A well-preserved conodont fauna from the Pennsylvanian Excello Shale of Iowa, U. S. A.

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ABSTRACT: A superbly preserved discrete element conodont fauna has been recovered from carbonate concretions from the upper Desmoinesian (Pennsylvanian) Excello Shale at two localities in south-central Iowa. The multielement apparatuses for *Gondolella wardlawi* (new species), *Idiognathodus acutus, Idioprioniodus conjunctus,* and *Neognathodus roundyi* are reconstructed. Rare specimens of *Idiognathodus tuberis* (new species) also occur in the fauna.

INTRODUCTION

The fortuitous discovery by Pope of concretions imbedded in the Excello Shale Member of the Mouse Creek Formation, Marmaton Group (Desmoinesian Stage (Moscovian), Pennsylvanian Series) at two localities in south-central Iowa near the towns of Booneville in Dallas County and Medora in Warren County (text-fig. 1), has resulted in the recovery of a few spectacularly preserved conodont specimens from some concretions that were initially processed for their radiolarian content (Pope et al. 2011; Nestell et al. 2012). After the discovery of these few good conodont specimens in one concretion, the careful processing in a 5% solution of formic acid of several pieces resulted in the recovery of a number of intact specimens. The number of well-preserved elements recovered totaled less than 200 and no quantative measurements were made of individual element counts or weight of material processed. The best preserved specimens actually came from the outer few centimeters of one of the large concretions that had been cleared of hydrocarbons by weathering for several months in the courtyard of the Geology Building at Northwest Missouri State University. Conodonts recovered from the concretions are very significant to conodont taxonomy because most of the elements are complete with unbroken denticles, thus providing a rare opportunity for the authors to propose complete reconstructions of the apparatus of several Middle Pennsylvanian conodont genera.

The concretions contain radiolarians, conodonts, agglutinated foraminifers, fish remains, bivalves, microgastropods, and sponge spicules (Pope 2002; Pope et al. 2010; Pope et al. 2011; Nestell et al. 2012). At the Booneville and Medora localities, strata of the Mouse Creek Formation (Excello Shale and Blackjack Creek Limestone Members, in ascending order) overlie the Mulky Coal bed of the upper part of the Swede Hollow Formation, and underlie the Morgan School Shale (text-fig. 2). The Booneville section used herein is the same section that Pope (2012) designated as a neostratotype for the Mouse Creek Formation.

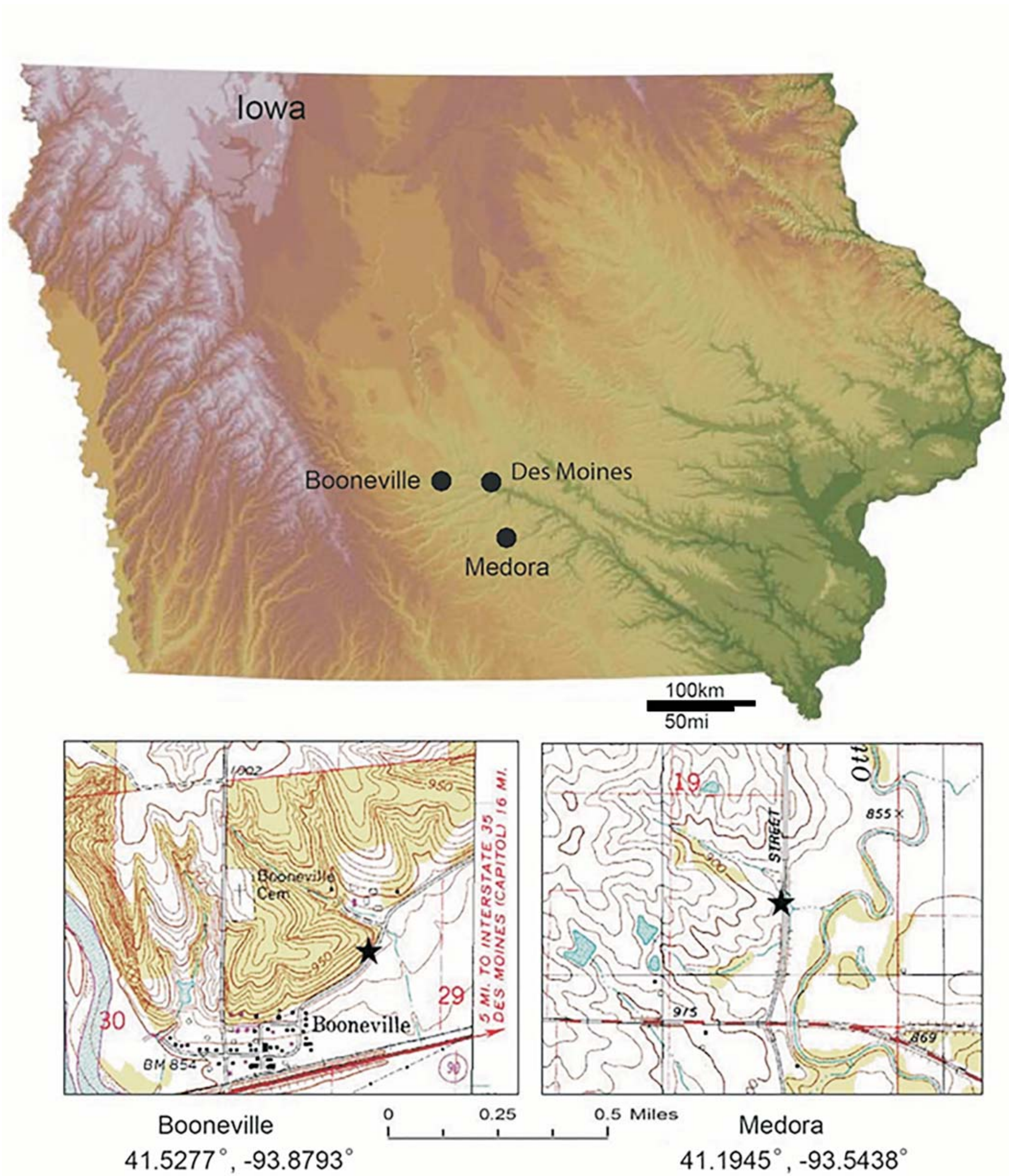
Swade (1985) reported an abundance of conodonts in six successive samples taken from the full thickness of an Excello Shale core. His extrapolated abundances for all samples commonly exceeded 1000 elements/kilogram. He reported *Idiognathodus*, *Neognathodus*, and *Idioprioniodus* to be present in the entire unit with *Gondolella* occurring only in the middle of the unit in the black phosphatic facies. *Diplognathodus* was reported to be rare in the Excello Shale.

