Journal of Paleontology, 86(3), 2012, p. 403–416

0022-3360/12/0086-0403$03.00

PENNSYLVANIAN (ATOKAN) AMMONOIDS FROM THE MAGOFFIN MEMBER OF THE FOUR CORNERS FORMATION, EASTERN KENTUCKY

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ABSTRACT—The Pennsylvanian ammonoids *Gastrioceras magoffinense* n. sp., *Maximites nassichuki* n. sp., *Dimorphoceratoides adamsi* n. sp., *Bisatoceras*? sp., *Phaneroceras chesnuti* n. sp., and Christioceratidae gen. indet. occur in the Magoffin Member of the Four Corners Formation in eastern Kentucky. The interval represented by the Magoffin ammonoid fauna should be known as the *Gastrioceras magoffinense* Assemblage Zone. This overlies the well-known *Diaboloceras neumeieri* Zone, represented in the Kendrick Shale Member of the Hyden Formation in eastern Kentucky. The *Gastrioceras magoffinense* Zone correlates to the *Diaboloceras varicostatum*–*Winslowoceras henbesti* Zone in the Winslow Member of the Atoka Formation in northwestern Arkansas. Ammonoids and associated conodonts, including *Declinognathodus marginodosus* and its descendant *D. donetzianus*, indicate an early Atokan age corresponding to the basal Bolsovian (basal Westphalian C) Substage in western Europe and the Bashkirian–Moscovian Stage boundary interval in eastern Europe and the South Urals.

INTRODUCTION

A WELL-KNOWN early Atokan ammonoid assemblage characterized by *Diaboloceras neumeieri* Quinn and Carr, 1963 in association with *Gastrioceras occidentale* (Miller and Faber, 1892) and *Dimorphoceratoides campbellae* Furnish and Knapp, 1966 occurs in the Kendrick Shale Member of the Hyden Formation in Floyd County, eastern Kentucky (Furnish and Knapp, 1966). The Kendrick was referred to the *Diaboloceras neumeieri* Zone by Saunders et al. (1977), equivalent to the Trace Creek Shale Member of the Atoka Formation in the type Morrowan succession in the southern Midcontinent and to the Westphalian B in western Europe (Rice et al., 1994). A second, stratigraphically higher, undescribed Atokan ammonoid assemblage with *Gastrioceras magoffinense* n. sp., *Maximites nassichuki* n. sp., *Dimorphoceratoides adamsi* n. sp., *Bisatoceras*? sp., *Phaneroceras chesnuti* n. sp., and Christioceratidae gen. indet. occurs in the Magoffin Member of the Four Corners Formation in Floyd and Perry counties, eastern Kentucky, and is the basis for the current report. The Magoffin ammonoid assemblage is particularly significant because of its association with conodonts that provide an indirect basis for analysis of the Bashkirian–Moscovian boundary elsewhere in North America, particularly the standard Morrowan–Atokan succession in the southern Midcontinent. These include the first reported sub-Arctic North American occurrence of *Declinognathodu*s *donetzianus* Nemirovskaya, 1990, an operational index to the base of the Moscovian Stage in many areas which is currently under consideration by the ICS Subcommission on Carboniferous Stratigraphy (SCCS) as a potential event marker for the base of the global Moscovian Stage (Middle Pennsylvanian Series, Carboniferous System) (Groves and Task Group, 2006; Nemyrovska et al., 2010).

LOCATION AND STRATIGRAPHIC OCCURRENCE

The Magoffin Member ammonoid assemblage is dominated by *Gastrioceras magoffinense* n. sp., but includes common *Maximites nassichuki* n. sp., *Bisatoceras*? sp., and *Phaneroceras chesnuti* n. sp., and rare *Dimorphoceratoides adamsi* n. sp. and Christioceratidae gen. indet. These ammonoids form the basis for the *Gastrioceras magoffinense* Assemblage Zone within the Magoffin Member of the Four Corners Formation. This interval has been identified at several localities in eastern Kentucky (Fig. 1; Appendix) but faunal relationships are best understood at the Martin roadcut section along Kentucky Highway 80, 2.1 km north of the New Bridge Road exit at Martin, Floyd County, Kentucky. The Magoffin sequence at Martin (Fig. 1) consists of 7.4 m of dark-gray to black fossiliferous mudstone with a thin, 0.1-m, muddy, bioclastic packstone 0.2 m above the base. The Magoffin Member immediately overlies the thin, 0.2-m-thick Taylor (Copeland) coal bed of the Hyden Formation, and is disconformably overlain by an unnamed, 12-m-thick, cross-bedded sandstone unit containing coal clasts and log impressions at its base. Ammonoids occur as testiferous internal molds in small, 2–5-cm thick carbonaceous limestone concretions (bullions) in the lower part of the shale sequence, 1.5 to 1.9 m above the base of the Magoffin, and as sideritic internal molds in the middle part, 2.5 to 4.4 m above the base (see Cobb et al., 1981, p. 40–42 [stop 10], pl. 16 for additional discussion; and Bennington, 1996, p. 178–180, section M28 in figs. 4–6; and Bennington, 2002, section M28 in fig. 6 for paleoenvironmental interpretations of the Magoffin at the Martin section).

SYSTEMATIC PALEONTOLOGY

Dimensions D, H, W, and U represent conch diameter, corresponding whorl height and width, and umbilical diameter measured from seam to seam, respectively. Suture terminology is that of Ruzhencev (1960, 1962); V, L, U, I, and D represent the ventral lobe, lateral lobe, umbilical lobe, internal lateral lobe, and dorsal lobe, respectively. Repository abbreviations are: SUI, University of Iowa; WMUC, Field Museum of Natural History (formerly Walker Museum, University of Chicago); GSC, Geological Survey of Canada, Ottawa; USNM, U. S. National Museum of Natural History.

Order GONIATITIDA Hyatt, 1884
Suborder TORNOCERATINA Wedekind, 1918
Superfamily PSEUDOHALORITOIDEA Ruzhencev, 1957
Family MAXIMITIDAE Ruzhencev, 1960
Genus MAXIMITES Miller and Furnish, 1957a

Type species.—*Imitoceras cherokeense* Miller and Owen, 1939.

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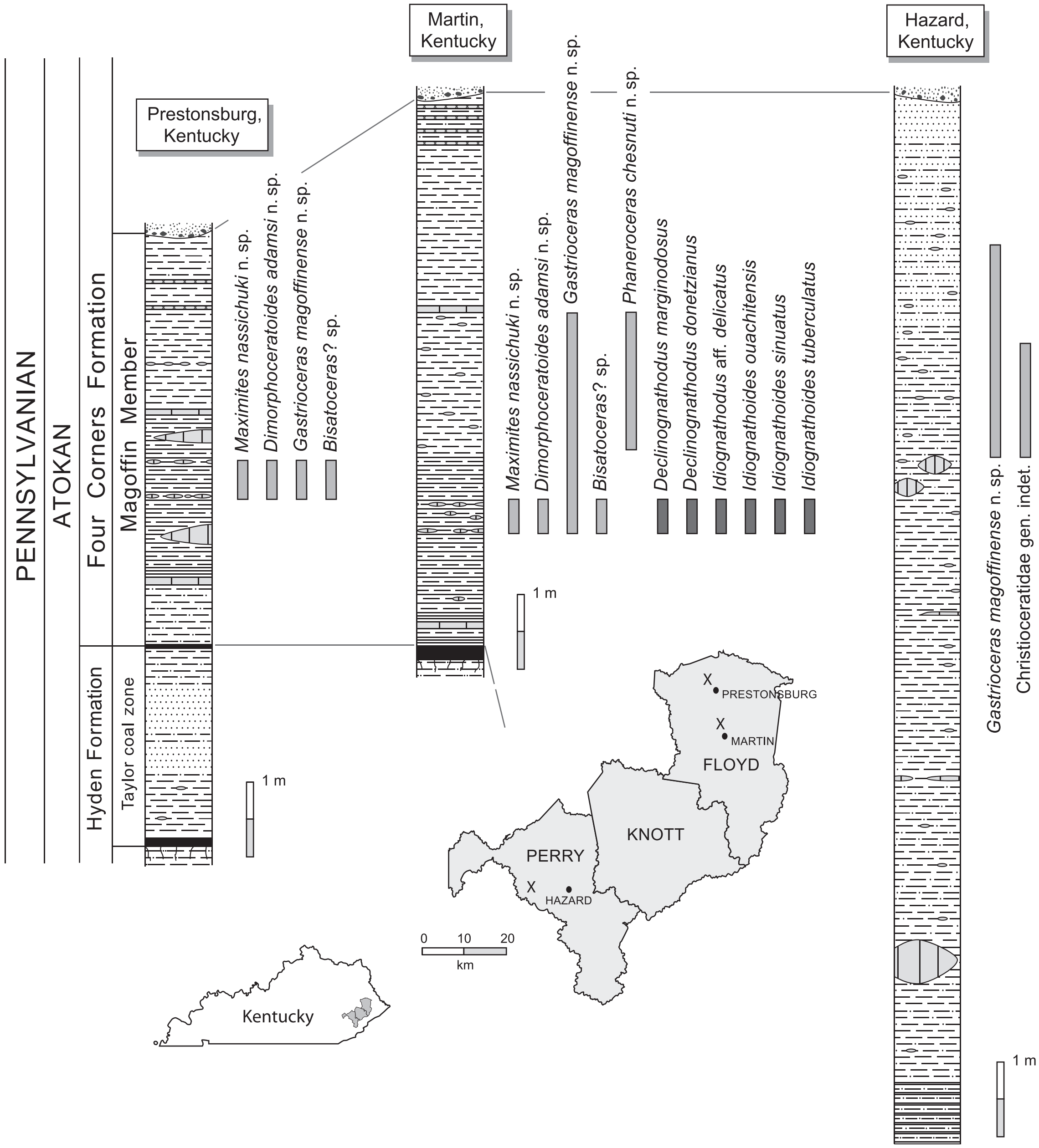

FIGURE 1—Stratigraphic position of Magoffin ammonoid and conodont occurrences. Inset maps show location of sections in eastern Kentucky. Precise location of sections is found in Appendix for Localities.

