Late Paleozoic turrilepadid machaeridians from North America

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Turrilepadids are not uncommon in late Paleozoic shales being often associated with ostracodes, foraminifers, and minute molluscs. In North America they range from the late Missippian (Chesterian) to early Permian (Leonardian). Sclerites of the inner scleritome row are more common than outer sclerites. Some clusters have been found. Sclerite consists of two layers with the thicker, lower layer penetrated by a transverse tubular structures oriented perpendicular to the sclerite surface, which may represent canals related to the papillae on the inner surface of the sclerite. *Turrilepas lepros* sp. n., *T. trigoniodes* sp. n., *T. asketos* sp. n., *Clarkeolepis alloeospinosa* sp. n., and *Ambonlepidos petalos* gen. et sp. n. are proposed.

Key words: Turrilepadidae, Machaeridia, Mississippian, Pennsylvanian, Permian.

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Introduction

The collection of machaeridian sclerites from 22 localities in North America provides insight into the diversity of this class in the late Paleozoic. Previous studies on machaeridians have focused primarily on early Paleozoic occurrences (see Adrain 1992 for references) although their presence in the Pennsylvanian has been noted (Chronic in Bengtson 1978). Elias

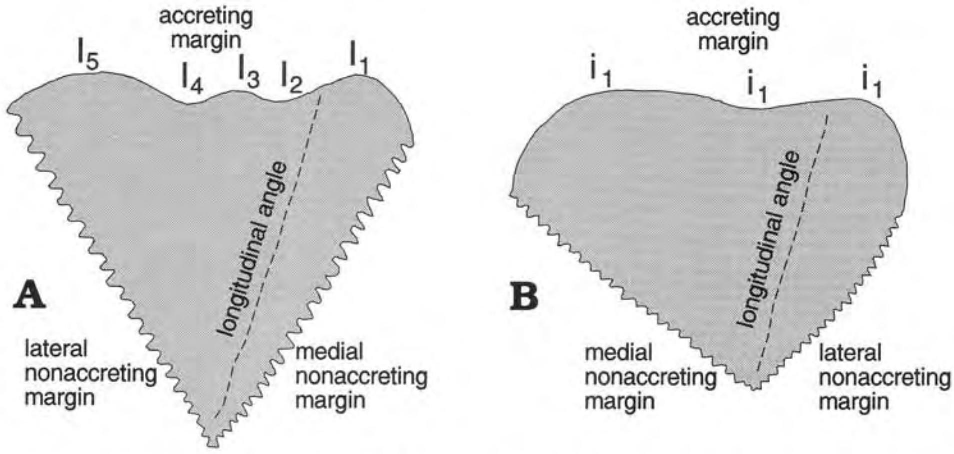


Fig. 1. Diagrammatic representation of sclerites illustrating terminology used in descriptions. A. Inner left sclerite. B. Outer right sclerite. Abbreviations: I_1–I_5 — inflections of accreting margin on inner sclerite; i_1–i_3 — inflections of accreting margin on outer sclerite.

(1958) provided the only previous study of late Paleozoic taxa in which he described two species, *Clarkeolepis clarkei* and *Turrilepas withersi* from the Mississippian Redoak Hollow Member of the Goddard Formation of Oklahoma. Unfortunately, the type specimens of these species cannot be located.

Withers (1926) produced the first basic study of the Machaeridia. The recent work of Adrain *et al.* (1991) and Adrain (1992), which provide a review of the Turrilepadidae and discussion of machaeridian classification, has been very helpful in the present study and much of the character terminology (Fig. 1) and classification herein is based upon their studies.

Turrilepadid sclerites are not uncommon in the microbiotas of late Paleozoic shales. Often found associated with ostracodes, foraminifers, and micromolluscs, these elements have probably been repeatedly overlooked or disregarded because attention has been focused on other types of organisms. Silicified residues from limestones may also contain preserved sclerites (Adrain *et al.* 1991; Adrain 1992).

Our specimens are from units in the Chesterian of Arkansas, the Morrowan of Oklahoma, the Atokan and Desmoinesian of Ohio, the Atokan of Kentucky, the Virgilian of Illinois, and the Desmoinesian, Missourian, Virgilian, and Leonardian of Texas (see p. 143). Each sample contains from one to over 300 specimens. Mostly, specimens are incomplete disarticulated inner sclerites, and in only a few cases are outer sclerites present. Rarely, clusters of sclerites have been found, but not as complete scleritomes. It is hoped that the present study will form a beginning framework for future work on this group in the late Paleozoic, and more collecting will provide additional information on stratigraphic and geographic ranges of taxa.

Specimens have been placed in the Ohio University Zoological Collections, Athens, Ohio (OUZC).

Organization of scleritome

The number of segments present in the scleritomes of late Paleozoic turrilepadids is unknown. Adrain *et al.* (1991) report at least 26 segments in Wenlockian *Turrilepas wrightiana* (de Koninck 1857) from Britain. Late Paleozoic taxa probably had a similar number.

The reason for the scarcity of outer sclerites has not been determined. Sorting or preservational factors might be involved. Outer sclerites are less strongly angled than inner sclerites which might lead to a sorting differential. Fused clusters of plates have been recovered from the Harpersville Formation, shales below the Bunger Limestone in the Graham Formation, and in the Mineral Wells Formation (East Mountain Shale). These clusters represent partial scleritomes of *Ambonlepidos petalos* gen. et sp. n. Further collecting in these units at localities 11, 18, and 19 (see p. 144) might provide complete scleritomes.

Structure and morphology of sclerites

Most species of turrilepadids are probably long ranging (e.g., *Ambonlepidos petalos* gen. et sp. n. of Atokan–Virgilian; *Turrilepas lepros* sp. n. of Morrowan–Missourian).

In many cases recrystallization has destroyed the microstructure of the sclerites. Where original microstructure of sclerites has been preserved, they are seen to have two layers, an outer thin layer and a much thicker inner layer (Fig. 2G). The inner and outer layers extend into the spines on the nonaccreting margins, as shown by the presence of papillae which mark the inner surface of the sclerite (Fig. 3). Thin sections of well preserved specimens show transverse tubular structures oriented perpendicular to the layers, extending from the papillate inner surface to the thin outer layer (Fig. 2E–G). These structures may represent canals leading from the papillae.

Adrain *et al.* (1991: p. 640) described the inner surface of turrilepadids as having a finely granular texture. The inner surface of late Paleozoic sclerites show discrete, elevated structures at high magnification (Fig. 3). We prefer to term these as papillae rather than grains. Mickwitziid brachiopods show a similar interior structure (M.A. McMenamin, personal communication). This may be the same structure as Adrain's granules in the early Paleozoic taxa. In most sclerites the papillae are arranged in rows radiating from the apical region. In some instances the radial pattern is indistinct or absent. The function of the papillae is unknown but they possibly serve as centers of calcification in the formation of the sclerite.

The number of transverse rugae on the outer surface of sclerites is often given in the published descriptions of taxa. On many sclerites rugae are more or less evenly spaced, but on some they are crowded near the apical end or near the accreting margin. In addition to the total number, a count of rugae per millimeter near midlength may give a more realistic figure for comparison of taxa.

None of our specimens have the previously described small, fragile, apical, bifid spines (illustrated by Adrain *et al.* 1991) preserved. Neither were inner grooves and doublures observed on the inner surface of any sclerites.

Systematics

Class Machaeridia Withers 1926
Order Turrilepadomorpha Pilsbry 1916
Family Turrilepadidae Clarke 1896
Genus *Turrilepas* Woodward 1865
Type species: *Turrilepas wrighti* Woodward 1865.

Turrilepas lepros sp. n.

Figs 2D, G, 3E–F, 4, 5A–G.
Holotype: Specimen OUZC 1354 (Fig. 4K).
Type horizon and locality: Gene Autry Formation at locality 2.
Etymology: *Lepros*, Greek, scaley, rough.

