral platform indicates weak inflation on internal mold. Peristome lobed, with deep U-shaped ventral (hyponomic) sinus, broad subround to subtrapezoid ventrolateral saddles, and relatively deep U-shaped lateral (ocular) sinus; dorsolateral to dorsal rim of peristome not observable. Sutures have very shallow ventral lobe, and relatively shallow but broad lateral lobes. Camerae short; there are 3 to 6 camerae in corresponding whorl height; septal curvature moderate for family. Siphuncle consists of retrochoanitic septal necks and cylindrical connecting rings;

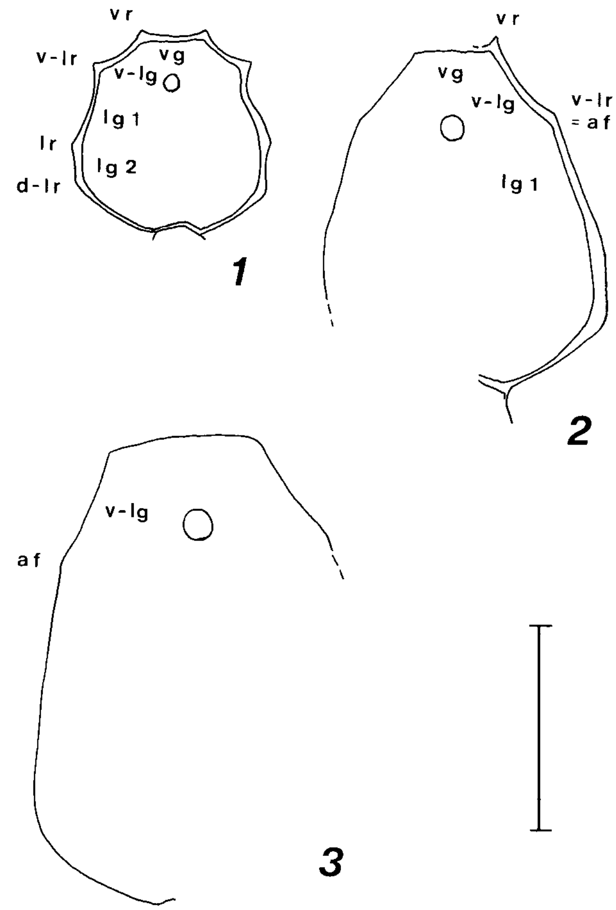


Figure 1. *Epistroboceras pitkinense* sp. nov., diagrams from cross sections of whorls in phragmocones, venter is up. **1**, **2**. Holotype, OUZC 5102. **3**. Paratype, OUZC 5103, internal mold. Abbreviations: vg = ventral groove; v-lg = ventrolateral groove; lg 1, 2 = lateral grooves; vr = ventral ridge; v-lr = ventrolateral ridge; lr = lateral ridge; d-lr = dorsolateral ridge; af = angle on flank. Scale bar equals 5 mm.