Included species.—*Maximites alexanderi* Nassichuk, 1975; *M. angustus* Popov, 1979; *M. nassichuki* n. sp.; *M. oklahomensis* Frest et al., 1981; *M. sinensis* Ruan and Zhou, 1987.

Diagnosis.—Conch small (≤10 mm diameter), subdiscoidal to subglobose (W/D=0.4–0.7), with very small or closed umbilicus. Growth lirae form deep ventral sinus flanked by equilateral salient and shallow lateral sinus. Suture characterized by narrow, incipiently bifid ventral lobe and broadly rounded lateral lobe. Siphuncle subcentral in early ontogenetic stages, subventral at maturity. Sutural formula: (V_1V_1)LU:ID.

Occurrence.—Pennsylvanian (Moscovian [Atokan]–Kasimovian [basal Missourian]); U.S.A. (Missouri, Oklahoma, Kentucky), Canada (Arctic Archipelago: Ellesmere Island), Ukraine (Donets Basin), northern China (Ningxia).

Discussion.—See Frest et al. (1981, p. 8–10) for discussion and clarification of the relationship of *Maximites* and the ancestral pseudohaloritid *Neoaganides* Plummer and Scott, 1937 (type species *N. grahamensis* Plummer and Scott, 1937).

MAXIMITES NASSICHUKI new species
Figures 2.1, 3.1–3.13, 3.16–3.20

Diagnosis.—Subdiscoidal *Maximites* with moderately compressed whorls. Suture characterized by relatively wide, weakly bifid ventral lobe with rounded prongs and subparallel flanks and very wide, weakly asymmetrical lateral lobe.

Description.—Conch thinly subdiscoidal with moderately compressed whorls and closed umbilicus (W/D=0.5 and H/W=1.25 at D=6 mm). Conch diameters and proportions listed in Table 1. At maturity, internal molds bear faint traces of fine growth lirae that trace deep, broadly rounded ventral sinus flanked by high, rounded ventrolateral salient, and shallow lateral sinus (Fig. 3.16–3.19). One to three transverse

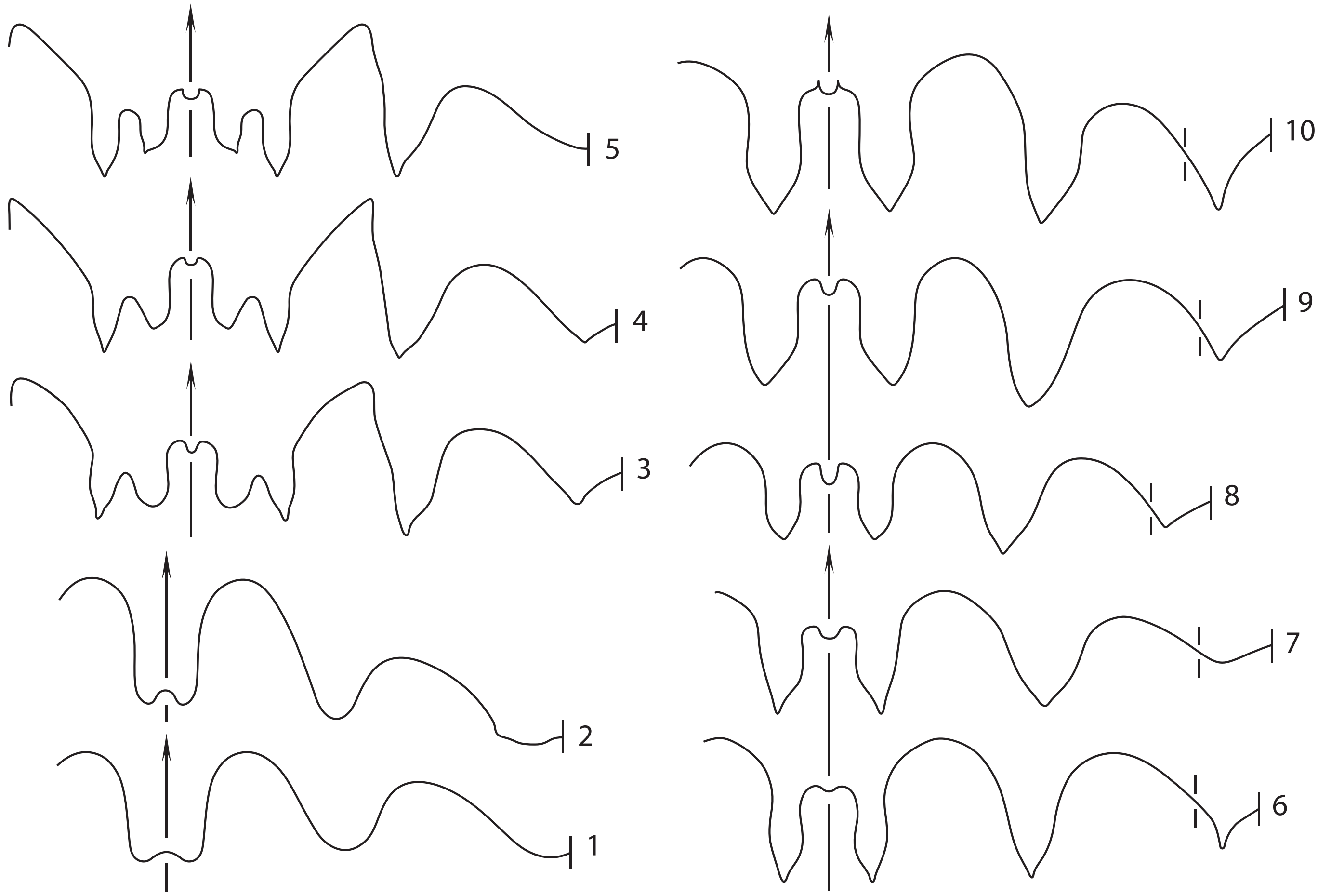

FIGURE 2—Sutural outlines of *Maximites* Miller and Furnish, 1957a, *Dimorphoceratoides* Furnish and Knapp, 1966, *Neodimorphoceras* Schmidt, 1925, and *Gastrioceras* Hyatt, 1884. *1, Maximites nassichuki* n. sp. from the Magoffin Member, Four Corners Formation, eastern Kentucky, paratype SUI 104353, diameter 3 mm; *2, Maximites alexanderi* Nassichuk, 1975 from the Hare Fiord Formation, Ellesmere Island, Canadian Arctic Archipelago, paratype GSC 33678, diameter 3 mm (after Nassichuk, 1975, text-fig. 25); *3, Dimorphoceratoides campbellae* Furnish and Knapp, 1966 from the Kendrick Shale Member, Hyden Formation, eastern Kentucky, holotype SUI 11854, diameter 34 mm (after Furnish and Knapp, 1966, text-fig. 5); *4, Dimorphoceratoides adamsi* n. sp. from the Magoffin Member, Four Corners Formation, eastern Kentucky, holotype SUI 104358, diameter 33 mm; *5, Neodimorphoceras sverdrupi* Nassichuk, 1975 from the Hare Fiord Formation, Ellesmere Island, Canadian Arctic Archipelago, holotype GSC 33681, diameter 30 mm (after Nassichuk, 1975, text-fig. 26d); *6, 7, Gastrioceras occidentale* (Miller and Faber, 1892) from the Kendrick Shale Member, Hyden Formation, eastern Kentucky: *6,* hypotype SUI 11855, diameter 38 mm (after Furnish and Knapp, 1966, text-fig. 2b); *7,* hypotype SUI 13775, diameter about 40 mm (after Furnish and Knapp, 1966, text-fig. 2a); *8, 9, Gastrioceras magoffinense* n. sp. from the Magoffin Member, Four Corners Formation, eastern Kentucky: *8,* paratype SUI 104366, diameter 31 mm; *9,* holotype SUI 104362, diameter 58 mm; *10, Gastrioceras formosum* McCaleb, 1963 from the Winslow Member, Atoka Formation, northwestern Arkansas, holotype SUI 10450, diameter 60 mm (after McCaleb, 1963, text-fig. 8).

constrictions per volution trace shallow ventral sinuses and are most prominent on inner, phragmocone volutions <4 mm diameter (Fig. 3.5–3.7, 3.16–3.20). Mature suture (Fig. 2.1) includes relatively wide, weakly bifid ventral lobe with rounded prongs and subparallel flanks; very wide, weakly asymmetrical lateral lobe; and small, shallow umbilical lobe. Siphuncle subventral at maturity (3 to 4 mm phragmocone diameter).

Etymology.—Named for Walter W. Nassichuk, in recognition of his contributions to Pennsylvanian ammonoid systematics and biostratigraphy, in particular Nassichuk (1975).

Types.—Holotype SUI 104349; paratypes SUI 104348, 104350–104355. The types are well-preserved internal molds (D=2.6–7.1 mm) that collectively display details of conch ontogeny, internal and external ornament (Fig. 3.1–3.13, 3.16–3.20), and suture (Fig. 2.1). The largest phragmocone, paratype SUI 104353, shows pronounced septal approximation at a diameter of 3.6 mm, indicating maturity at a reconstructed conch diameter of ~7 mm.

Other material examined.—SUI 104356 (four unfigured topotypes); SUI 104357 (seven unfigured hypotypes).