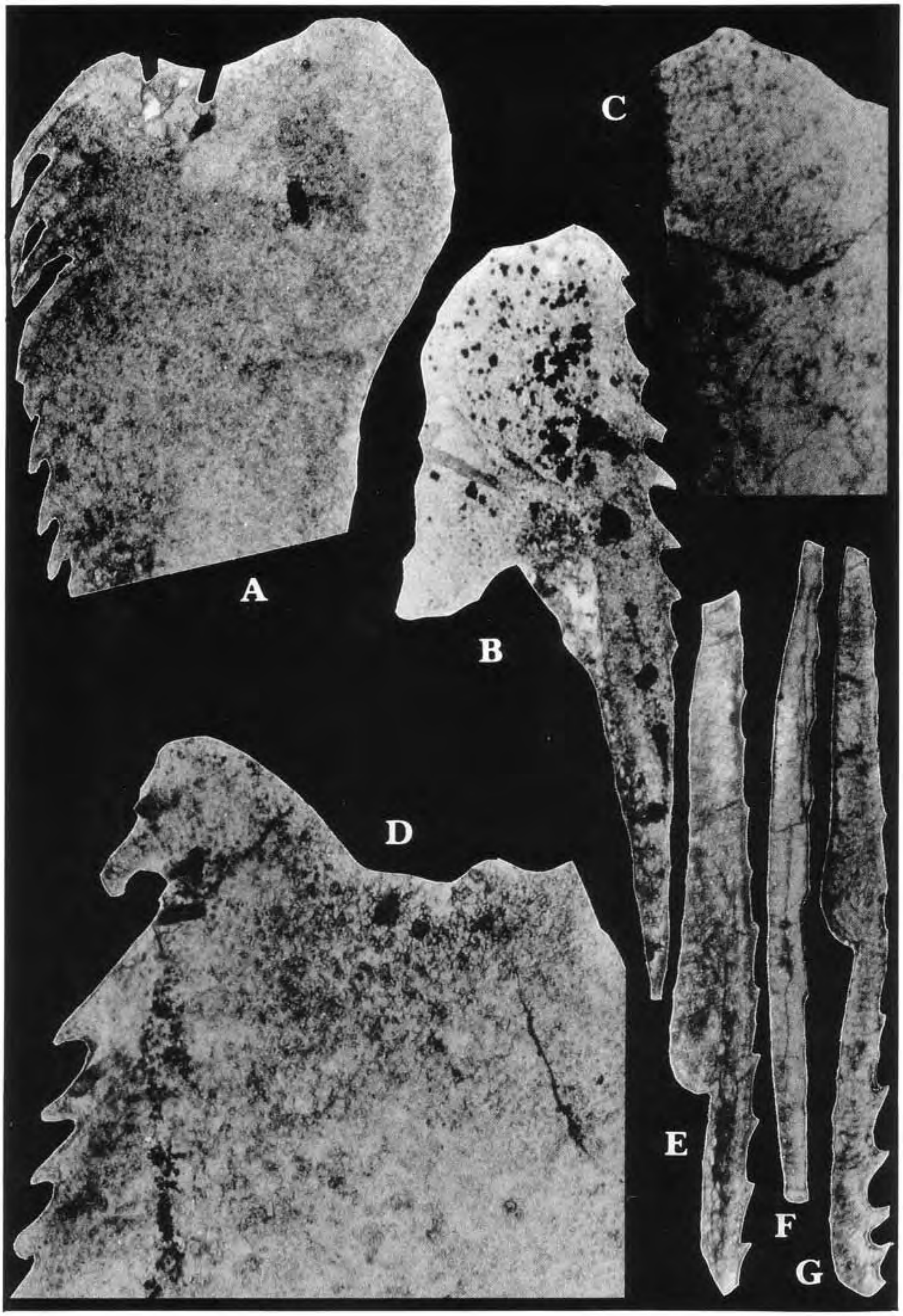
Diagnosis. – Turrilepadid with coarse, closely spaced spines; up to 17 rugae on mature inner sclerites; I strongly developed at or just beside longitudinal angle on medial portion; terminal sclerite with deep, notchlike I_2.

Description. – Thick, medium-sized sclerites with coarse rugae thickened in region of angle; rugae average 7.5 per mm near midlength; nonaccreting margins with closely spaced spines, 1–2 per rugae; many rugae terminating at spines; accreting margin with strongly developed I_1 at or near longitudinal angle on medial portion, I_2–I_4 moderately developed, I_5 more strongly developed; longitudinal angle averages approximately 110°; left medial area larger than right medial area on inner sclerites; inner surface with minute papillae which may or may not be arranged in rows radiating from apical area; thick inner layer extending into spines, with curved, transverse microstructure leading from papillae to thin outer layer; muscle scar large, adjacent to longitudinal angle on outer portion; outer sclerites not observed.

Remarks. – *Turrilepas lepros* cannot be compared with the Late Mississippian *T. withersi* Elias 1958, from Oklahoma on the basis of the descriptions and illustrations provided of the latter species.

Turrilepas lepros differs from *T. asketos* sp. n. in having fewer and coarser rugae and larger, more widely spaced spines. *Turrilepas trigo-*

Fig. 2. Thin sections of sclerites; all × 72 except G which is × 44. □A, E. *Clarkeolepis clarkei* Elias 1958, specimens OUZC 1259, 1260, Imo Formation, locality 1. □B. *Turrilepas trigonoides* sp. n., specimen OUZC 1389, Graford Formation (Wolf Mountain Shale), locality 14.



❑C, F. *Ambonlepidos petalos* gen. et sp. n., specimens OUZC 1416, 1417, Lazy Bend Formation (Dickerson Shale), locality 11. ❑D, G. *Turrilepas lepros* sp. n., specimens OUZC 1362, 1363, Gene Autry Formation, locality 2.

niodes sp. n. differs in having larger and more widely spaced spines than *T. lepros*.

Occurrence. – Gene Autry Formation, Oklahoma, locality 2 (Morrowan); Mogoffin and Kendrick Shales, Kentucky, localities 3 and 4, and Lower Mercer Shale, Ohio, locality 7 (Atokan); Graford Formation (Wolf Mountain Shale), Texas, locality 14 (Missourian).

Turrilepas asketos sp. n.

Fig. 5H–W.

Holotype: Specimen OUZC 1368 (Fig. 5J).

Type horizon and locality: The Kendrick Shale at locality 4.

Etymology: *Asketos*, Greek, ornamented.

Diagnosis. – Turrilepadid with inner sclerites having small, closely spaced spines; up to 17 rugae only slightly thickened at longitudinal angle on mature sclerites.

Description. – Small inner sclerites with relatively fine rugae only slightly thickened in region of longitudinal angle and not reaching margins; rugae range from 12 to 17 per mm near midlength; nonaccreting margins with small, closely spaced spines, 1–3 per rugae; accreting margins with weakly developed inflections except for sharp downturn apically of I_5; longitudinal angle ranges from 90 to 125° at or near I_2; inner surface with fine papillae arranged in rows radiating from apex; muscle scars lightly impressed; possible outer sclerite with more closely spaced rugae, angle at i_3, shallow i_2, and broadly curved i_1 on accreting margin.

Remarks. – *Turrilepas asketos* is distinguished from other species within the collections by the fineness and only slight thickening of the rugae associated with the small, closely spaced spines. The outer sclerite described above (Fig. 5W) could possibly be a terminal sclerite of either the inner or outer series.

Occurrence. – Mogoffin and Kendrick shales, Kentucky, localities 3 and 4 (Atokan); Graford Formation (Wolf Mountain Shale), Texas, locality 14 (Missourian); Caddo Creek Formation (Colony Creek Shale), Texas, localities 17 and 18, and Mattoon Formation, Illinois, locality 21 (Virgilian).