Barrick et al. (2013a) recognized dual conodont zones for the Middle Pennsylvanian; one based on the ranges of *Neognathodus* species, and one based on the ranges of *Idiognathodus* and *Swadelina* species. Barrick et al. (2013a) placed the Excello Shale within the *Neognathodus roundyi* Zone and the *Idiognathodus delicatus* Zone.

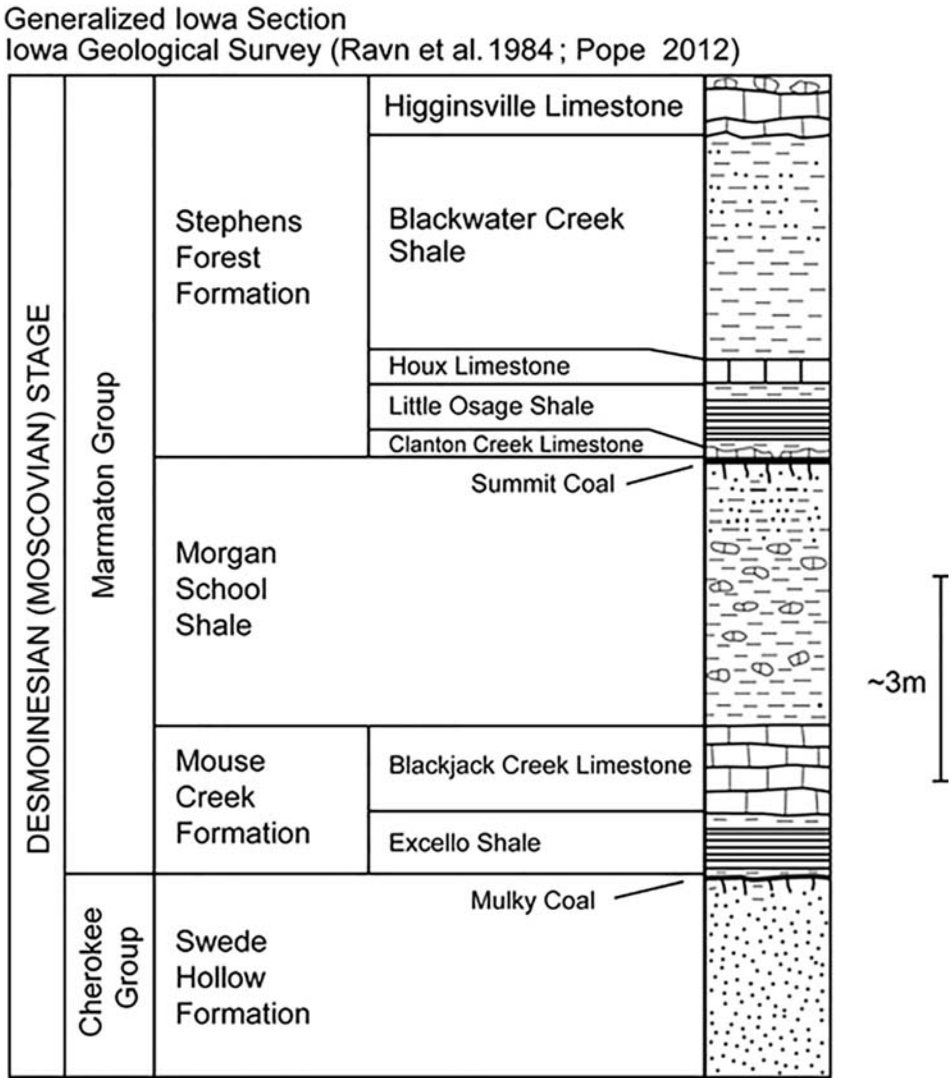
The upper Desmoinesian Mouse Creek Formation of Iowa is part of a major cyclothem characterized by a conodont-rich, widespread, gray to black shale that extends across the entire northern Midcontinent shelf southward into the Arkoma Basin of Oklahoma. The base of the cyclothem begins at the top of the exposure surface below the Mulky Coal and continues upward to the top of the paleosol below the Summit Coal, with the Excello Shale representing the highstand deposits. The cyclothem consists of transgressive, highstand, regressive, and lowstand system tracts. Initial transgression began with the coal followed by marine shale/mudstone deposition. In Iowa, non-sandy, phosphatic, conodont- and radiolarian-rich shale represents highstand, whereas marine shale/mudstone with fossiliferous limestone concretions and limestone with a shallow marine biota represent the regressive system tract. Shallow marine to marginal marine shale/mudstone with paleosols represent the lowstand system tract.