Occurrence.—The holotype, SUI 104349, paratypes SUI 104352 and 104354, and four unfigured topotypes, SUI 104356, were recovered 1.5 to 1.9 m above the base of the Magoffin Member of the Four Corners Formation at the Martin locality; paratypes SUI 104348, 104350, 104351, 104353, and 104355, and seven unfigured hypotypes, SUI 104357, were recovered from an equivalent interval 1.9 to 2.4 m above the base of the Magoffin Member at the Prestonsburg locality (Fig. 1).

Discussion.—*Maximites nassichuki* is the stratigraphically lowest species of *Maximites* and extends the generic range to the base of the Moscovian. It appears to be closest to equivalent growth stages of *M. alexanderi* Nassichuk, 1975 from the Hare Fiord Formation on Ellesmere Island in the Canadian Arctic Archipelago. At maximum size (D ~7 mm), the conch proportions of *M. nassichuki* fall within the probable range of variability of *M. alexanderi*, but during earlier ontogenetic stages (D=3.6 mm) the width of the

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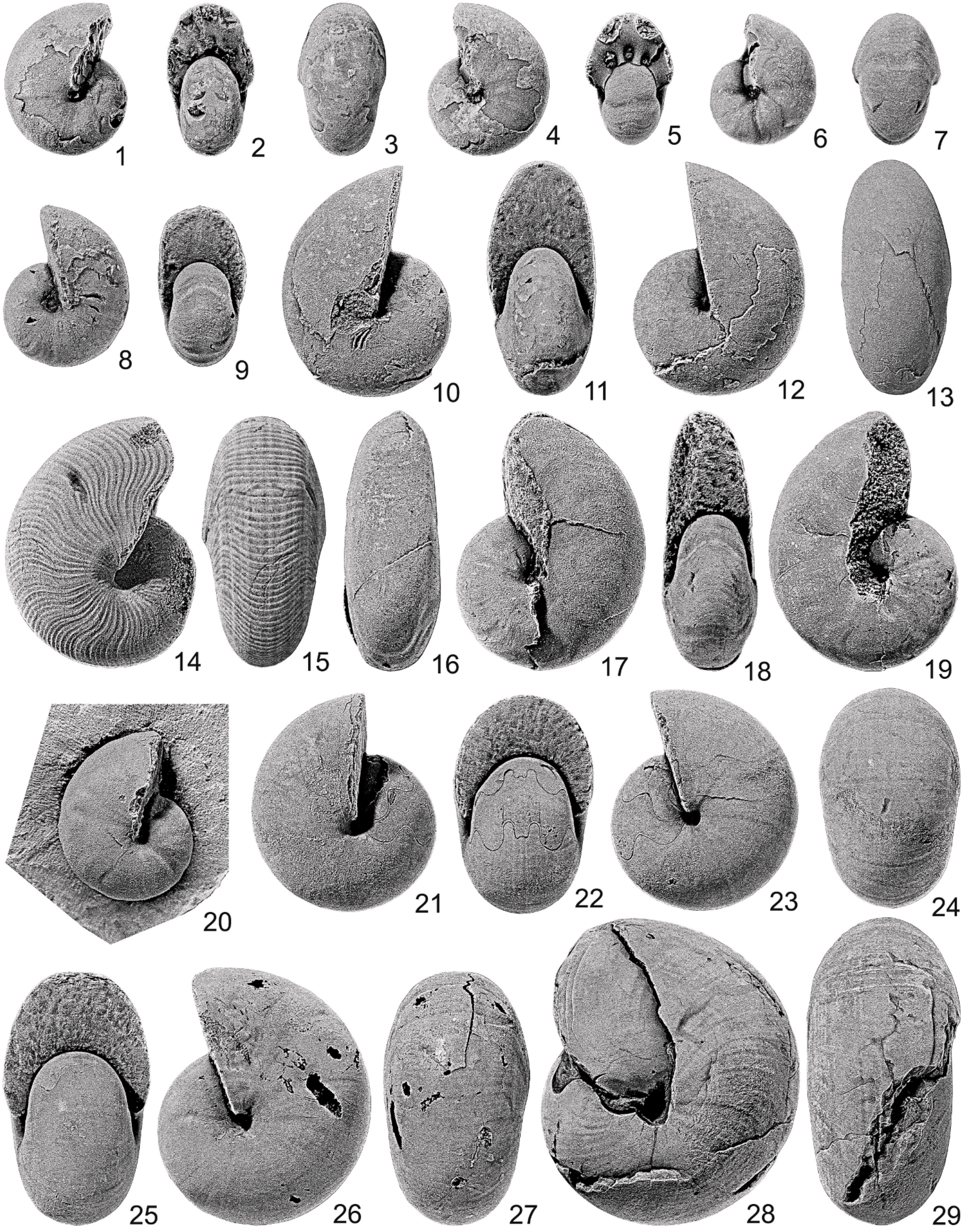

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TABLE 1—Conch diameters (in mm) and proportions of species of *Maximites* Miller and Furnish, 1957a.

Specimen	D	H/D	W/D	H/W
Maximites nassichuki n. sp.				
Holotype SUI 104349	6.3	0.60	0.48	1.26
Paratype SUI 104350	6.1	0.63	0.49	1.27
Paratype SUI 104351	4.0	0.59	0.58	1.02
Paratype SUI 104352	3.8	0.61	0.58	1.04
Paratype SUI 104353	3.6	0.57	0.57	1.00
Paratype SUI 104354	3.1	0.58	0.66	0.87
Paratype SUI 104355	2.6	0.54	0.65	0.82
Maximites alexanderi Nassichuk, 1975				
Holotype GSC 33679[1]	8.0	0.59	0.51	1.15
Paratype GSC 33678[2]	3.6	0.44	0.75	0.59

[1] After Nassichuk (1975, p. 69).
[2] Frest et al. (1981, table 1).

Kentucky specimens is significantly less and the whorls are proportionately higher than representatives of *M. alexanderi* (Table 1). Sutures of *M. nassichuki* differ from those of *M. alexanderi* in depth, width, and degree of inflation of the ventral and lateral lobe (compare Fig. 2.1 and Fig. 2.2). The ventral lobe of *M. nassichuki* is proportionately wider and shallower than that of *M. alexanderi* at comparable diameters with less pronounced bifurcation and shorter prongs, and the lateral lobe is wider and more broadly rounded. In addition, *M. nassichuki* lacks the shallow, incipient secondary lobe on the ventrad flank of the umbilical lobe of *M. alexanderi*.

Suborder GONIATITINA Hyatt, 1884
Superfamily NEODIMORPHOCERATOIDEA Furnish and Knapp, 1966
Family NEODIMORPHOCERATIDAE Furnish and Knapp, 1966
Genus DIMORPHOCERATOIDES Furnish and Knapp, 1966

Type species.—*Dimorphoceratoides campbellae* Furnish and Knapp, 1966.

Included species.—*Dimorphoceratoides adamsi* n. sp.

Emended diagnosis.—Neodimorphoceratids distinguished by sutures with narrowly to broadly rounded ventrad subdivision of ventral prong ($V_{1.2}$). Tertiary median saddle in ventral prong with divergent, nonparallel flanks. Sutural formula: $(V_{1.1}V_{1.2}V_{1.2}V_{1.1})$LU:ID.

Occurrence.—Pennsylvanian (upper Bashkirian–Moscovian [Atokan]); USA (Kentucky, Ohio, Arkansas).

Discussion.—The definition of *Dimorphoceratoides* has rested with the type species, *D. campbellae*, which has a broadly rounded ventrad subdivision of the ventral prong ($V_{1.2}$) (Fig. 2.3). This original concept of the genus is here emended to include a slightly younger species, *D. adamsi*, which at maturity has a narrowly rounded, wedge-shaped ventrad subdivision of the ventral prong (Fig. 2.4) that is virtually identical to that of juvenile sutures of the descendant genus *Neodimorphoceras* Schmidt, 1925 (type species *Dimorphoceras texanum* Smith, 1903), but which differs from even the most primitive species of that genus, *N. sverdrupi* Nassichuk, 1975, in its low, narrowly rounded tertiary ventral saddle with divergent, as opposed to parallel, flanks (compare Fig. 2.4 and Fig. 2.5).

DIMORPHOCERATOIDES ADAMSI new species
Figures 2.4, 3.14, 3.15, 4.5–4.7

Diagnosis.—*Dimorphoceratoides* distinguished by suture with low, narrowly rounded tertiary ventral saddle with divergent, nonparallel flanks; narrowly rounded, wedge-shaped ventrad subdivision of the ventral prong ($V_{1.2}$); and narrow, asymmetrical, bluntly pointed dorsad subdivision ($V_{1.1}$).

Description.—Conch subdiscoidal with strongly compressed whorls (W/D=0.42 and H/W=1.5 at D=34 mm), nearly closed umbilicus, and narrowly rounded venter. Umbilical wall uniformly rounded, merging smoothly into flank without abrupt shoulder. Conch diameters and proportions listed in Table 2. During early ontogenetic stages, shell ornament consists of fine biconvex ribs that form shallow ventral and lateral sinuses (Fig. 3.14, 3.15). Ribs significantly reduced in strength at diameters >20 mm, fading progressively into faintly impressed growth lamellae that form deep, broadly rounded ventral sinus flanked by high, rounded ventrolateral salient, and shallow lateral sinus (Fig. 4.5, 4.6). Mature suture (Fig. 2.4) includes wide, quadripartite ventral lobe with high median saddle; low, narrowly rounded tertiary ventral saddle with divergent, nonparallel flanks; narrowly rounded, wedge-shaped ventrad subdivision of ventral prong ($V_{1.2}$) and narrow, asymmetrical, bluntly pointed dorsad subdivision of ventral prong ($V_{1.1}$); wide, asymmetrical, bluntly pointed first lateral saddle; deep, asymmetrical, narrowly acuminate lateral lobe; and small, pointed umbilical lobe.

Etymology.—Named for T. H. Adams, of Tollesboro, Kentucky, who collected and contributed the holotype for study.