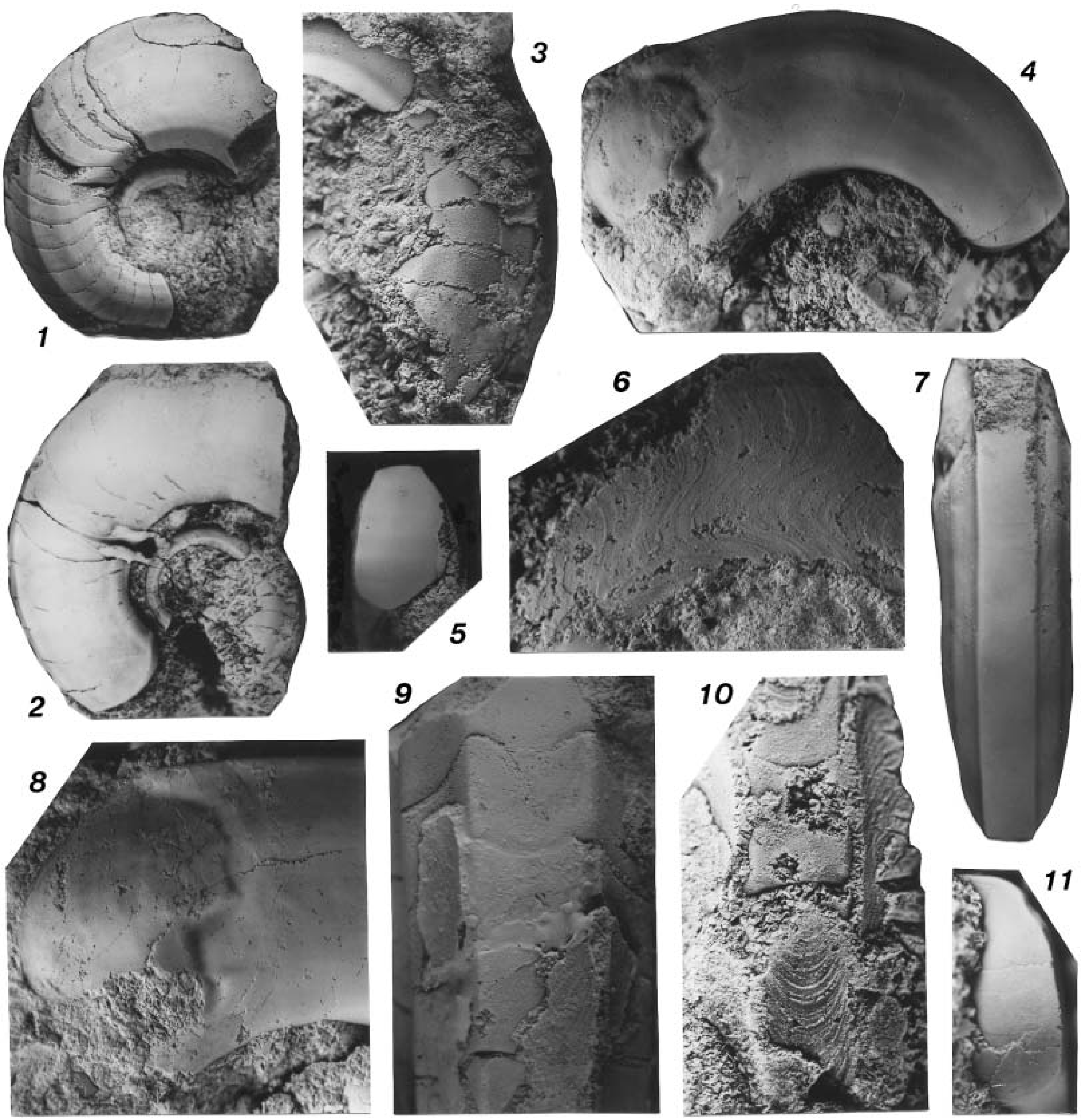


Figure 2. **1–8**, **10**, **11**. *Epistroboceras pitkinense* sp. nov. **1**. Paratype, OUZC 5101, lateral view, ×2. **2**, **3**, **10**, **11**. Holotype, OUZC 5102. **2**, lateral view, ×2; **3**, partial enlargement of lateral view showing *Stroboceras*-like immature portion, ×5; **10**, partial enlargement of ventral view showing growth lines outlining the ventral (hyponomic) sinus on the peristome, and the ventral lobe of the suture, ×10; **11**, cross-sectional view, ×5. **4–8**. Paratype, OUZC 5103. **4**, lateral view of body chamber, ×2; **5**, cross-sectional view at the last septum, ×2; **6**, partial enlargement of lateral view showing growth lines outlining the lateral (ocular) sinus on the peristome, ×5; **7**, ventral view of body chamber, ×2; **8**, partial enlargement of lateral view showing the peristome, shell wall depression probably caused by sublethal injury, ×3. **9**. *Stroboceras gordoni* sp. nov., holotype, OUZC 5104, partial enlargement of ventral view showing the ventral lobes of the sutures, ×5.

its position is near midway between the center and ventral margin; ratios of distance of central axis of siphuncle from ventral whorl surface per corresponding whorl height in dorsoventral section (siphuncular position ratio) are 0.23–0.25; ventral septal necks orthochoanitic, shift to cyrtochoanitic in dorsal ones; di-