Turrilepas trigoniodes sp. n.

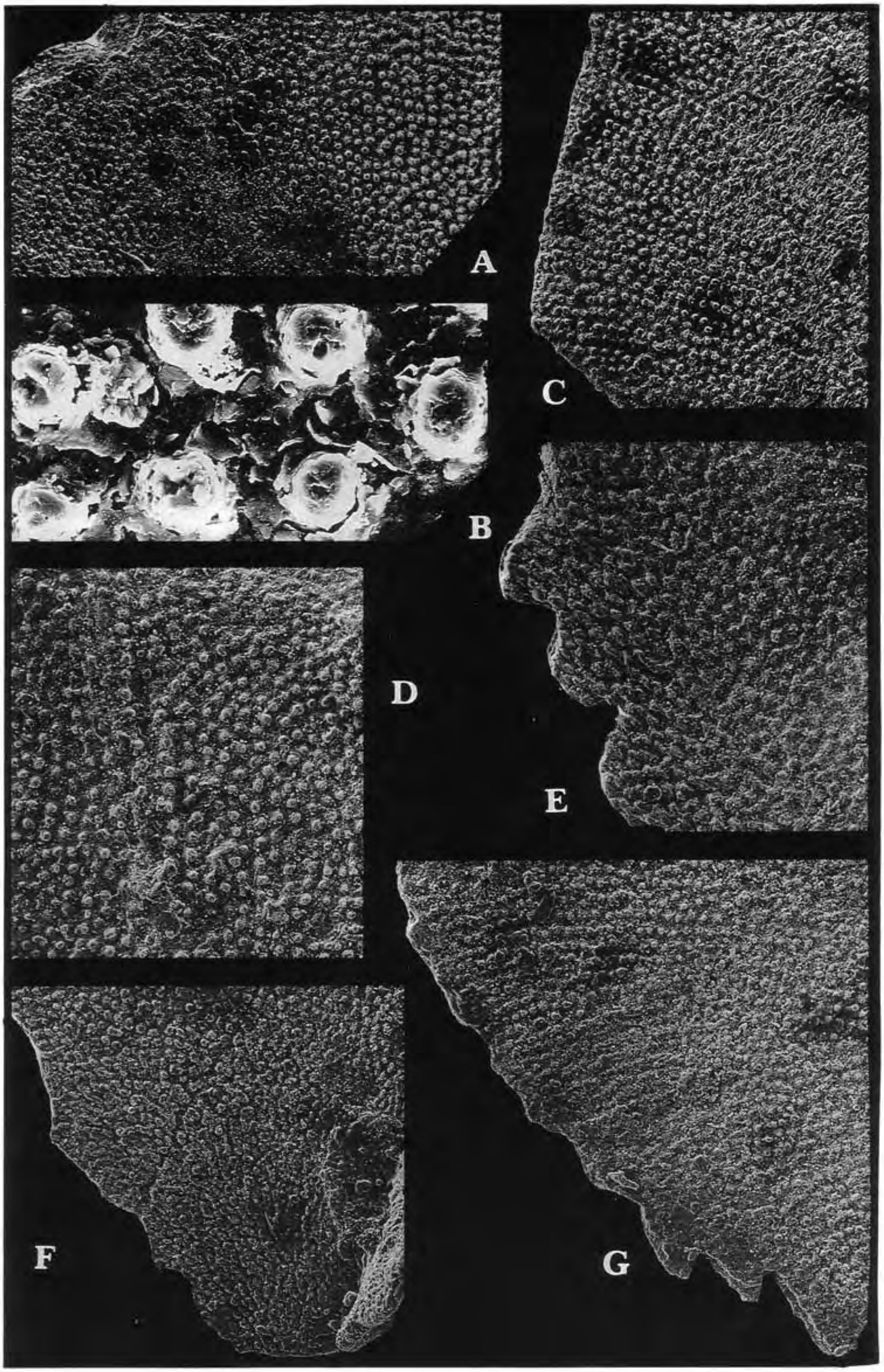
Figs 2B, 3D, 6A–G.

Holotype: Specimen OUZC 1383 (Fig. 6B).

Type horizon and locality: The Graford Formation (Wolf Mountain Shale) exposed at locality 14.

Etymology: *Trion*, Greek, three and *goniodes*, Greek, angular.

Fig. 3. Inner surface of sclerites showing papillae; all × 150 except B which is × 1500. ❑A–B. *Clarkeolepis clarkei* Elias 1958, specimen OUZC 1258 (same specimen as in Fig 6P), Imo Formation, locality 1. ❑C, G, *Ambonlepidos petalos* gen. et sp. n., specimens OUZC 1418, 1419, Kendrick Shale, locality 4 and Harpersville Formation, locality 20 respectively. ❑D. *Turrilepas trigonoides* sp. n., specimen OUZC 1390, Lazy Bend Formation (Dickerson Shale), locality 11. ❑E–F. *Turrilepas lepros* sp. n., specimens OUZC 1364, 1365, Gene Autry Formation, locality 2 and Mogoffin Shale, locality 3 respectively.


A
B
C
D
E
F
G

Diagnosis. — Turrilepadid with inner sclerites having large, widely spaced spines, one or less per rugae; up to 22 rugae on mature sclerites; I_1 strongly developed; longitudinal angle at or on median side of I_1.
Description. — Medium to large, thick, inner sclerites with coarse rugae thickened in region of longitudinal angle, some reaching margins; rugae average seven per millimeter near midlength; non-accreting margins with large spines, usually one per rugae; accreting margins with strongly developed I_1, moderately developed I_2–I_5; longitudinal angle averages 110°, at or on median side of I_1; inner surface with fine papillae aligned in rows radiating from apex; muscle scar weakly to strongly impressed.
Remarks. — *Turrilepas trigoniodes* has larger and more widely spaced spines than either *T. lepros* or *T. asketos* which readily differentiates the species.
Occurrence. — Lazy Bend Formation, Texas, locality 11 (Desmoinesian); Graford Formation (Wolf Mountain Shale) and Palo Pinto Formation (Wynn Member), Texas, localities 14 and 13 (Missourian).

Turrilepas sp.

Fig. 6H.

Description. — Medium-sized inner sclerite with 23 or more rugae thickened in region of longitudinal angle, not reaching margins; 12 rugae per millimeter near midlength; nonaccreting margins with one spine per rugae; accreting margin with well-developed I_1–I_3, I_4 and I_5 weakly developed; longitudinal angle of 105 degrees located at I_2; inner surface with fine papillae aligned in rows radiating from apex; muscle scar deeply impressed.
Remarks. — A single silicified sclerite. The margins are not well preserved, making judgement of spine character questionable.
Occurrence. — Cathedral Mountain Formation, Texas, locality 22 (Leonardian).

Genus *Clarkeolepis* Elias 1958

Type species: *Clarkeolepis clarkei* Elias 1958.

Diagnosis. — Inner sclerites with strong transverse rugae thickened at longitudinal angle; numerous, closely spaced, longitudinal ridges between rugae; nonaccreting margins with either spines of equal size and spacing on both margins or with unequal size and spacing on the two margins.

Clarkeolepis clarkei Elias 1958

Figs 2A, E, 3A–B, 7, 8.

Clarkeolepis clarkei n. sp. Elias 1958: p. 49, pl. 4: 26, 27; Dzik 1986: p. 122, fig. 13; Adrain *et al.* 1991: p. 649.

Clarkeolepis elegans n. sp. Elias 1958: p. 49, pl. 4: 28.