Types.—Holotype SUI 104358; paratypes SUI 104359–104361. The holotype, SUI 104358, and paratypes SUI 104360 and 104361 are internal molds (D=9–34 mm) that preserve characteristic features of conch form, internal shell sculpture (Figs. 3.14, 3.15, 4.5, 4.6), and suture (Fig. 2.4). The largest paratype, SUI 104359, is a testate body chamber fragment of 20 mm restored diameter that retains an intact apertural margin (Fig. 4.7).

Occurrence.—The holotype, SUI 104358, and paratypes SUI 104359 and 104360 of *Dimorphoceratoides adamsi* were recovered 1.9 to 2.4 m above the base of the Magoffin Member of the Four Corners Formation at the Prestonsburg locality; paratype SUI 104361 was recovered from an equivalent interval 1.5 to 1.9 m above the base of the Magoffin Member at the Martin locality (Fig. 1).

Discussion.—Sutures of *D. adamsi* are similar in general proportions to those of the type species, *D. campbellae* Furnish and Knapp, 1966, but differ in attenuation of the

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FIGURE 3—Atokan ammonoids from the Magoffin Member, Four Corners Formation, eastern Kentucky. *1–13, 16–20, Maximites nassichuki* n. sp.: *1–4,* right lateral, apertural, ventral, and left lateral views of paratype SUI 104353, ×8; *5–7,* apertural, left lateral, and ventral views of paratype SUI 104354, ×8; *8, 9,* left lateral and apertural views of paratype SUI 104352, ×8; *10–13,* right lateral, apertural, left lateral, and ventral views of holotype SUI 104349, ×7; *16–19,* ventral, left lateral, apertural, and right lateral views of paratype SUI 104348, ×7; *20,* right lateral view of paratype SUI 104351, ×8; *14, 15, Dimorphoceratoides adamsi* n. sp. right lateral and ventral views of paratype SUI 104360, ×4.5; *21–29, Bisatoceras*? sp.: *21–24,* right lateral, apertural, left lateral, and ventral views of hypotype SUI 104377, ×4; *25–27,* apertural, left lateral, and ventral views of hypotype SUI 104375, ×4; *28, 29,* left lateral and ventral views of hypotype SUI 104374, ×3.5.

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FIGURE 4—Atokan ammonoids from the Magoffin Member, Four Corners Formation, eastern Kentucky. *1, 2, 8–10, Gastrioceras magoffinense* n. sp.: *1, 2,* apertural and right lateral views of paratype SUI 104366, ×2; *8–10,* apertural, left lateral, and ventral views of holotype SUI 104362, ×1.4; *3, 4,* Christioceratidae gen. indet., left lateral and ventral views of hypotype SUI 104386, ×2.2; *5–7, Dimorphoceratoides adamsi* n. sp.: *5, 6,* ventral and right lateral views of holotype SUI 104358, ×2.2; *7,* right lateral view of paratype SUI 104359, ×2.2.

TABLE 2—Conch diameters (in mm) and proportions of species of *Dimorphoceratoides* Furnish and Knapp, 1966.

Specimen	D	H/D	W/D	H/W
Dimorphoceratoides adamsi n. sp.				
Holotype SUI 104358	33.6	0.63	0.42	1.48
Paratype SUI 104360	10.5	0.61	0.50	1.23
Paratype SUI 104361	9.3	0.58	0.58	1.00
Dimorphoceratoides campbellae Furnish and Knapp, 1966				
Holotype SUI 11854	50.0	0.59	0.40	1.47

ventral prongs and first lateral lobe (compare Fig. 2.3 and Fig. 2.4). *Dimorphoceratoides adamsi* is distinguished from *D. campbellae* by its narrowly rounded, wedge-shaped ventrad subdivision of the ventral prong ($V_{1.2}$) and narrow, asymmetrical, bluntly pointed dorsad subdivision ($V_{1.1}$). In addition, the lateral lobe in *D. adamsi* is widely expanded with strongly divergent flanks and approximates the ventral lobe in depth (Fig. 2.4), whereas in *D. campbellae* this element is narrowly attenuate with a flexed dorsad flank and asymmetrically constricted tip and is conspicuously deeper than the ventral lobe (Fig. 2.3).

Superfamily GASTRIOCERATOIDEA Hyatt, 1884
Family GASTRIOCERATIDAE Hyatt, 1884
Genus GASTRIOCERAS Hyatt, 1884

Type species.—*Ammonites listeri* Sowerby, 1814.

GASTRIOCERAS MAGOFFINENSE new species
Figures 2.8, 2.9, 4.1, 4.2, 4.8–4.10, 5.1–5.10

Gastrioceras montgomeryense (Miller and Gurley, 1896). MORSE, 1931, p. 326–327 [Magoffin].

Gastrioceras n. sp. A. RICE, BELKIN, HENRY, ZARTMAN, AND KUNK, 1994, p. 92, table 2 [Magoffin].

Gastrioceras cf. *occidentale* (Miller and Faber, 1892). WORK, MASON, AND MAPES, 2009, pl. 9.1, figs. 11, 12.

Diagnosis.—Thickly subdiscoidal, narrowly umbilicate *Gastrioceras* with depressed to equidimensional whorls. Juvenile and intermediate growth stages exhibit 15–22 umbilical nodes per volution that are progressively diminished at diameters greater than 30 mm. Suture characterized by wide ventral lobe with medially inflated, attenuate ventral prongs and deep, angular, narrowly acuminate first lateral lobe.

Description.—Conch thickly subdiscoidal (W/D=0.54–0.68 at D=16–64 mm) with depressed to equidimensional whorls (H/W=0.62–0.89) and narrow umbilicus (U/D=0.22–0.28). Conch ontogeny represented in Figure 5.7. Conch diameters and proportions listed in Table 3. Whorl sections at larger diameters uniformly rounded across flanks, converging to narrowly rounded venter. Umbilical shoulder narrowly rounded at maturity and umbilical walls steep, wide, and gently convex. Internal molds bear traces of fine growth lamellae that form shallow, rounded ventral sinus flanked by low, rounded ventrolateral salient. Three to seven moderately incised constrictions per volution are most prominent on internal molds at diameters less than 30 mm. Juvenile and intermediate growth stages exhibit 15–22 transversely elongate umbilical nodes per volution that are progressively diminished or absent at diameters greater than 30 mm. Suture (Fig. 2.8, 2.9) includes wide ventral lobe with high median saddle and medially inflated, attenuate ventral prongs; wide, broadly rounded first lateral saddle; deep, angular, narrowly acuminate first lateral lobe; and small, pointed umbilical lobe centered on outer umbilical wall.

Etymology.—After the Magoffin Member of the Four Corners Formation.

Types.—Holotype SUI 104362; paratypes SUI 104276, 104363–104370, 104373. The holotype and paratypes SUI 104276 and 104363–104370 are well-preserved internal molds (D=16–64 mm) that collectively provide details of conch form and ontogeny (Fig. 5.7), internal ornament (Figs. 4.1, 4.2, 4.8–4.10, 5.1–5.6, 5.8–5.10), and suture (Fig. 2.8, 2.9). The largest paratype, SUI 104373, is an incomplete phragmocone consisting of nearly one-half of a conch of approximately 92 mm restored diameter.

Other material examined.—SUI 104371 (14 juvenile topotypes); SUI 104372 (six unfigured hypotypes).

Occurrence.—*Gastrioceras magoffinense* is the most abundant and widely distributed ammonoid in the Magoffin Member of the Four Corners Formation in eastern Kentucky. The holotype, SUI 104362, paratypes SUI 104276, 104363–104367, 104369, 104370, and 14 juvenile topotypes, SUI 104371, were recovered 1.5 to 4.4 m above the base of the Magoffin Member at the Martin locality; six unfigured hypotypes, SUI 104372, were recovered 1.9 to 2.4 m above the base of the Magoffin Member at the Prestonsburg locality; and paratypes SUI 104368 and 104373 were recovered 1.8 to 4.7 m below the top of the Magoffin Member at the Hazard locality (Fig. 1).

Discussion.—Conch proportions and general suture pattern of *G. magoffinense* are closest to *G. formosum* McCaleb, 1963 from the Atoka Formation (Winslow Member) of northwestern Arkansas. *Gastrioceras magoffinense* can be distinguished from *G. formosum* by its narrower conch and higher, more compressed whorls (Table 3). Sutures of *G. magoffinense* differ from those of *G. formosum* in width and depth of the ventral lobe and degree of asymmetry of the ventral prongs (compare Fig. 2.9 and Fig. 2.10). Also, the first lateral lobe in *G. magoffinense* is symmetrical and bluntly pointed, whereas in *G. formosum* this element is strongly asymmetrical with a flexed dorsad flank and constricted tip. *Gastrioceras magoffinense* can be distinguished from *G. occidentale* (Miller and Faber, 1892), including representatives of the compressed, narrowly umbilicate morphotype designated form α by Furnish and Knapp (1966, p. 297, 298), by its narrower umbilicus and higher, more compressed whorls (Table 3). Also, the ventral lobe of *G. magoffinense* is proportionately wider and shallower than that of *G. occidentale* at comparable diameters with wider, less attenuate ventral prongs (compare Fig. 2.6 and Fig. 2.7 with Fig. 2.8 and Fig. 2.9).

Superfamily THALASSOCERATOIDEA Hyatt, 1900
Family BISATOCERATIDAE Miller and Furnish, 1957b
Genus BISATOCERAS Miller and Owen, 1937

Type species.—*Bisatoceras primum* Miller and Owen, 1937.