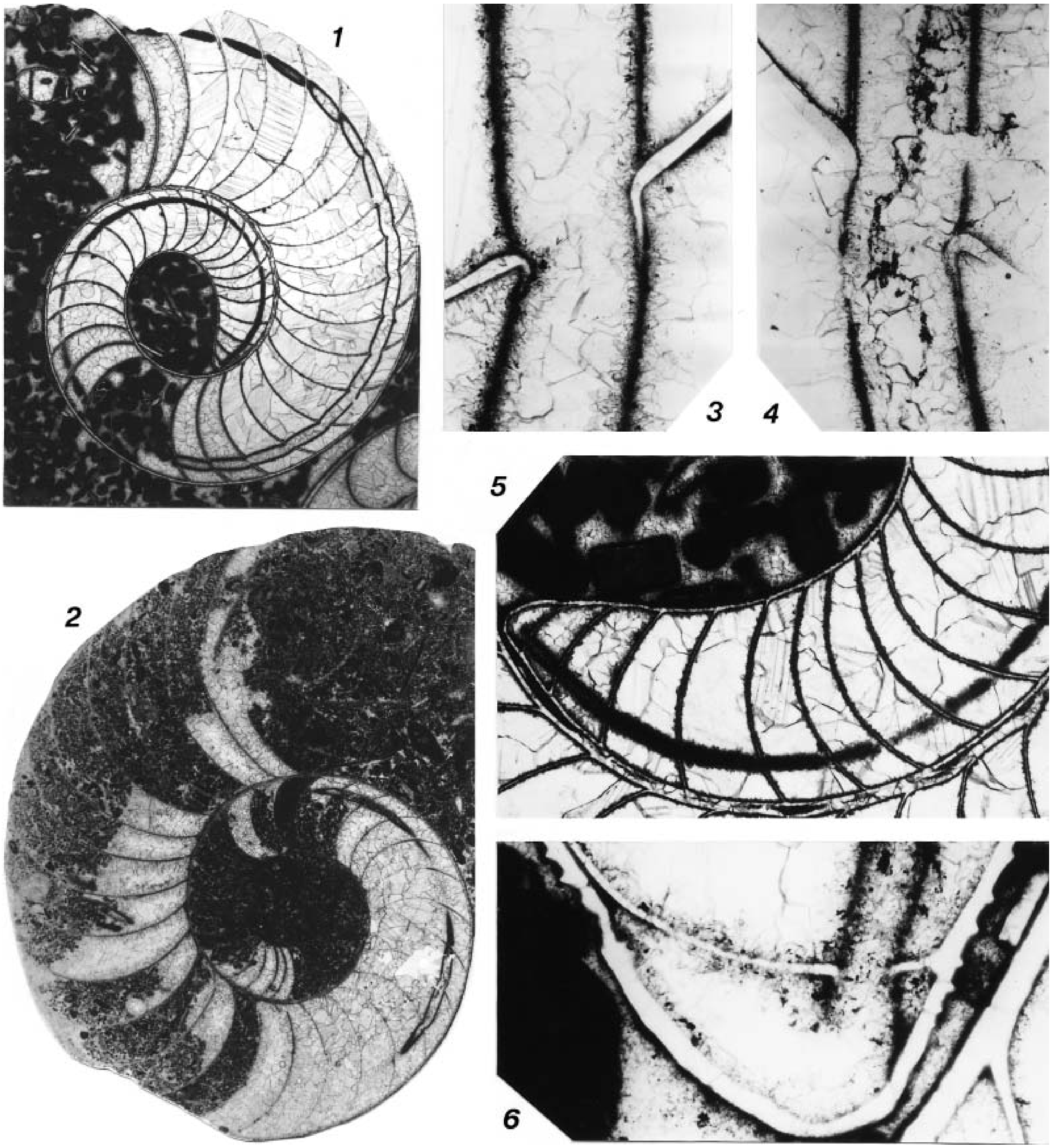


Figure 3. **1**, **3**, **5**, **6**. *Stroboceras gordoni* sp. nov., paratype, OUZC 5105, dorsoventral thin section. **1**, ×4; **3**, partial enlargement of septal neck, ×50; **5**, partial enlargement of apical portion, ×14; **6**, partial enlargement of initial camera, ×75. **2**, **4**. *Epistroboceras pitkinense* sp. nov., paratype, OUZC 5101, dorsoventral thin section. **2**, ×4; **4**, partial enlargement of septal neck, ×50.

ameter of connecting ring is 0.33 mm at whorl height (in dorsoventral section) of 3.8 mm. Cameral and endosiphuncular deposits absent.