Description. — Medium-sized thick, inner sclerites with coarse rugae thickened in region of longitudinal angle; up to 22 rugae present on mature sclerites, nine per millimeter near midlength; nonaccreting margins with one large spine per rugae; accreting margin with strongly

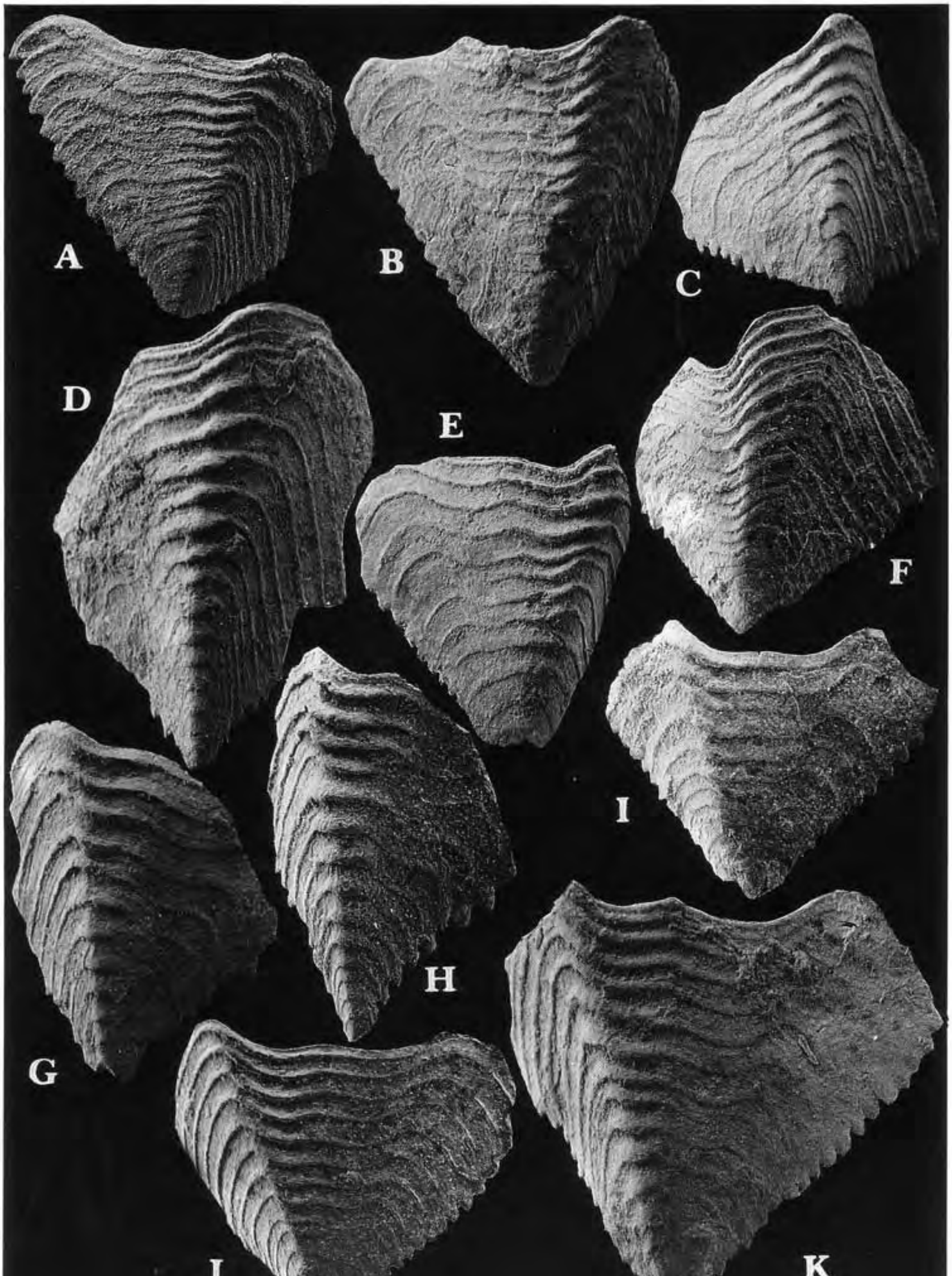


Fig. 4. *Turrilepas lepros* sp. n., Gene Autry Formation, locality 2; all inner sclerites, × 25. A–J. Specimens OUZC 1344–1353. K. Holotype OUZC 1354.

developed I_1 and moderately developed I_2–I_5; longitudinal angle of 120°, at I_1; finer, more closely spaced, longitudinal ridges present between rugae; terminal sclerite with closely spaced rugae and strongly developed I_5; inner surface with small papillae aligned in rows radiating from apex; muscle scars deeply impressed.

Remarks. – *Clarkeolepis clarkei* is the most highly ornamented turrilepadid. It differs from *C. alloeospinosus* sp. n. in having more extensive radiating ridges on the outer surface and spines of equal size on both nonaccreting margins. A diagrammatic reconstruction of *C. clarkei* is given in Fig. 8.

The holotype of *C. elegans*, as described by Elias (1958), differs from *C. clarkei* in lacking a longitudinal angle and a less equidistant spacing of the rugae. As Elias (1958) noted, only about two-thirds of the specimen is preserved, and the angle and medial part is missing. A search of the Redoak Hollow material in the collections of the University of Nebraska State Museum failed to locate the type specimen. Specimens from the Imo Formation are commonly broken in a similar manner and some show differences in the spacing and number of rugae. On this basis we agree with Adrain *et al.* (1991) that *C. elegans* is a subjective junior synonym of *C. clarkei*.

Occurrence. – Goddard and Imo Formations, Oklahoma, locality 1 (Chesterian).

Clarkeolepis alloeospinosa sp. n.

Fig. 6I–M.

Holotype: Specimen OUZC 1392 (Fig. 6I).

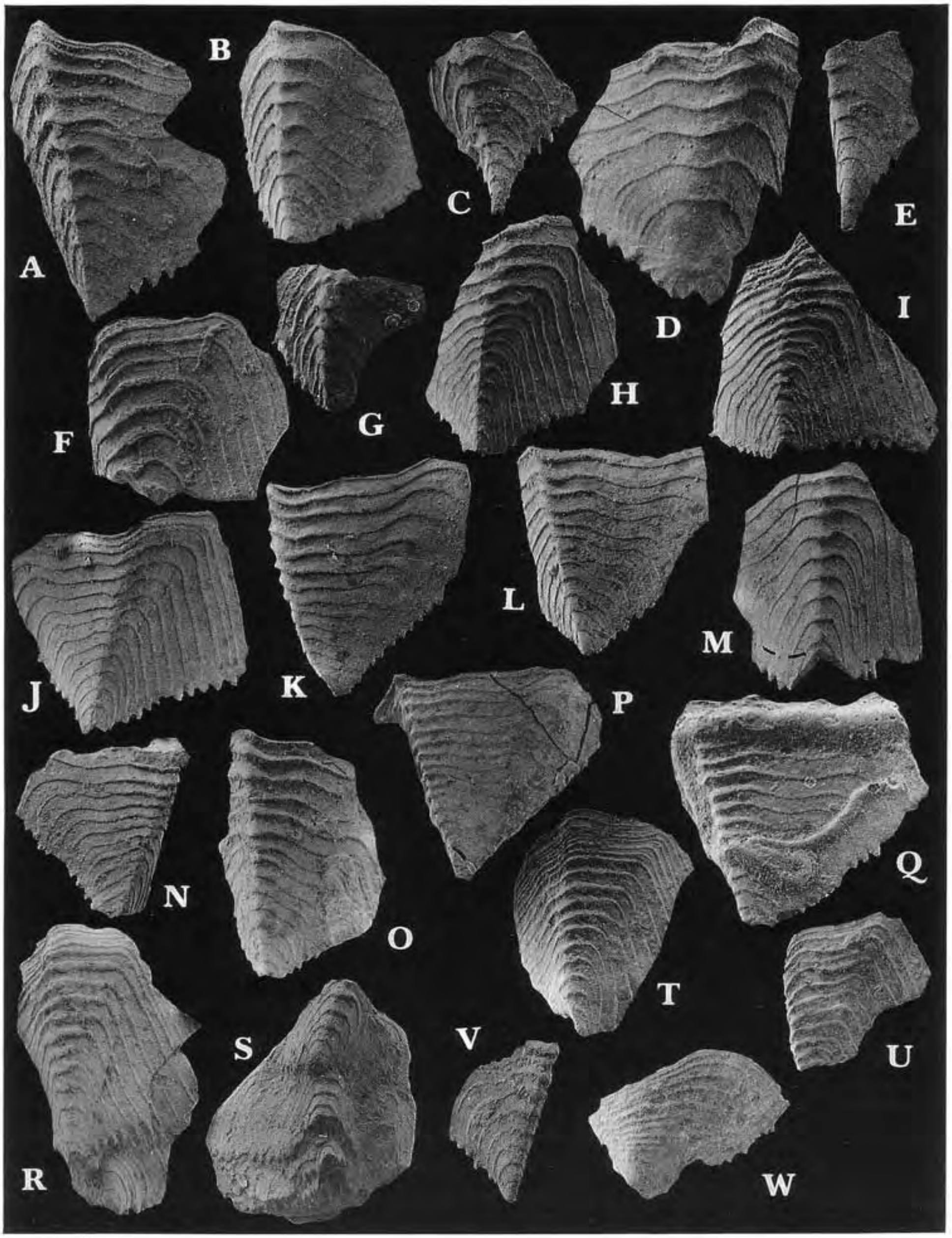
Type horizon and locality: The Palo Pinto Formation (Wynn Member) exposed at locality 13.