BISATOCERAS? sp.
Figures 3.21–3.29, 6.1

Description.—Conch thickly subdiscoidal with equidimensional to moderately compressed whorls (W/D=0.58–0.64 and H/W=0.89–1.01 at D=10–12 mm), broadly rounded venter, and small, nearly closed umbilicus. Conch diameters and proportions listed in Table 4. Internal molds bear faint traces of fine, essentially straight, transverse lamellae that form shallow ventral sinuses (Fig. 3.28, 3.29). Constrictions absent. Suture (Fig. 6.1) includes wide ventral lobe with large, bluntly pointed ventral prongs, high median saddle, and flanks that diverge gently orad into broadly rounded first lateral saddle;

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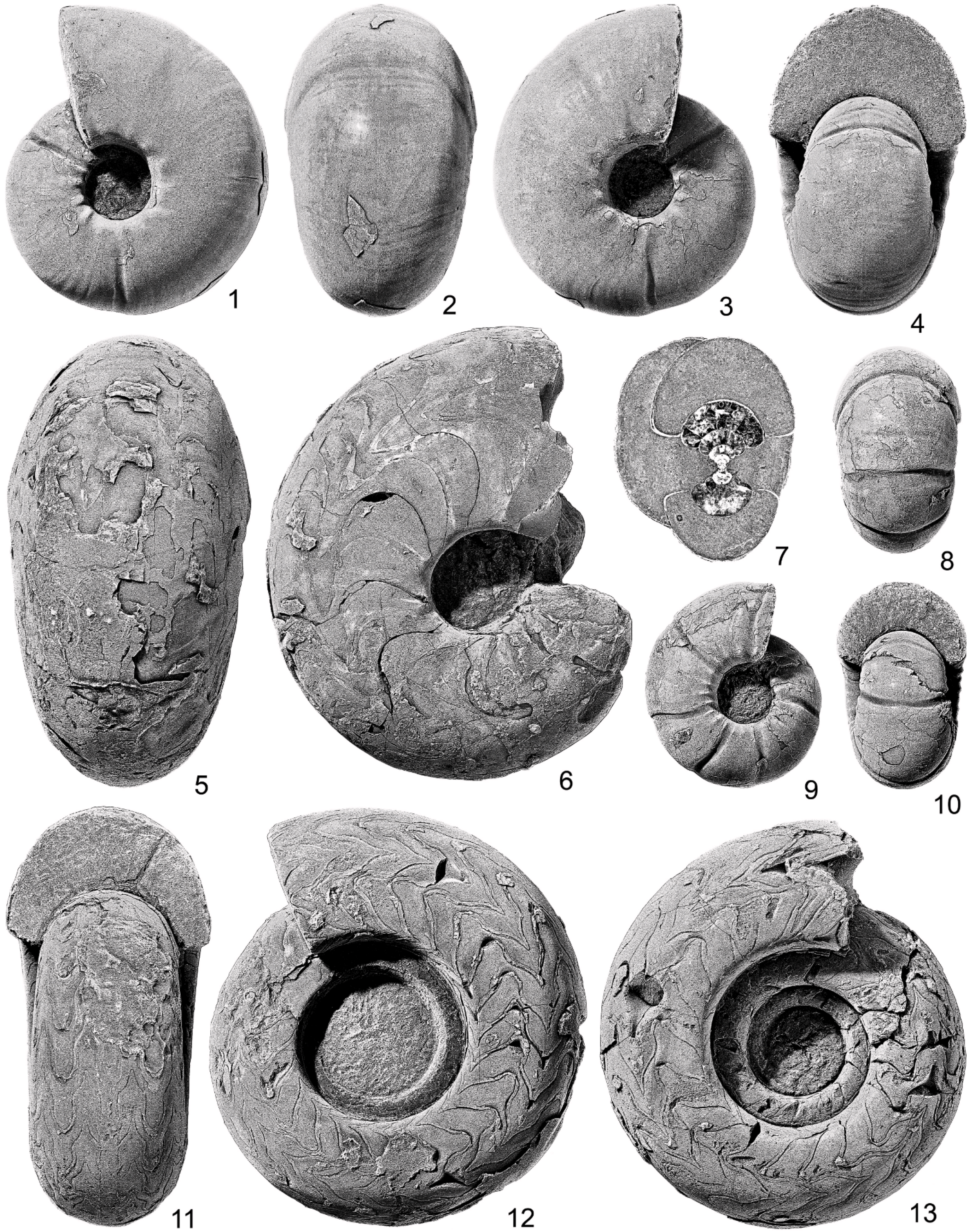

FIGURE 5—Atokan ammonoids from the Magoffin Member, Four Corners Formation, eastern Kentucky. *1–10, Gastrioceras magoffinense* n. sp.: *1–4,* left lateral, ventral, right lateral, and apertural views of paratype SUI 104367, ×2; *5, 6,* ventral and right lateral views of paratype SUI 104363, ×1.5; *7,* cross section of paratype SUI 104369, ×2; *8–10,* ventral, right lateral, and apertural views of paratype SUI 104276, ×2; *11–13, Phaneroceras chesnuti* n. sp.: *11, 12,* apertural and left lateral views of paratype SUI 104382, ×1.5; *13,* right lateral view of paratype SUI 104383, ×1.5.

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TABLE 3—Conch diameters (in mm) and proportions of species of *Gastrioceras* Hyatt, 1884.

Specimen	D	U/D	H/D	W/D	H/W
Gastrioceras magoffinense n. sp.					
Holotype SUI 104362	64.0	0.22	0.49	0.55	0.89
Paratype SUI 104363	56.6	0.24	0.46	0.54	0.85
Paratype SUI 104364	49.5	0.25	0.45	0.55	0.82
Paratype SUI 104365	46.8	0.27	0.43	0.54	0.80
Paratype SUI 104366	31.7	0.25	0.47	0.62	0.75
Paratype SUI 104367	29.3	0.25	0.48	0.62	0.77
Paratype SUI 104368	25.0	0.24	0.48	0.66	0.72
Paratype SUI 104369	21.1	0.23	0.45	0.66	0.68
	11.0	0.29	0.42	0.72	0.58
	6.3	0.30	0.39	0.71	0.55
	3.8	0.30	0.38	0.65	0.58
Paratype SUI 104276	19.4	0.29	0.42	0.62	0.68
Paratype SUI 104370	16.4	0.28	0.43	0.68	0.64
Gastrioceras occidentale (Miller and Faber, 1892)					
SUI 11862[1]	53.0	0.24	0.40	0.54	0.74
Hypotype SUI 11855[1]	40.0	0.34	0.45	0.61	0.73
SUI unfigured[1]	35.0	—	0.44	0.59	0.76
Holotype WMUC 8757	30.0	0.37	0.40	0.60	0.67
Hypotype SUI 11856[1]	22.0	0.41	0.44	0.59	0.58
Hypotype SUI 11855[1]	21.0	0.41	0.38	0.76	0.50
Gastrioceras formosum McCaleb, 1963					
SUI unnumbered [Winslow][2]	70	0.26	0.43	0.67	0.64
SUI unnumbered [Winslow][2]	65	0.25	0.42	0.64	0.64
SUI unnumbered [Winslow][2]	60	0.25	0.42	0.67	0.63
SUI unnumbered [Winslow][2]	55	0.25	0.44	0.68	0.64
SUI unnumbered [Winslow][2]	50	0.24	0.45	0.61	0.74

[1] After Furnish and Knapp (1966, table 1).
[2] McCaleb (1963, table 4).

broadly rounded lateral lobe shorter than ventral prongs; and small, rounded umbilical lobe centered on umbilical wall.

Types.—Hypotypes SUI 104374–104377 are well-preserved internal molds (D=10.3–16.4 mm) that provide details of juvenile conch form and ornament (Fig. 3.21–3.29) and suture (Fig. 6.1).

Other material examined.—SUI 104378 (eight unfigured specimens); SUI 104379 (two unfigured specimens).

Occurrence.—Hypotypes SUI 104374–104377 and two unfigured specimens, SUI 104379, were recovered 1.9 to 2.4 m above the base of the Magoffin Member of the Four Corners Formation at the Prestonsburg locality; eight additional unfigured specimens, SUI 104378, were recovered from an equivalent interval 1.5 to 1.9 m above the base of the Magoffin Member at the Martin locality (Fig. 1).

Discussion.—Provisional assignment to *Bisatoceras*, rather than *Wiedeyoceras* Miller, 1932 (type species *Eumorphoceras sanctijohanis* Wiedey, 1929), is based on sutural differences, particularly the wide ventral lobe, high median saddle, and large, wide, bluntly pointed ventral prongs (Fig. 6.1). Small size, however, precludes confident diagnosis or species-level identification.

Superfamily SCHISTOCERATOIDEA Schmidt, 1929
Family PSEUDOPARALEGOCERATIDAE Librovitch, 1957
Genus PHANEROCERAS Plummer and Scott, 1937

Type species.—*Gastrioceras compressum* Hyatt, 1891.

Included species.—*Gastrioceras amotapense* Thomas, 1928; *Phaneroceras chesnuti* n. sp.; *Eoparalegoceras clariondi* Delépine, 1939; *Phaneroceras gandli* Wagner-Gentis, 1985; *Eoparalegoceras inflatum* Delépine, 1951; *Gastrioceras kesslerense* Mather, 1915; *Phaneroceras lenaense* Andrianov, 1966; *Phaneroceras lenticulare* Plummer and Scott, 1937; *Eoparalegoceras orlovkense* Popov, 1979; *Pseudoparalegoceras williamsi* Miller and Downs, 1948.

Diagnosis.—Pseudoparalegoceratids with umbilical lobe of suture centered on umbilical wall or umbilical shoulder. Sutural formula: (V_1V_1)LU:ID.

Occurrence.—Pennsylvanian (upper Bashkirian [upper Morrowan]–Moscovian [Atokan]); U.S.A. (Texas, Oklahoma, Arkansas, Missouri, Ohio, Kentucky), Canada (Arctic Archipelago: Ellesmere Island, Axel Heiberg Island), Mexico (Tamaulipas), Peru, China (Ningxia, Guizhou), Japan, Russia (Moscow Basin; eastern Siberia: Verkhoyan), Ukraine (Donets Basin), Spain (Cantabrian Mountains), Morocco, Algeria.