Material examined.—Holotype, OUZC 5102. Paratypes, OUZC 5101, 5103.

Occurrence.—"The Upper Pitkin Member" at locality 2. The fossil-bearing exposure is a road cut on the south side of Arkansas Highway 66, approximately

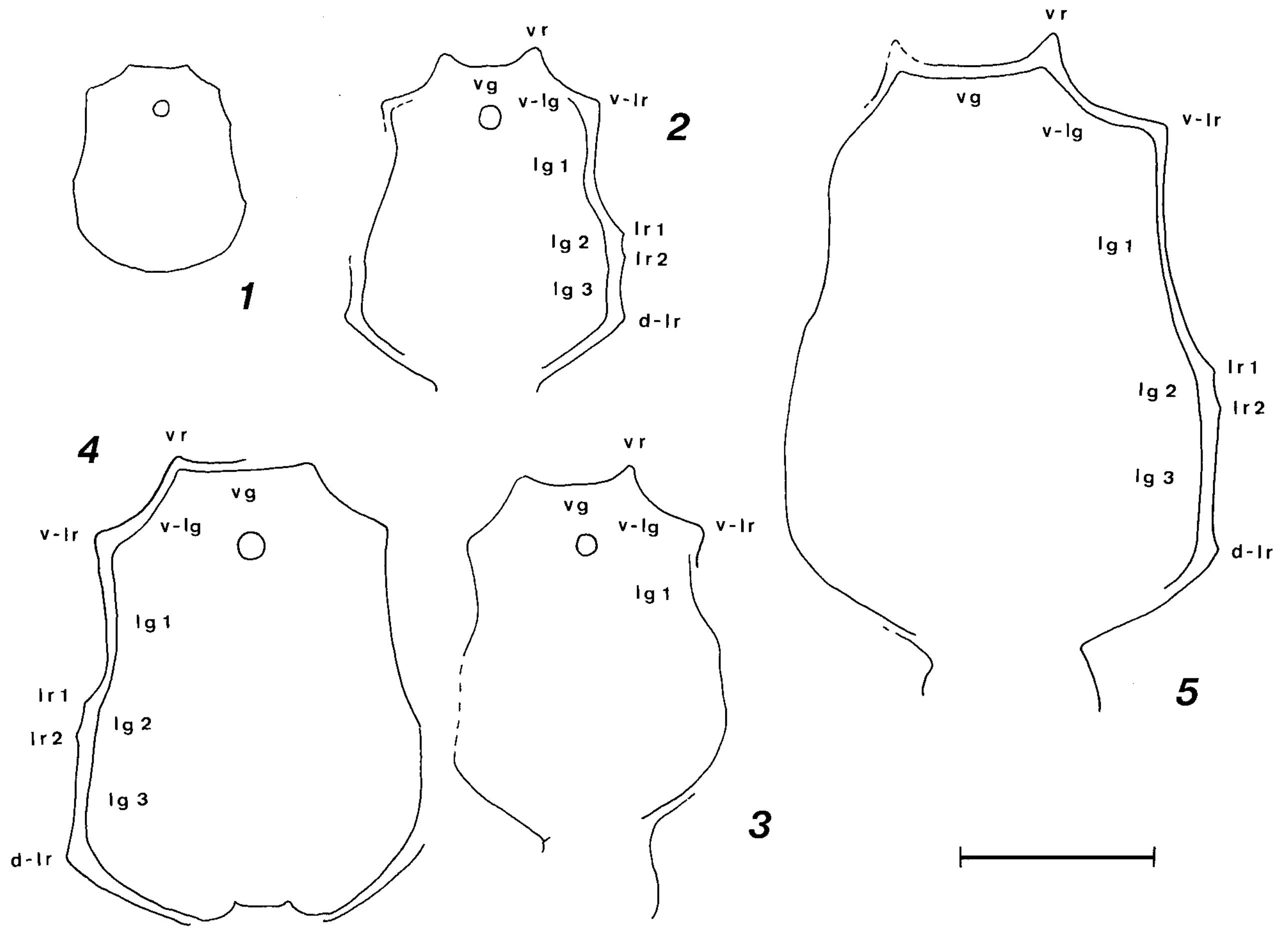


Figure 4. *Stroboceras gordoni* sp. nov., diagrams from cross sections of whorls, venter is up. **1**, **2**. Holotype, OUZC 5104. **1**, internal mold, phragmocone; **2**, phragmocone. **3**, **5**. Paratype, OUZC 5114. **3**, phragmocone; **5**, body chamber. **4**. Paratype, OUZC 5106, phragmocone. Abbreviations are given in explanation of