Etymology: *Alloios*, Greek, different and *spina*, Greek, thorn, spine.

Diagnosis. – Turrilepadid with inner sclerites having smaller, more closely spaced spines on medial margin, larger, more widely spaced spines on outer margin; low, radiating ridges between rugae on apical half of sclerite; up to 13 rugae on mature sclerite; longitudinal angle at I_1.

Description. – Medium-sized, thick, inner sclerites with relatively coarse rugae, thickened in region of longitudinal angle, not reaching margins; rugae average seven per millimeter near midlength; nonaccreting margins with one small spine per rugae on medial margin, one large spine per two rugae on outer margin; accreting margin with moderately strong I_1, weakly developed I_2–I_5; longitudinal angle 120°, at I_1; low, equally spaced, radiating ridges between rugae on apical outer portion; terminal sclerite with closely spaced rugae and strongly developed I_1 and I_5; inner surface with minute papillae aligned in radiating rows from apex; muscle scar deeply impressed.

Fig. 5. ❑A–G. *Turrilepas lepros* sp. n.; all inner sclerites, × 25. A–D. Specimens OUZC 1355–1358, Mogoffin Shale, locality 3. E–F. Specimens OUZC 1359–1360, Kendrick Shale,



locality 4. G. Specimen OUZC 1361, Lower Mercer Shale, locality 7. ❑H–W. *Turrilepas asketos* sp. n.; all inner sclerites, except W which may be an outer or terminal sclerite. H–I. Specimens OUZC 1366, 1367, Mogoffin Shale, locality 3. J–N. Holotype OUZC 1368 and specimens OUZC 1369–1372, Kendrick Shale, locality 4. O–P. Specimens OUZC 1373, 1374, Graford Formation (Wolf Mountain Shale), locality 14. Q. Specimen OUZC 1375, Caddo Creek Formation (Colony Creek Shale), locality 18. R–S. Specimens OUZC 1376, 1377, Caddo Creek Formation (Colony Creek Shale), locality 17. T–W. Specimens OUZC 1378–1381, Mattoon Formation, locality 21.

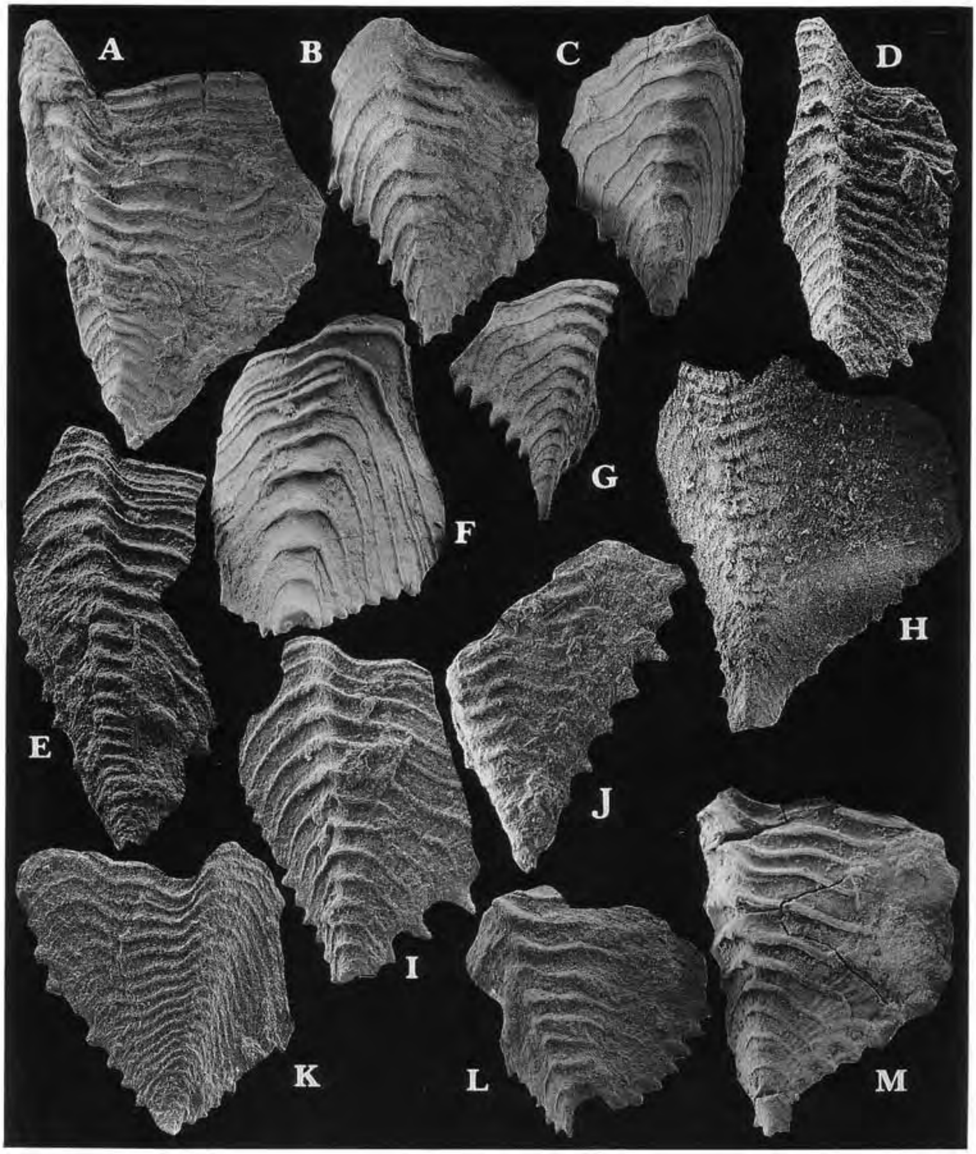


Fig. 6. ❑A–G. *Turrilepas trigonoides* sp. n.; all inner sclerites, × 25. A, C, F–G. Specimens OUZC 1382, 1384–1386, Graford Formation (Wolf Mountain Shale), locality 14. B. Holotype OUZC 1383, same locality. D. Specimen OUZC 1387, Lazy Bend Formation (Dickerson Shale), locality 11. E. Specimen OUZC 1388, Palo Pinto Formation (Wynn Member), locality 13. ❑H. *Turrilepas* sp., specimen OUZC 1391, Cathedral Mountain Formation, locality 22. ❑I–M. *Clarkeolepis alloeospinosa* sp. n.; all inner sclerites × 25. I–K. Holotype OUZC 1392 and specimens OUZC 1393–1394, Palo Pinto Formation (Wynn Member), locality 13. L. Specimen OUZC 1395, Caddo Creek Formation (Colony Creek Shale), locality 17. M. Specimen OUZC 1396, Necessity Shale, locality 19.