Discussion.—See Nassichuk (1975, p. 110–112) for discussions of this genus and related pseudoparalegoceratids, particularly its taxonomic relationship with the subjective synonym *Eoparalegoceras* Delépine, 1939 (type species *E. clariondi* Delépine, 1939).

PHANEROCERAS CHESNUTI new species
Figures 5.11–5.13, 6.2, 6.3, 7

Phaneroceras compressum (Hyatt, 1891). RICE, BELKIN, HENRY, ZARTMAN, AND KUNK, 1994, p. 92, table 2 [Magoffin]; SAUNDERS AND WORK, 1996, p. 214; WORK, MASON, AND MAPES, 2009, pl. 9.1, figs. 13, 14.

Diagnosis.—Thinly subdiscoidal, widely umbilicate *Phaneroceras* with evolute, moderately depressed whorls that lack constrictions. Mature suture characterized by deep, pointed, asymmetrical umbilical lobe centered on umbilical shoulder or outermost umbilical wall.

Description.—Conch thinly subdiscoidal (W/D=0.46–0.51 at D=20–78 mm) and evolute with moderately depressed whorls (H/W=0.59–0.7) and deep, wide umbilicus (U/D=0.4–0.48). Conch ontogeny represented in Figure 7.3. Conch diameters and proportions listed in Table 5. Whorl sections at larger diameters uniformly rounded across flanks, converging toward depressed to broadly rounded venter. Umbilical shoulder narrowly rounded to subangular at maturity and umbilical walls steep, narrow, and gently convex. Test ornamented with faint growth lamellae that form moderately deep ventral sinus, equilateral salient, and shallow lateral sinus. Constrictions absent. Mature suture (Fig. 6.2, 6.3) includes wide ventral lobe with high median saddle; medially inflated, attenuate ventral prongs and lateral lobe; and deep, pointed, asymmetrical umbilical lobe centered on umbilical shoulder or outermost umbilical wall.

Etymology.—Named for Donald R. Chesnut, Jr., in recognition of his contributions to the Pennsylvanian geology of the central Appalachian Basin.

Types.—Holotype, SUI 104381, and paratypes SUI 104277, 104380, and 104382–104385. The types are well-preserved sideritic phragmocones (D=40–78 mm) that provide details of conch form and ontogeny (Fig. 7.3), external and internal ornament (Figs. 5.11–5.13, 7.1, 7.2), and suture (Fig. 6.2, 6.3).

Occurrence.—The types of *Phaneroceras chesnuti* were recovered 2.5 to 4.4 m above the base of the Magoffin Member of the Four Corners Formation at the Martin locality (Fig. 1).

Discussion.—*Phaneroceras chesnuti* is distinguished from most species assigned to the genus by its deep, wide umbilicus. Closest similarities are with the type species, *P. compressum* (Hyatt, 1891), which possesses a similar subdiscoidal, evolute conch form. However, *P. chesnuti* has more depressed whorls than *P. compressum* at equivalent ontogenetic stages and it lacks growth constrictions (Table 5). Also, at maturity (D=50–60 mm) the axis of the umbilical lobe in *P. chesnuti* is centered on or just inside the umbilical shoulder, whereas in

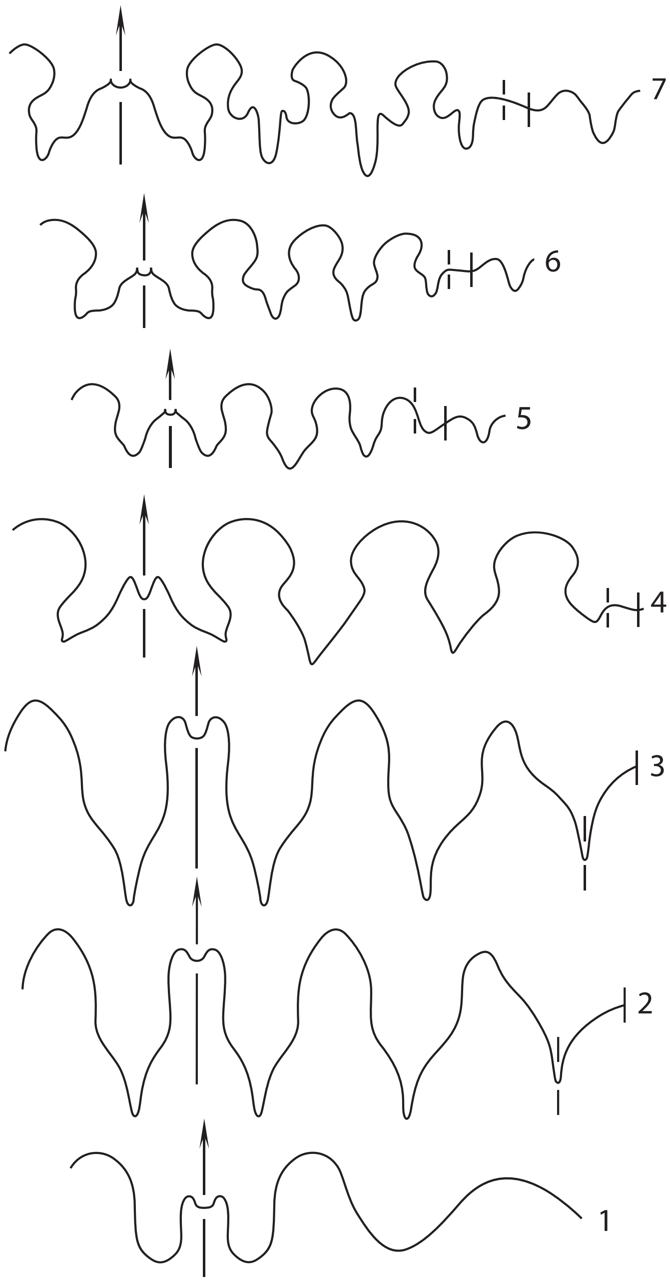

FIGURE 6—Sutural outlines of *Bisatoceras* Miller and Owen, 1937, *Phaneroceras* Plummer and Scott, 1937, Christioceratidae gen. indet., and *Christioceras* Nassichuk and Furnish, 1965. *1, Bisatoceras*? sp. from the Magoffin Member, Four Corners Formation, eastern Kentucky, SUI 104374, estimated diameter 9.5 mm; *2, 3, Phaneroceras chesnuti* n. sp. from the Magoffin Member, Four Corners Formation, eastern Kentucky: *2,* holotype SUI 104381, diameter 62 mm; *3,* paratype SUI 104277b, diameter 78 mm; *4,* Christioceratidae gen. indet. from the Magoffin Member, Four Corners Formation, eastern Kentucky, hypotype SUI 104386, diameter 40 mm; *5–7, Christioceras trifurcatum* Nassichuk and Furnish, 1965 from the Hare Fiord Formation, Ellesmere Island, Canadian Arctic Archipelago: *5,* paratype GSC 19880, diameter 8 mm (after Nassichuk and Furnish, 1965, text-fig. 2c); *6,* paratype GSC 19882, diameter 14 mm (after Nassichuk and Furnish, 1965, text-fig. 2d); *7,* holotype GSC 19879, diameter 19 mm (after Nassichuk and Furnish, 1965, text-fig. 2e).

P. compressum this element in centered on the umbilical wall (compare Fig. 6.2, 6.3 with Gordon's [1965, text-fig. 83a] revised suture of the lectotype of *P. compressum*, USNM 23872).

TABLE 4—Conch diameters (in mm) and proportions of *Bisatoceras*? sp.

Specimen	D	H/D	W/D	H/W
Bisatoceras? sp.				
Hypotype SUI 104375	11.9	0.59	0.58	1.01
Hypotype SUI 104376	11.6	0.58	0.62	0.93
	5.7	0.54	0.67	0.67
Hypotype SUI 104377	10.3	0.56	0.64	0.89

Family CHRISTIOCERATIDAE Nassichuk and Furnish, 1965
CHRISTIOCERATIDAE genus indeterminate
Figures 4.3, 4.4, 6.4

Description.—Conch lenticular with strongly compressed whorls (W/D=0.17 and H/W=2.44 at D=40 mm), moderately wide umbilicus (U/D=0.31), and narrow, grooved venter at maturity. Conch diameter and proportions listed in Table 6. Earliest growth stages unknown, but presumedly as in *Christioceras*, with strong sinuous ribs in juvenile stages, reduced to weak umbilical nodes at maturity. Mature growth lirae strongest on umbilical shoulder, form deep, rounded ventral sinus, high, broadly rounded ventrolateral salient, and shallow lateral sinus. Weaker, more widely spaced longitudinal lirae impart reticulate pattern to ornament on outer flanks (Fig. 4.3, 4.4). Suture (Fig. 6.4) includes wide, bifid ventral lobe with apically divergent, medially inflated ventral prongs with constricted tips (V_1); medially inflated lateral (L) and umbilical (U) lobes; and incipiently subdivided internal lateral lobe (I) with small, medially inflated ventrad subdivision (I_1) on dorsolateral flank and incipient dorsad subdivision (I_2) centered on seam. Sutural formula interpreted as: $(V_1V_1)LU(I_1{:}I_2)D$.

Types.—Hypotype SUI 104386 is a well-preserved, partial phragmocone that provides details of mature conch form, mature ornament (Fig. 4.3, 4.4), and suture (Fig. 6.4).

Occurrence.—The hypotype was recovered 3.2 to 4.7 m below the top of the Magoffin Member of the Four Corners Formation at the Hazard locality (Fig. 1).