Figure 1, additionally: lg 3 = lateral groove, lr 1, 2 = lateral ridges. Scale bar equals 5 mm.

midway on the hill slope. The fossils are in a dense, fine-grained limestone (grainstone to packstone) about 1 meter thick. The abundant and diverse cephalopod fauna including *Eumorphoceras bisulcatum* and *Richardsonites richardsonianus* (see Mapes, 1979, locality M-28) is mixed with plant debris; surprisingly, only a cephalopod fauna is present in the limestone.

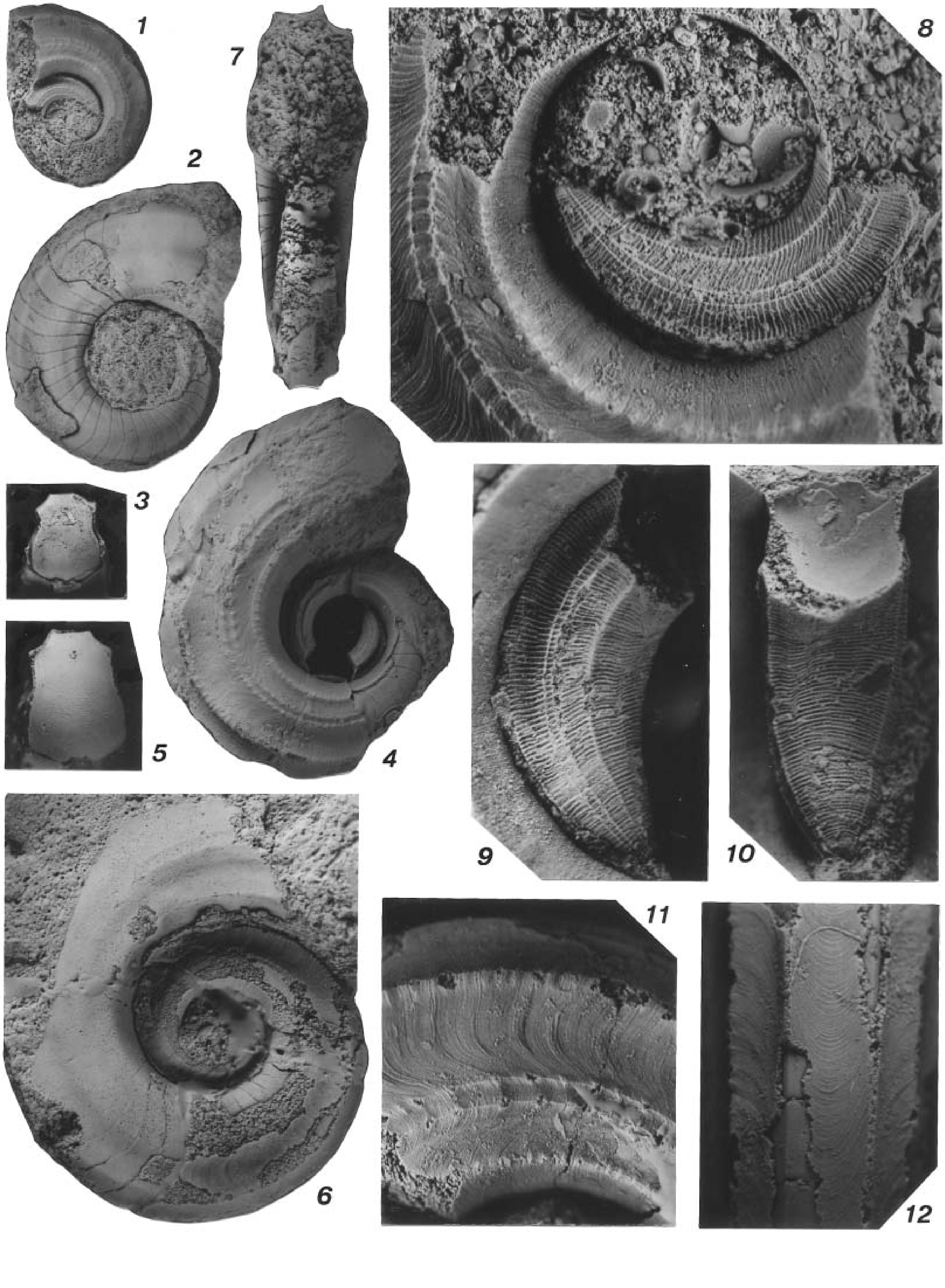
Etymology.—The specific name is derived from the Pitkin Formation from which the new species was recovered.