Remarks. – *Clarkeolepis alloeospinosa* differs from *C. clarkei* Elias 1958, in having radiating ridges on only the apical portion of the sclerite, in

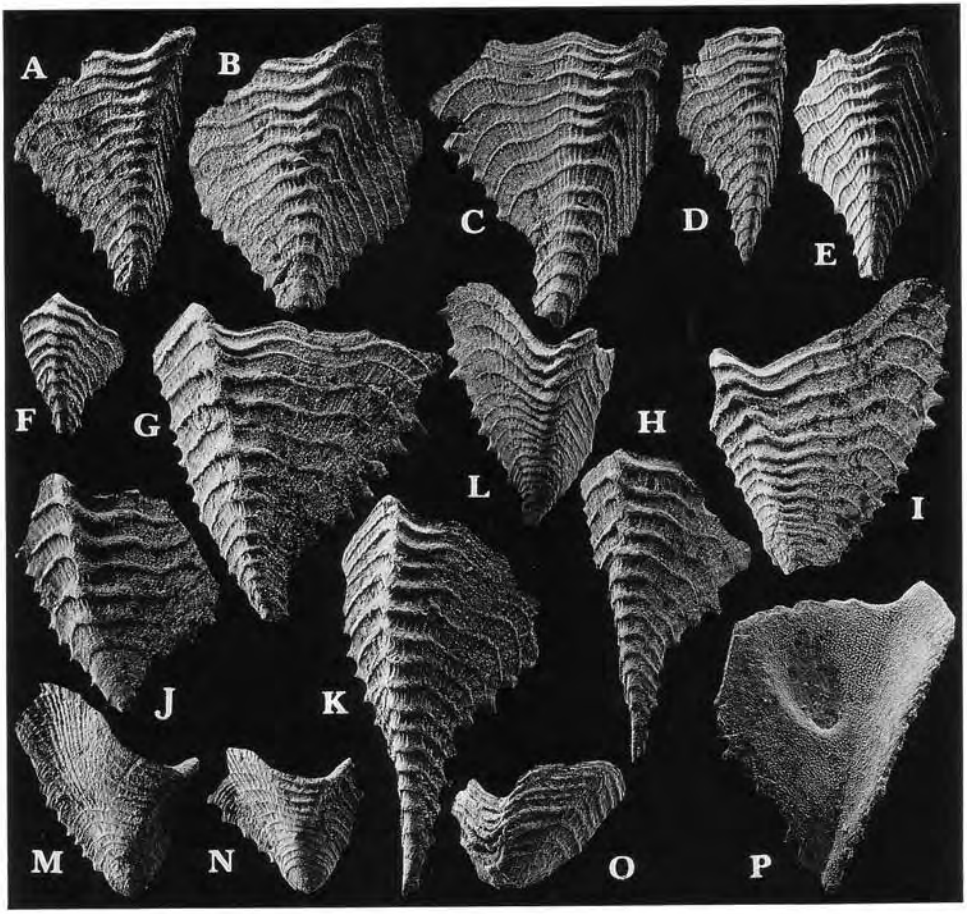


Fig. 7. *Clarkeolepis clarkei* Elias 1958, specimens OUZC 1243–1258, Imo Formation, locality 1; all figures × 25. M–O. Terminal sclerites. P. Inner surface of sclerite showing muscle scar and papillae, same specimen as for Fig. 1A–B.

different size and spacings of spines on the non-accreting margins, and in more flatly curved inflections of the accreting margin. No other turrilepadid has been reported with a similar size and spacing differential of spines on the nonaccreting margins.

Occurrence. — Palo Pinto Formation, Texas, locality 13 (Missourian); Caddo Creek Formation (Colony Creek Shale) and Graham Formation (Necessity Shale), Texas, localities 15 and 19 (Virgilian).

Genus *Ambonlepidos* gen. n.

Type species: *Ambonlepidos petalos* sp. n.

Etymology: *Ambon*, Greek, ridge and *lepidos*, Greek, scale.

Diagnosis. — Turrilepadid with small, closely spaced spines, one per rugae on inner sclerites, 1–2 per rugae on outer sclerites; rugae fine, not thickened in region of longitudinal angle; longitudinal angle at median edge of I_1, carinate, often with ridge.

Fig. 8. Diagrammatic reconstruction of *Clarkeolepis clarkei* Elias 1958 from the Imo Formation.

Remarks. – *Ambonlepidos* is readily distinguished from other genera of turrilepadids by its fine, non-thickened rugae and longitudinal carinate angle.
Range. – Pennsylvanian (Atokan to Virgilian).

Ambonlepidos petalos sp. n.

Figs 2C, F, 3C, G, 9, 10.

Holotype: Specimen OUZC 1406 (Fig. 9J).

Type horizon and locality: The Lazy Bend Formation (Dickerson Shale Member) exposed at locality 11.

Etymology: *Petalos*, Greek, broad, outspread.

Diagnosis. – As for the genus.

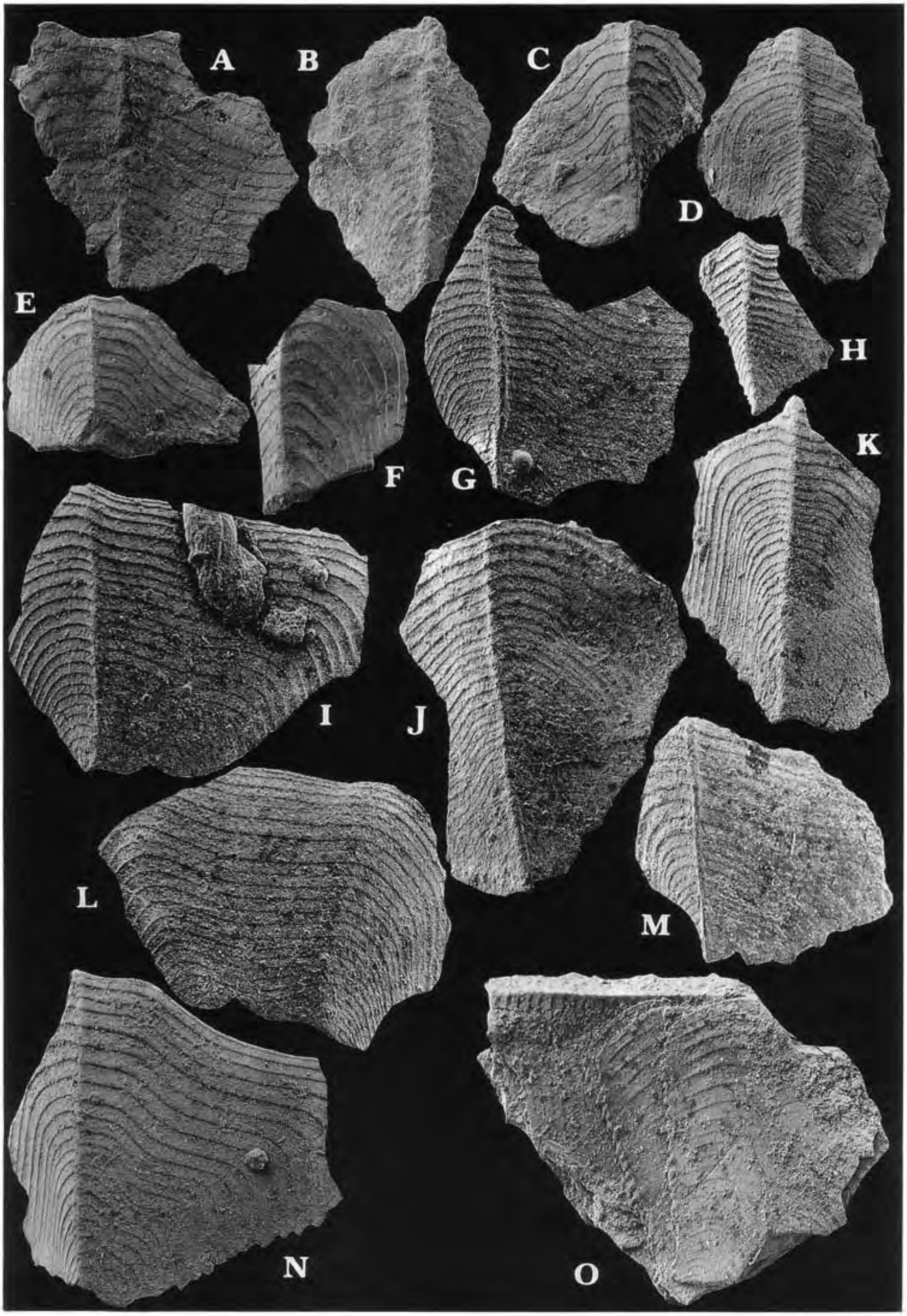
Description. – Large, thin, inner sclerites with fine, nonthickened rugae not reaching margins; up to 27 rugae on mature sclerites; 14–18 rugae per millimeter near midlength; nonaccreting margins with one small spine per rugae; accreting margin with moderately developed inflections, I_1 and I_5 with strongly down-turned outer portions; longitudinal angle of 110°, at median edge of I_1; outer sclerites large without carina; 1–2 spines per rugae; accreting margin with broad i_1, broad and shallow i_2, and narrow i_3; inner surface with fine papillae aligned in radiating rows from apex; muscle scar large.