BOONEVILLE SECTION

The Booneville section is located in southern Dallas County, 8 km west of Interstate Highway 35 near the town of Booneville, about 16 km west of Des Moines (text-fig. 1). About 1.2 m of the upper part of the Swede Hollow Formation is exposed at the base of the section (text-figs. 3, 4). It consists of light gray sandy shale that grades upward into slightly silty, rooted, medium light gray blocky mudstone, with abundant carbonaceous



TEXT-FIGURE 1
Location of Booneville and Medora sections of the Excello Shale. See Nestell et al. 2012 for more precise locality data.



TEXT-FIGURE 2
Generalized section showing stratigraphic position of the Excello and Little Osage Shales in the Pennsylvanian section of Iowa. Nomenclature of the Iowa Geological Survey (modified from Ravn et al. 1984; Pope 2012).

debris in the upper 15 cm below the Mulky Coal. The Mulky Coal bed consists of slightly argillaceous coal about 15 cm thick.

The overlying Excello Shale Member is 1.2 m thick, consisting of a 10 cm medium-gray shale which grades upward to 30 cm of black shale with abundant phosphatic laminae and small nodules. Large grayish-black carbonate mudstone concretions, up to 60 cm in diameter and 20 cm thick, also occur in the black shale. The black shale, in turn, grades upward into 36 cm of dark greenish-gray shale with abundant phosphatic laminae. The black phosphatic shale and dark greenish-gray phosphatic shale, as well as the carbonate concretions, contain moderately-to well-preserved conodonts and radiolarians. The dark greenish-gray shale grades upward into 51 cm of medium greenish-gray shale with abundant skeletal wackestone nodules in the upper 30 cm and contains a diverse open marine fauna.

Exposures of the Blackjack Creek Limestone Member are about 76 cm of light gray skeletal wackestone that contains a diverse open marine invertebrate fauna. The upper one-half of the member is argillaceous with greenish-gray shale filled vertical to sub-vertical tubes that increase upward.

The Morgan School Shale is 0.91 m thick and is poorly exposed at the measured section. The lower 30 cm has numerous light gray wackestone nodules in a medium light gray mudstone matrix. The middle 53 cm is a blocky greenish-gray mudstone. The upper 7.6 cm is greenish-gray shale with scattered invertebrate fossils. The Summit Coal bed is not present in this section.

MEDORA SECTION

The Medora section is located 4.8 km east and 0.8 km north of the town of Medora, in a pasture near Otter Creek in south-central Warren County, about 45 km south of Des Moines (text-fig. 1). About 12.2 m of very poorly exposed Swede Hollow Formation occurs below the Excello Shale, and only 1.2 m were well-exposed by trenching. The Mulky Coal bed occurs as a 3 cm bed at the top of the formation (text-fig. 3, 5).