Discussion.—*Epistroboceras pitkinense* sp. nov. is most similar to *E. caneyense* Niko and Mapes (2004, p. 342, 343, fig. 1.1–1.6) from the middle Chesterian (Early Carboniferous) Caney Formation of Oklahoma, but differs by having the dorsally shifted umbilical angle in the adoral whorls, namely 0.17–0.25 in the ratios of umbilical zone height per whorl height versus approximately a ratio of 0.28 in *E. caneyense*. In addition, the ventral (hyponomic) sinus of *E. pitkinense* is less angular than that of *E. caneyense*.

Genus ***Stroboceras*** Hyatt, 1884

Type species.—*Gyroceras harttii* [sic] Dawson (1868, p. 311, fig. 125) from Nova Scotia.

Other included species.—*Stroboceras chancharense* Shimansky (1967, p. 153, 154, pl. 19, figs. 3a, b, 4a, b) from the southern Urals, *S. crassum* Foord (1900, p. 64, 65, pl. 20, figs. 13a–c) from Fermanagh, Ireland, *S. crispum* Gordon (1957, p. 28, 29, pl. 3, figs. 1–4, text-figs. 9A, B) from Alaska, *S. duplicatum* Schmidt (1951, p. 33, 34, pl. 4, fig. 5, text-fig. 3c; Gordon, 1964, p. 145; = *Nautilus bisulcatus* Koninck, 1878) from Belgium and the Harz Mountains, Germany, *S.* ? *edwardsianum* (Koninck, 1851, p. 712, pl. 60, fig. 7) from Belgium, *S. furnishi* Elias (1958, p. 31, pl. 3, fig. 9, text-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figs. 5, 6) from Oklahoma, *S. gordoni* (this report), *S.* ? *parammoneus* Shimansky (1996, p. 26, 27, pl. 2, figs. 7a, b; = *Stroboceras ammoneus* (Eichwald, 1857) in Shimansky, 1967, 1993) from Novaya Zemlya, *S. pauperum* (Whitfield, 1882, p. 226; 1891, p. 595, pl. 14, fig. 23) from Ohio, *S. sulcatum sulcatum* (Sowerby, 1826, p. 137, pl. 571, figs. 1, 2) from Derbyshire, Great Britain, *S. s. desulcatum* Schmidt (1951, p. 32, pl. 4, figs. 1, 2) from Belgium and Schlesien (Silesia), Poland, *S. s. multisulcatum* Schmidt (1951, p. 32, 33, pl. 4, figs. 6, 7) from Dillkreis, Germany, *S. triferum* Schmidt (1951, p. 34, 35, pl. 4, figs. 8a, b, 9a, b, text-fig. 3d) from Schlesien (Silesia), Poland, *S.* ? *trigonum* (Winchell, 1862, p. 359) from Michigan, *S. varsoviense* (Weigner, 1938, p. 50, 51, pl. 3, figs. 8, 8a) from Gołonoga, Poland, *S*. sp. from Illinois (Weller, 1916, p. 263, pl. 19, fig. 18).

Range.—Visean to early Serpukhovian (Early Carboniferous).