Discussion.—Although clearly related to *Christioceras* Nassichuk and Furnish, 1965 (type species *C. trifurcatum* Nassichuk and Furnish, 1965) by details of mature conch form, mature ornament, and sutural ontogeny, this form lacks the degree of sutural complexity attained by that genus. The trifurcation of major sutural elements (ventral prongs and adjacent lateral, umbilical, and internal lateral lobes) that characterizes the mature suture of *Christioceras* (D=19 mm; Fig. 6.7) is only incipiently developed in Christioceratidae gen. indet. which presents an external suture (D=40 mm; Fig. 6.4) that is fundamentally similar to that developed by *Christioceras* in the juvenile stage of development (D=8–14 mm; Fig. 6.5, 6.6). As such, Christioceratidae gen. indet. is considered a plausible ancestor to that genus. However, because the juvenile growth stages are presently unknown and knowledge of the sutural ontogeny is incomplete, this taxon is left in open nomenclature pending discovery of additional material.

BIOSTRATIGRAPHY AND CORRELATION

The *Gastrioceras magoffinense* assemblage correlates with the *Diaboloceras–Winslowoceras* ammonoid Genozone and, on the evidence of the involute Magoffin *Gastrioceras, G. magoffinense* and the suturally advanced *Dimorphoceratoides, D. adamsi,* with the *Diaboloceras varicostatum–Winslowoceras henbesti* Zone in the early Atokan Winslow Member of the Atoka Formation in northwestern Arkansas. Conodonts associated with the ammonoids in the Martin section

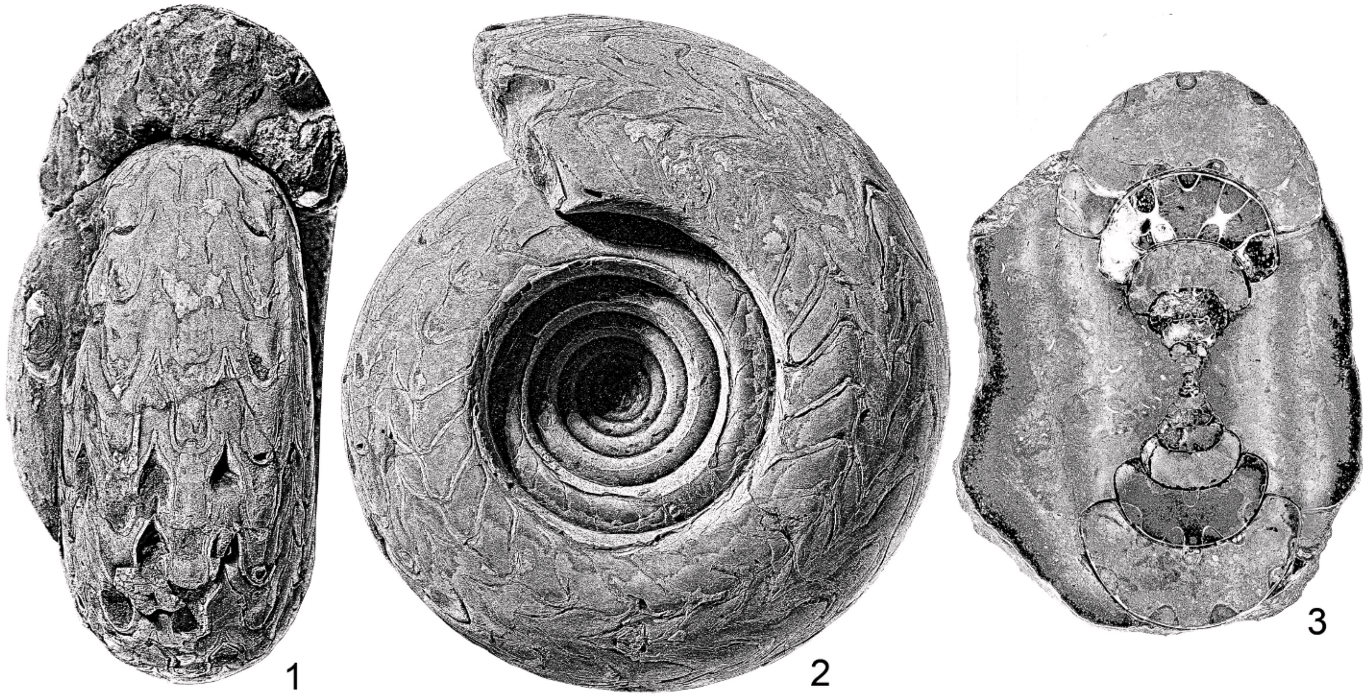

FIGURE 7—*Phaneroceras chesnuti* n. sp. from the Magoffin Member, Four Corners Formation, eastern Kentucky. *1, 2,* apertural and left lateral views of holotype SUI 104381, ×1.4; *3,* cross section of paratype SUI 104384, ×1.5.

(Fig. 1) include *Declinognathodus marginodosus* (Grayson, 1984) (Fig. 8.2, 8.3), *D. donetzianus* Nemirovskaya, 1990 (Fig. 8.1), the nominate species of the *D. donetzianus* Zone of Nemyrovska (1999), *Idiognathodus* aff. *delicatus* Gunnell, 1931, *Idiognathoides ouachitensis* (Harlton, 1933), *Idiognathoides sinuatus* Harris and Hollingsworth, 1933, and *Idiognathoides tuberculatus* Nemirovskaya in Kozitskaya et al., 1978. *Declinognathodus marginodosus* appears first near the base of equivalents of the early Atokan Winslow Member in southern Oklahoma (Grayson, 1984; Groves et al., 1999, fig. 4). Co-occurrence of this species with its descendant *D. donetzianus* in the lower ammonoid-bearing interval in the Magoffin Member at Martin establishes a maximum age and indicates correlation with the basal Bolsovian (basal Westphalian C) Substage in western Europe and the Bashkirian–Moscovian Stage boundary interval in eastern Europe (Donets and Moscow basins) and the South Urals (Nemyrovska, 1999; Nemyrovska et al., 1999, 2010; Goreva and Alekseev, 2001; Alekseev et al., 2004; Groves and Task Group, 2006, 2009; Pazukhin et al., 2006).

Conodont and ammonoid evidence thus relate the Magoffin assemblage to a relatively narrow range of early Atokan age corresponding to the basal Bolsovian (basal Westphalian C) Substage in western Europe and the Bashkirian–Moscovian Stage boundary interval in eastern Europe (Fig. 9). Comparable early Atokan ammonoid assemblages (reviewed by Gordon [1970] and Nassichuk [1975]) are known from the post-Trace Creek sequence in the Atoka Formation (lower part of the overlying Winslow Member) in northwestern Arkansas (Miller and Downs, 1948; McCaleb, 1963; Gordon, 1965; Mapes and Furnish, 1981); and the Canyon Fiord,

TABLE 5—Conch diameters (in mm) and proportions of species of *Phaneroceras* Plummer and Scott, 1937.

Specimen	D	U/D	H/D	W/D	H/W
Phaneroceras chesnuti n. sp.					
Paratype SUI 104277b	78.0	0.42	0.32	0.45	0.71
Paratype SUI 104380	68.2	0.44	0.31	0.48	0.64
	46.6	0.41	0.32	0.49	0.65
	30.7	0.40	0.32	0.51	0.63
	19.6	0.44	0.31	0.51	0.61
Holotype SUI 104381	64.3	0.46	0.30	0.46	0.65
Paratype SUI 104277a	63.3	0.42	0.33	0.48	0.70
Paratype SUI 104382	52.5	0.43	0.32	0.48	0.68
Paratype SUI 104383	51.1	0.44	0.33	0.47	0.70
Paratype SUI 104384	49.7	0.46	0.30	0.48	0.63
	33.4	0.46	0.30	0.48	0.62
	21.8	0.48	0.30	0.50	0.59
	14.2	0.51	0.25	0.50	0.51
Paratype SUI 104385	40.0	0.44	0.32	0.48	0.67
Phaneroceras compressum (Hyatt, 1891)					
Hypotype SUI 11016 [Winslow][1]	50	0.45	0.32	0.40	0.80
SUI unnumbered [Bloyd][2]	80	0.41	0.39	0.45	0.86
SUI unnumbered [Bloyd][2]	75	0.41	0.36	0.45	0.82
SUI unnumbered [Bloyd][2]	70	0.41	0.35	0.44	0.79
SUI unnumbered [Bloyd][2]	65	0.42	0.35	0.46	0.77
SUI unnumbered [Bloyd][2]	60	0.43	0.38	0.45	0.81
SUI unnumbered [Bloyd][2]	50	0.44	0.36	0.44	0.82
SUI unnumbered [Bloyd][2]	40	0.40	0.39	0.51	0.76
SUI unnumbered [Bloyd][2]	32	0.42	0.38	0.50	0.75
SUI unnumbered [Bloyd][2]	26	0.42	0.40	0.46	0.83
SUI unnumbered [Bloyd][2]	22	0.45	0.45	0.55	0.83

[1] After McCaleb (1963, table 3).
[2] McCaleb (1968, table 7).

TABLE 6—Conch diameters (in mm) and proportions of Christioceratidae gen. indet. and *Christioceras* Nassichuk and Furnish, 1965.

Specimen	D	U/D	H/D	W/D	H/W
Christioceratidae gen. indet.					
Hypotype SUI 104386	40.0	0.31	0.42	0.17	2.44
Christioceras trifurcatum Nassichuk and Furnish, 1965					
Holotype GSC 19879[1]	22.0	0.33	0.44	0.15	2.91
Paratype GSC 19880[1]	9.3	0.40	0.38	0.23	1.52

[1] After Nassichuk and Furnish (1965, table 1).