Remarks. – *Ambonlepidos petalos* is the only known species of the genus.

The ventral view of the cluster in Fig. 10D–E shows a strange saddle-shaped element which is different from either the inner or outer sclerites. It is doubtful that this element is part of the scleritome of *A. petalos*, but could be a separate internal skeletal secretion of the turrilepadid animal.

Occurrence. – Boggs and Lower Mercer Shales, Ohio, localities 5 and 7 (Atokan); Putnam Hill Shale, Ohio, localities 9 and 10, and Lazy Bend Formation and Mineral Wells Formation (East Mountain Shale), Texas, localities 11 and 12 (Desmoinesian); Palo Pinto Formation, Texas, locality 13 (Missourian); Caddo Creek Formation (Colony Creek Shale), shales beneath the Bunger Limestone in the Graham Formation, and Harpersville Formation, Texas, localities 16, 18, 19, and 20 (Virgilian).

Fig. 9. *Ambonlepidos petalos* gen. et sp. n.; all inner sclerites except L which is an outer sclerite, × 25. A–B. Specimens OUZC 1397–1398, Boggs Shale, locality 5. C–D. Specimens OUZC 1399–1400, Putnam Hill Shale, localities 9 and 10 respectively. E–F. Specimens OUZC



1401–1402, Lower Mercer Shale, locality 8. G–I, K–L. Specimens OUZC 1403–1405, 1407–1408, Lazy Bend Formation (Dickerson Shale), locality 11. J. Holotype OUZC 1406, same locality. M–O. Specimens OUZC 1409–1411, Harpersville Formation, locality 20.

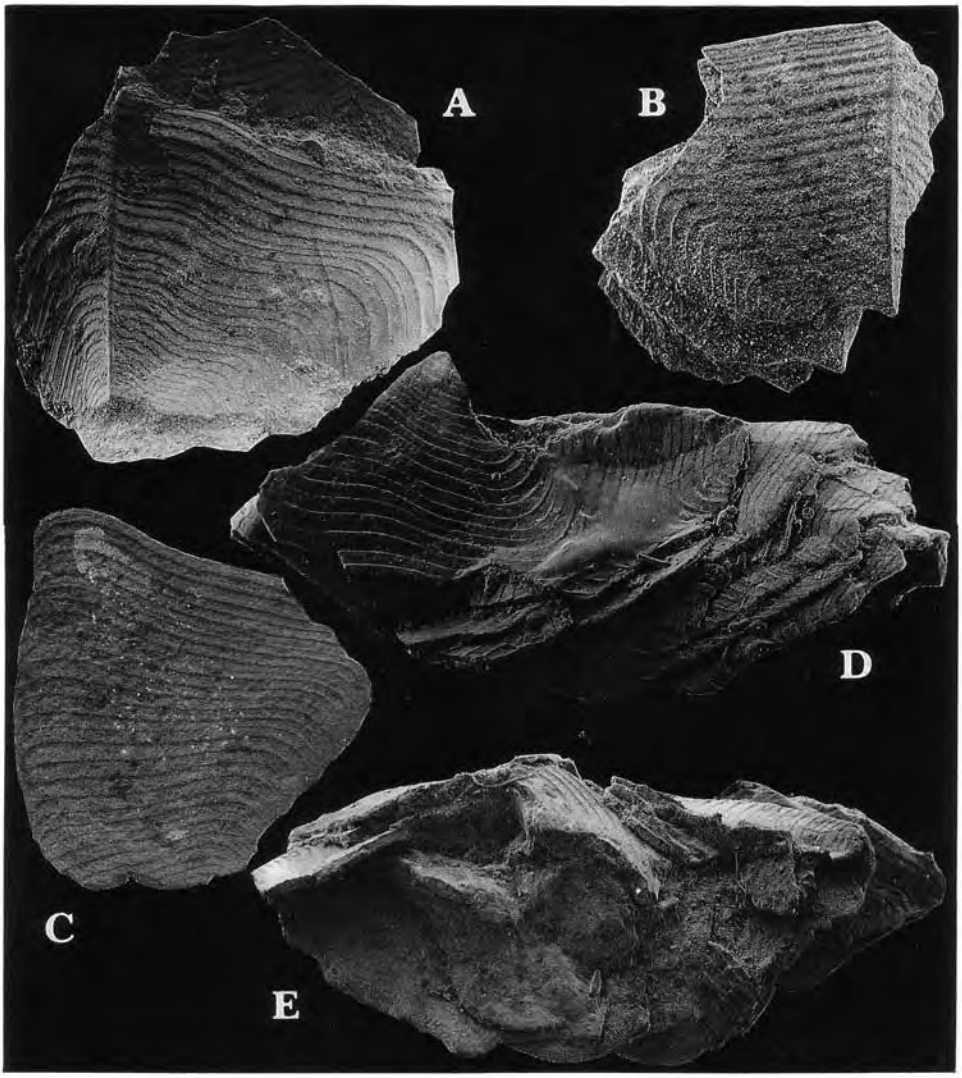


Fig. 10. *Ambonlepidos petalos* gen. et sp. n.; all inner sclerites except C which is an outer sclerite, ×25. A. Specimen OUZC 1412, Caddo Creek Formation (Colony Creek Shale), locality 18. B. Specimen OUZC 1413, Harpersville Formation, locality 20. C. Specimen OUZC 1414, Palo Pinto Formation (Wynn Member), locality 13. D–E. Dorsal and ventral views of cluster, specimen OUZC 1415, shales beneath the Bunger Limestone in the Graham Formation, locality 19; saddle-shaped element that may be a non-scleritome secretion of the turrilepadid animal is present in the left center (anterior) part of the cluster E.

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Collecting localities

1. Imo Formation (Chesterian) exposed in road cut on southeast side of US Hwy. 65 about 0.8 km southwest and uphill from Peyton Creek bridge, about 6.4 km southeast of Leslie, Searcy Co., Arkansas, NE 1/4 sec. 11, T13N, R15W, Leslie 7 1/2' quadrangle.