Discussion.—Schmidt (1951) assigned *Nautilus* (*Discus*) *trisulcatus* Meek and Worthen, 1860 to *Stroboceras*. Subsequently, *Nautilus bicarinatus* Verneuil *in* Murchison, Verneuil and Keyserling, 1845 was added to the genus by Shimansky (1967). However, the absence of the lateral groove even in the immature whorls and the angle on the flanks of these species suggests that they have a closer relationship with *Epidomatoceras* (Turner, 1954) rather than *Stroboceras*. *Stroboceras evansi* Ramsbottom and Moore, 1961 has an almost circular whorl section and six spiral (longitudinal) ridges, and its diagnosis suggests a close generic relationship to *Discitoceras* (Hyatt, 1884). *Stroboceras mstense* Shimansky, 1967 has a nearly quadrate whorl section with lateral ridges on the flanks; these characteristics are the diagnostic features of *Pseudocatastroboceras* (Turner, 1965). *Nautilus* (*Trematodiscus*) *planidorsalis* Winchell, 1862, which was refered to *Stroboceras* by Miller and Garner (1953), and *S. intermedium* Miller and Garner, 1953 are unique and do not belong in *Stroboceras*; these two species may represent two new genera.

Stroboceras gordoni sp. nov.

Figures 2.9, 3.1, 3.3, 3.5, 3.6, 4, 5

Stroboceras cf. *S. sulcatum* (Sowerby). Gordon, 1964, p. 145, pl. 11, fig. 4, text-fig. 21A.

Diagnosis.—Species of *Stroboceras* with width/height ratios of 0.72–0.76 in adoral whorl, two bilaterally symmetrical lateral ridges, and weak nodes at intersections of ridges and growth lines; lg 2 (second lateral groove; see the description for its detailed definition) narrow; ventrolateral saddles in peristome have very shallow bilobate rim; a siphuncular position ratio of approximately 0.23.

Description.—Compressed, evolute shells; the largest specimen (paratype, OUZC 5106) has at least approximately 2 1/6 volutions with 37.8 mm in maximum observable diameter (ventral region partly missing) whose adoral approximately 1/2 volution is an incomplete body chamber; holotype is an incomplete phragmocone of 34.8 mm in maximum observable diameter and 10.9 mm in maximum observable whorl width, consisting approximately of 2 volutions; gyroceraconic stages are not observable in all examined specimens; umbilicus perforate with 3.8–4.4 mm and 5.1–5.3 mm in short and long diameters of umbilical perforation; whorls rapidly inflate during growth, thus umbilical area narrow for evolute form with ratios of umbilical area diameter per shell diameter of 0.33–0.34, and umbilical slope deeply concave. Embryonic shell cone-shaped with smooth apex; initial camera shallow, asymmetrical, 0.96 mm in maximum diameter and 0.71 mm in maximum length; early juvenile whorl, representing the first approximately 1/2 volution, has accentuated surface lirae; whorl sections laterally compressed subtrapezoidal with width/height ratios of 0.87–0.91 in juvenile, then decreasing to 0.72–0.76 in adoral whorls, indented, having concave venter with ventral groove (vg), concave ventrolateral shoulders with ventrolateral grooves (v-lg), roughly converging flanks and subrounded dorsum; three bilaterally symmetrical lateral (lg 1, 2, 3) grooves developed on flanks; dorsal (contact) groove present except for juvenile whorl; among these grooves, lg 1 forms widest concavity, where whorl section strongly constricted; lg 2 is very narrow, representing approximately 1/4–1/3 of lg 3 width; shell surface ornamented by five longitudinal ridges with bilateral symmetry and distinct growth lines; strongly prominent ventral ridges (vr) at boundary between vg and v-lg, strongly prominent ventrolateral ridges (v-lr) at boundary between v-lg

← **Figure 5**. *Stroboceras gordoni* sp. nov. **1**, **8**. Paratype, OUZC 5112. **1**, lateral view, ×2; **8**, partial enlargement of lateral view showing the apical shell morphology, ×10. **2**. Paratype, OUZC 5113, lateral view, ×2. **3**, **4**, **9**, **10**. Holotype, OUZC 1504. **3**, cross-sectional view, ×2; **4**, lateral view, ×2; **9**, partial enlargement of lateral view showing the apical shell morphology, ×10; **10**, partial enlargement of dorsal view showing the apical shell morphology, ×10. **5**, **6**, **11**, **12**. Paratype, OUZC 5106. **5**, cross-sectional view, ×2; **6**, lateral view, ×2; **11**, partial enlargement of lateral view showing growth lines outlining the ventrolateral saddle and the lateral (ocular) sinus on the peristome, and the development of nodes at intersections of ridges and growth lines, ×5; **12**, partial enlargement of ventral view showing growth lines outlining the ventral sinus on the peristome, ×5.