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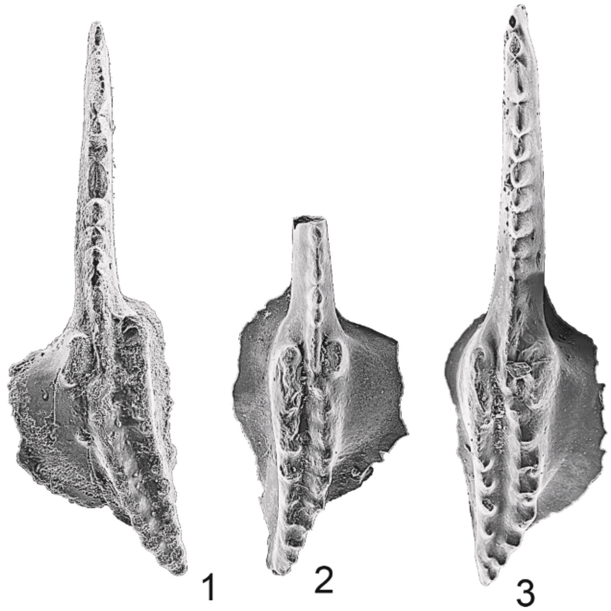

FIGURE 8—Atokan conodonts from the Magoffin Member, Four Corners Formation, eastern Kentucky. All figures are upper views of Pa elements; all magnifications ×60. See *Figure 1* for stratigraphic position. *1, Declinognathodus donetzianus* Nemirovskaya, 1990, SUI 104389; *2, 3, Declinognathodus marginodosus* (Grayson, 1984): *2,* SUI 104390; *3,* SUI 104391.

Nansen, and Hare Fiord formations on Ellesmere Island and Axel Heiberg Island in the Canadian Arctic Archipelago (Nassichuk, 1975).

BASHKIRIAN–MOSCOVIAN BOUNDARY

Correlation of the Bashkirian–Moscovian boundary into sub-Arctic North America is complicated by distinct provincial differences in fossil assemblages between the two areas. Comprehensive reviews of historical and faunal aspects of this correlation problem are provided by Groves et al. (1999, 2007). Although no consensus has been established on the position of the boundary in the Appalachian Basin and the southern Midcontinent, there is general agreement that the conodont *Declinognathodus donetzianus,* which first appears in Limestone K_1 of the C_2^5 (K) Suite in the standard Donets Basin succession, in the lower Vereisky Horizon in the type Moscovian succession in the Moscow Basin and the equivalent Solontsovsky Horizon in the type Bashkirian succession in the South Urals, and in the basal Bolsovian (basal Westphalian C) Aegiranum marine band in western Europe, is positive operational evidence of Moscovian age and it is currently being evaluated by the ICS Subcommission on Carboniferous Stratigraphy (SCCS) as a potential event marker for the base of the global Moscovian Stage (Nemyrovska, 1999; Nemyrovska et al., 1999, 2010; Goreva and Alekseev, 2001; Alekseev et al., 2004; Groves and Task Group, 2006, 2009; Pazukhin et al., 2006). *Declinognathodus donetzianus* has never been recovered in the standard Morrowan–Atokan succession in the southern Midcontinent, or, until this report, from anywhere in sub-Arctic North America. Nevertheless, it does occur in direct association with ammonoids from the Magoffin Member in Kentucky, which can, in turn, be correlated with ammonoids from the lower part of the Winslow Member of the Atoka Formation in northwestern Arkansas. Accordingly, it is possible to correlate the ammonoid-bearing strata of the Magoffin Member directly to the standard Arkansas succession and by inference point to the probable position of an operational, conodont-based Bashkirian–Moscovian boundary in the southern Midcontinent. Since the representatives of *Declinognathodus donetzianus* that occur in the Magoffin Member are also in equivalents of the *Diaboloceras varicostatum–Winslowoceras henbesti* ammonoid Zone, it follows that the operational Bashkirian–Moscovian boundary falls within the *Diaboloceras varicostatum–Winslowoceras henbesti* Zone [=lower part of *Diaboloceras–Winslowoceras* ammonoid Genozone] and thus corresponds to a position within the lower part of the lower Atokan Winslow Member of the Atoka Formation in northwestern Arkansas (Fig. 9).

ACKNOWLEDGMENTS

The ammonoid collection upon which this study is based represents the efforts of a number of individuals, particularly T. H. Adams of Tollesboro, Kentucky; former students of Morehead State University, Morehead, Kentucky, including J. E. Aragon, A. J. Fannin, and S. K. Williams; D. R. Chesnut,

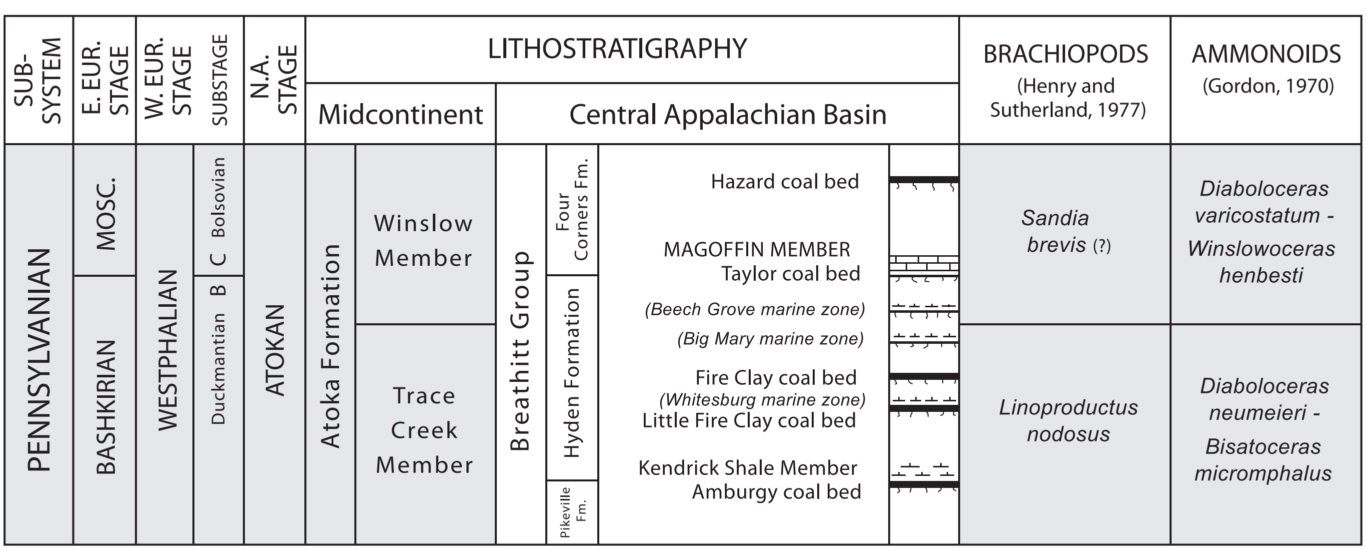

FIGURE 9—Correlation of the Magoffin ammonoid assemblage in the Magoffin Member of the Four Corners Formation with standard biostratigraphic successions in the southern Midcontinent and western and eastern Europe. Based on Rice et al. (1994, fig. 1, p. 91–93), Greb et al. (2009, fig. 4.2), and our own observations. Abbreviations: Mosc.=Moscovian.

Jr., Kentucky Geological Survey; T. W. Henry, formerly U.S. Geological Survey; L. H. Howard and D. J. Phelps, Kentucky Department of Environmental Protection; and D. S. Fine and R. N. Schrantz of Lexington, Kentucky. We thank T. I. Nemyrovska, Ukrainian Academy of Sciences, Kiev, for identifications and interpretations of conodonts from the Martin section; D. R. Chesnut, Jr. and S. F. Greb, Kentucky Geological Survey, for discussions on lithostratigraphy and facies relationships; and P. H. Heckel, University of Iowa, for discussions on chronostratigraphy. T. S. Adrain, University of Iowa; S. Lidgard, Field Museum of Natural History; J. W. Thompson and D. Levin, U. S. National Museum of Natural History; and W. W. Nassichuk, Geological Survey of Canada, Calgary, provided access to types and comparative specimens. The final manuscript benefited from reviews by D. Korn, Museum für Naturkunde, Humboldt University, Berlin, and an anonymous reviewer, as well as constructive comments by editors P. J. Harries, University of Southern Florida, and B. R. Pratt, University of Saskatchewan.

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ACCEPTED 11 NOVEMBER 2011

APPENDIX

Localities

The ammonoids described in this report are from the Magoffin Member of the Four Corners Formation (Fig. 1) at three localities in Floyd and Perry counties, eastern Kentucky.

Prestonsburg, Floyd County.—Roadcut exposure along the west side of Top of Abbott Mountain Road (County Road 1476), 0.3 km south and west of its intersection with US Highway 23, which is at a point 1.6 km north of the Stonewall Road exit at Prestonsburg, Floyd County, Kentucky (latitude N 37°41′50.0″, longitude W 82°47′33.9″; Prestonsburg 7.5′ quadrangle).

Martin, Floyd County.—Roadcut exposure along the northbound lane of Kentucky Highway 80, 5.8 km south of its intersection with US Highway 23 and 2.1 km north of the New Bridge Road exit at Martin, Floyd County, Kentucky (latitude N 37°35′20.1″, longitude W 82°45′56.9″; Martin 7.5′ quadrangle). This corresponds to stop 10 of Cobb et al. (1981, p. 40–42, pl. 16) and section M28 of Bennington (1996, p. 178–180, figs. 4–6; 2002, fig. 6).

Hazard, Perry County.—Roadcut exposure along the eastbound lane of the Hal Rogers Parkway at Milepost 53, 3.1 km east of the Leslie/Perry County line and 9.7 km west of the Kentucky Highway 15 exit at Hazard, Perry County, Kentucky (latitude N 37°14′56.3″, longitude W 83°17′51.4″; Hyden East 7.5′ quadrangle).