2. Gene Autry Formation (Morrowan) exposed in a series of east-west gullies, on the east side of an unnamed tributary of Sycamore Creek on the Daube Ranch, NW1/4, NW1/4, SW1/4 sec. 2, T4S, R4E, Johnson Co., Okahoma, Ravia 7 1/2' quadrangle.

3. Mogoffin Shale (Atokan) exposed in road cut at Mile Post 42.3 on north side of Daniel Boone Parkway, approx. 2.99 km west of Thousand Sticks at junction of Parkway and State Rte. 118, Perry County, Kentucky, 37°10'23"N, 83°27'19"W, Hyden West 7 1/2' quadrangle.

4. Kendrick Shale (Atokan) exposed in the bed of Cow Creek adjacent to Cow Creek Road, approx. 5.0 km east of the junction of Cow Creek Road and Rtes. 460 and 23, Floyd Co., Kentucky, 37°37'33"N, 82°38'11"W, Lancer 7 1/2' quadrangle.

5. Boggs Shale (Atokan) exposed in road cut on east side of Ohio Rte. 93, approx. 0.6 km north of Mt. Pleasant, Hocking Co., Ohio, NE1/4, SW1/4 sec. 34, T14N, R17W, New Plymouth 7 1/2' quadrangle.

6. Boggs Limestone (Atokan) exposed in road cut on east side of Ohio Rte. 146, on east side of Dillon Reservoir, approx. 13.5 km northwest of Zanesville, Muskingum Co., Ohio, E ctr. NW1/4 sec. 2, T1N, R8W, Dresden 7 1/2' quadrangle.

7. Lower Mercer Shale (Atokan) exposed in roadcut on north side of U.S. 36, 2.5 km east of junction with Ohio Rte. 93, approx. 3.2 km northeast of West Lafayette, Coshocton Co., Ohio, NE1/4 sec 1, T6N, R4W, Fresno 7 1/2' quadrangle.

8. Lower Mercer Shale (Atokan) exposed at abandoned tipple of Vinton Coal Co., north side of U.S. 50, Vinton Co., Ohio, SW1/4 NE1/4 sec. 18, T11N, R17W, Allensville 7 1/2' quadrangle.

9. Putnam Hill Shale (Desmoinesian) exposed in abandoned Vinton Coal Co. strip mine on northeast side of road 1.8 km north-northwest of road junction at elev. no, 799. Vinton Co., Ohio, ctr. sec. 20 and NW1/4 sec. 17, T11N, R17W, Allensville and Zaleski 7 1/2' quadrangles.

10. Putnam Hill Shale (Desmoinesian) exposed in an abandoned borrow pit and strip mine on east side of Interstate 77, Tuscarawas Co., Ohio, NW1/4 sec. 17, T7N, R2W, New Philadelphia 7 1/2' quadrangle.

11. Lazy Bend Formation, Dickerson Shale Member, (Desmoinesian) exposed 30 m north of crossing of FM 1189 over Rocky Branch, a small tributary of Kickapoo Creek, approx. 0.75 km south of Kickapoo Falls, Hood Co., Texas, 32°26'24"N, 98°0'56"W, Dennis 7 1/2' quadrangle.

12. Mineral Wells Formation (East Mountain Shale), at Desmoinesian–Missourian boundary (Missourian) in road cut on north side of U.S. 180, 0.2 km east of bridge over Brazos River and 7.2 km due west of Mineral Wells, Palo Pinto Co., Texas, 32°47'N, 98°11'W, Mineral Wells West 7 1/2' quadrangle.

13. Palo Pinto Formation, Wynn Member (Missourian) exposed in road cut on west side of Texas Rte. 337 on north side of Reilly Ridge, between Turkey Creek and Keechi Creek, 9.7 km northwest of Mineral Wells, Palo Pinto Co., Texas, 32°53'N, 98°11'W, Mineral Wells West 7 1/2' quadrangle.

14. Graford Formation (Wolf Mountain Shale), middle portion (Missourian) exposed on north slopes of Kyle Mountain located just southeast of the Brazos River, 6.4 km north of Palo Pinto, Palo Pinto Co., Texas, 32°50'N, 98°19'W, Palo Pinto 7 1/2' quadrangle.

15. Caddo Creek Formation (Colony Creek Shale), lower portion of Brad section (Virgilian) exposed in road cut on north side of U.S. 180, 3.2 km west of Brad and 25.7 km due east of Mineral Wells, Palo Pinto Co., Texas, 32°45'N, 98°32'W, Caddo NE 7 1/2' quadrangle.

16. Caddo Creek Formation (Colony Creek Shale), upper portion of Brad North section (Virgilian) exposed in road cut on north side of U.S. 180, 3.2 km west of Brad and 25.7 km due west of Mineral Wells, Palo Pinto Co., Texas, 32°45'N, 98°32'W, Caddo NE 7 1/2' quadrangle.

17. Caddo Creek Formation (Colony Creek Shale), basal part of Park section (Virgilian) exposed in old quarry site at foot of high ridge in north part of Lake Brownwood State Park, 3.2 km northwest of Lake Brownwood dam and 16.1 km northwest of Brownwood, Brown Co., Texas, 31°52'N, 99°02'W, Lake Brownwood 7 1/2' quadrangle.

18. Caddo Creek Formation (Colony Creek Shale), middle portion of Lakeside section (Virgilian) exposed in road cut on south side of small dirt road dropping down from bluff on north side of Lake Brownwood, 3.2 km southwest of Lake Bownwood State Park and 16.1 km northwest of Bownwood, Brown Co., Texas, 31°50'N, 99°03'W, Lake Brownwood 7 1/2' quadrangle.

19. Graham Formation (Necessity Shale and shales below the Bunger Limestone (Virgilian) exposed in road cut on south side of Park Road 15, 1.1 km east of intersection of Park Road

15 and Rte. 2559, 3.2 km west of Brownwood State Park and 19.3 km northwest of Brownwood, Brown Co., Texas, 31°52'N, 99°03'W, Lake Brownwood 7 1/2' quadrangle.

20. Harpersville Formation (Virgilian) limestone D between the Belknap Limestone and Waldrip No. 3 limestone exposed on northeast slope of hill, 0.5 km southwest of elevation no. 1359 and 25 m south of ranch road, approx. 2.5 km south-southwest of top of Gray Mountain near western margin of quadrangle map, Stephens Co., Texas (Winslow, 1983, section 7, unit 9), 32°33'10"N, 98°59'30"W, Harpersville 7 1/2' quadrangle.

21. Mattoon Formation (Virgilian) exposed along Mint Creek, NE1/4, SW1/4 sec. 32, T8N, R9E, Jasper Co., Illinois, Teutopolis 71/2' quadrangle.

22. Cathedral Mountain Formation (Leonardian) exposed in large flat on southeast side of dirt road between Appel Ranch and Split Tank, 0.6 km east-northeast of Appel Ranch headquarters, central part of Glass Mountains, 16.1 km north of Marathon, Brewster Co., Texas, 30°24'N, 103°23'W, Hess Canyon 71/2' quadrangle.

Streszczenie

Machaeridia (pospolite we wczesnym paleozoiku organizmy o nieustalonych pokrewieństwach) z rzędu Turrilepadida są częstsze w młodszym paleozoiku, niż się dotąd spodziewano. W Ameryce Płn. występują od namuru (Chesterian) do wczesnego permu. Skleryty wewnętrznego rzędu pancerza są z jakichś powodów częstsze w materiale kopalnym. Każdy skleryt składa się z dwu warstw. Wewnętrzna, grubsza warstwa przebita jest licznymi rurkowatymi strukturami prostopadłymi do powierzchni sklerytu, które mogły pierwotnie stanowić kanały.