and lg 1, two weakly developed lateral ridges (lr 1, 2) between lg 1 and lg 2 (lr 1) and lg 2 and lg 3 (lr 2), and relatively weak dorsoventral ridges (d-lr) at boundary between lg 3 and umbilical wall; intersections of ridges and growth lines periodically form weak nodes; vg forms relatively wide ventral platform bordered by vr with ventrolateral angle of 115° to 145° in internal mold; ratio of vg width per whorl width is approximately 0.35; angles of ventrolateral shoulders (= v-lr) 95° to 125°; umbilical angle (= d-lr) subangular except for juvenile whorl with 110° to 130°; all grooves and ridges are not obsolescent even in adoral whorls. Growth lines indicate the lobed peristome shape that is characterized by deep U- to V-shaped ventral (hyponomic) sinus, broad subtrapezoidal ventrolateral saddles with very shallowly bilobate rim, relatively deep U-shaped lateral (ocular) sinus, and nearly transverse dorsolateral apertural rim; dorsal rim of peristome not observable. Sutures with very shallow ventral lobe and relatively shallow but broad lateral lobes. Camerae short; there are 3 to 7 camerae in corresponding whorl height; 28 camerae occur in the last-preserved (second?) volution of paratype (OUZC 5105); septal curvature moderate for family. Siphuncle consists of retrochoanitic septal necks and cylindrical connecting rings; its position is near midway between the center and ventral margin; ratio of minimum distance of central axis of septal foramen from whorl surface per corresponding whorl height in dorsoventral section (siphuncular position ratio) is approximately 0.23; ventral septal necks orthochoanitic, shift to cyrtochoanitic in dorsal ones; diameter of connecting ring is 0.59 mm at whorl height (in dorsoventral section) of 6.2 mm; caecum weakly inflated, attached to bottom of initial camera. Cameral and endosiphuncular deposits absent.

Material examined.—Holotype, OUZC 5104. Paratypes, OUZC 5105, 5106, 5112–5115, 5120. In addition, nine specimens of the fragmentary shells, OUZC 5107–5111, 5116–5119, are assigned to *Stroboceras gordoni* sp. nov.

Occurrence.—Limestone (oolitic grainstone) of "the Lower Pitkin Member" at locality 1 (OUZC 5104–5115). "The Upper Pitkin Member" at locality 2 (OUZC 5116–5120).

Etymology.—The specific name honors the late Dr. Mackenzie Gordon, Jr., who was the first to illustrate this species as indicated in the synonymy.

Discussion.—*Stroboceras gordoni* sp. nov. can be distinguished from the morphologically nearest species, *S. sulcatum sulcatum* and *S. s. desulcatum*, in that *S. gordoni* possesses narrower lg 2 (lg 2 width/lg 3 width = approximately 1/4–1/3 in *S. gordoni* versus nearly 1 in the latter two species) and weak nodes at intersections of the ridges and the growth lines. In the width/height ratios of the whorl, this new species also resembles *S. duplicatum*, but the latter has three lateral ridges with bilateral symmetry.

The indented whorl sections with the ventral platform bordered by prominent ventrolateral ridges and the distinct growth lines of *Stroboceras* are also characteristic of the juvenile growth stages of the girtyoceratid ammonoid genus *Eumorphoceras* (Girty, 1909) of Early Carboniferous age, especially in the Chesterian species *E. richardsoni* McCaleb, Quinn and Furnish (1964, p. 24, 25, pl. 3, figs. 5, 6) and *E. rostratum* Yates (1962, p. 387, 388, pl. 55, figs. 1–4). It is possible that the surface nodes of *S. gordoni* are analogous to the lateral ribs observed in the juvenile growth stages of *Eumorphoceras*. These similarities in shell ornament between the nautilids described herein and the ammonoid *Eumorphoceras*, which cooccurs with the nautilids at both localities, is a case of synchronized convergent evolution.

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