Only 1.5 m of the overlying Excello Shale Member is well exposed in the section. The lower 6 cm is medium-gray shale, which grades upward to 36 cm of dark gray shale with abundant phosphatic laminae. Large grayish-black carbonate mudstone concretions up to 1.8 m in diameter and 18 cm thick also occur in the shale. Both the dark-gray phosphatic shale and the carbonate concretions contain moderately-to well-preserved conodonts and radiolarians. The dark-gray shale grades upwards into 55 cm of medium greenish-gray shale with abundant skeletal wackestone nodules that contain an abundant open marine invertebrate fauna. The contact with the overlying Blackjack Creek Limestone Member is not well exposed in the section. The Morgan School Shale is not exposed in the measured section.

SYSTEMATICS

Phylum CHORDATA Bateson 1886
Subphylum VERTEBRATA Cuvier 1812
Class CONODONTA Pander 1856
Subclass EUCONODONTA Janvier 1996
Order PRIONIODINIDA Sweet 1988
Family PRIONIODINIDAE Bassler 1925
Genus ***Idioprioniodus*** Gunnell 1933

Idioprioniodus conjunctus (Gunnell)
Plate 1, figures 1-8

Prioniodus conjunctus GUNNELL 1931, p. 247, pl. 29, fig. 7 (P2 element).
Prioniodus bidentatus GUNNELL 1931, p. 247-248, pl. 29, fig. 6 (P1 element).
Prioniodus missouriensis GUNNELL 1931, p. 247, pl. 29, fig. 9 (S3 element).
Prioniodus clarki GUNNELL 1931, p. 247, pl. 29, fig. 8 (S3 element).
Prioniodus subacodus GUNNELL 1931, p. 246, pl. 29, fig. 5 (S0 element).
Prioniodus lexingtonensis GUNNELL 1931, p. 246, pl. 29, fig. 4 (M element).
Prioniodus tridentatus GUNNELL 1931, p. 246, pl. 29, fig. 3 (S1 element).
Idioprioniodus conjunctus (Gunnell) - LANDING and WARDLAW 1981, p. 1263-1265, pl. 1, figs. 13-17, 22, 24, 25. – HIGGINS and WAGNER-GENTIS 1982, p. 332-333, pl. 34, figs. 18, 21, 23, 27, 29. – SAVAGE and BARKELEY 1985, p. 1459, fig. 5, no. 1-14. – GRAYSON et al. 1987, pl. 1, figs. 1-7. – BROWN et al. 1991, fig. 7, no. 23-25, 26?, 27-29. – REXROAD 1993, figs. 4:1?, 2-12, 13?, 14? – KRUMHARDT et al. 1996, p. 45, pl. 5, figs. 11, 14, 17. – POPE et al. 2011, pl. 1, figs. 2-4.

Description: P1 element (pl. 1, fig. 2): dolabrate; large cusp of medium height; short anticusp; posterior process laterally-turned and bears recurved, sharply pointed denticles that generally decrease in size distally; a relatively large flared basal cavity beneath cusp and first posterior denticle forms a narrowing groove distally.

P2 element (pl. 1, fig. 8): digyrate; cusp long and medium length posterior and anterior processes; anterior process with long sharply pointed denticles that increase in size (width and height) to about mid-length, then decrease in size distally; distal-most denticle small; posterior process with a first denticle on posterior-lateral side of cusp, short and blunt, remaining denticles sharply pointed, next four denticles high, of subequal height, but increasing in width distally, then denticles decrease in size distally, distal-most denticle small, basal cavity slightly flared under cusp, forming a narrowing groove under both processes.

M element (pl. 1, fig. 3): extensiform digyrate; cusp medium sized, slightly recurved; lateral process sharply declining, twists to the posterior and bears sharply pointed denticles. The second denticle from the cusp is the largest, of medium height; other denticles decrease regularly in size distally; a lateral process that is not twisted declines less steeply and bears sharply pointed denticles; the second from the cusp is the largest; denticles decrease regularly in size distally; basal cavity forms a small cup.

S0 element (pl. 1, fig. 6): alate; cusp very large, slightly recurved, bearing a posterior costa; furrow at the base and costa at mid-length to tip; two lateral processes bear narrow, sharply pointed denticles of moderate length. First denticle from cusp very narrow, second denticle the highest, then decreases in height but increases in width laterally except the distalmost which is very small; posterior process very short, bearing a few denticles, second denticle from the cusp is the highest.

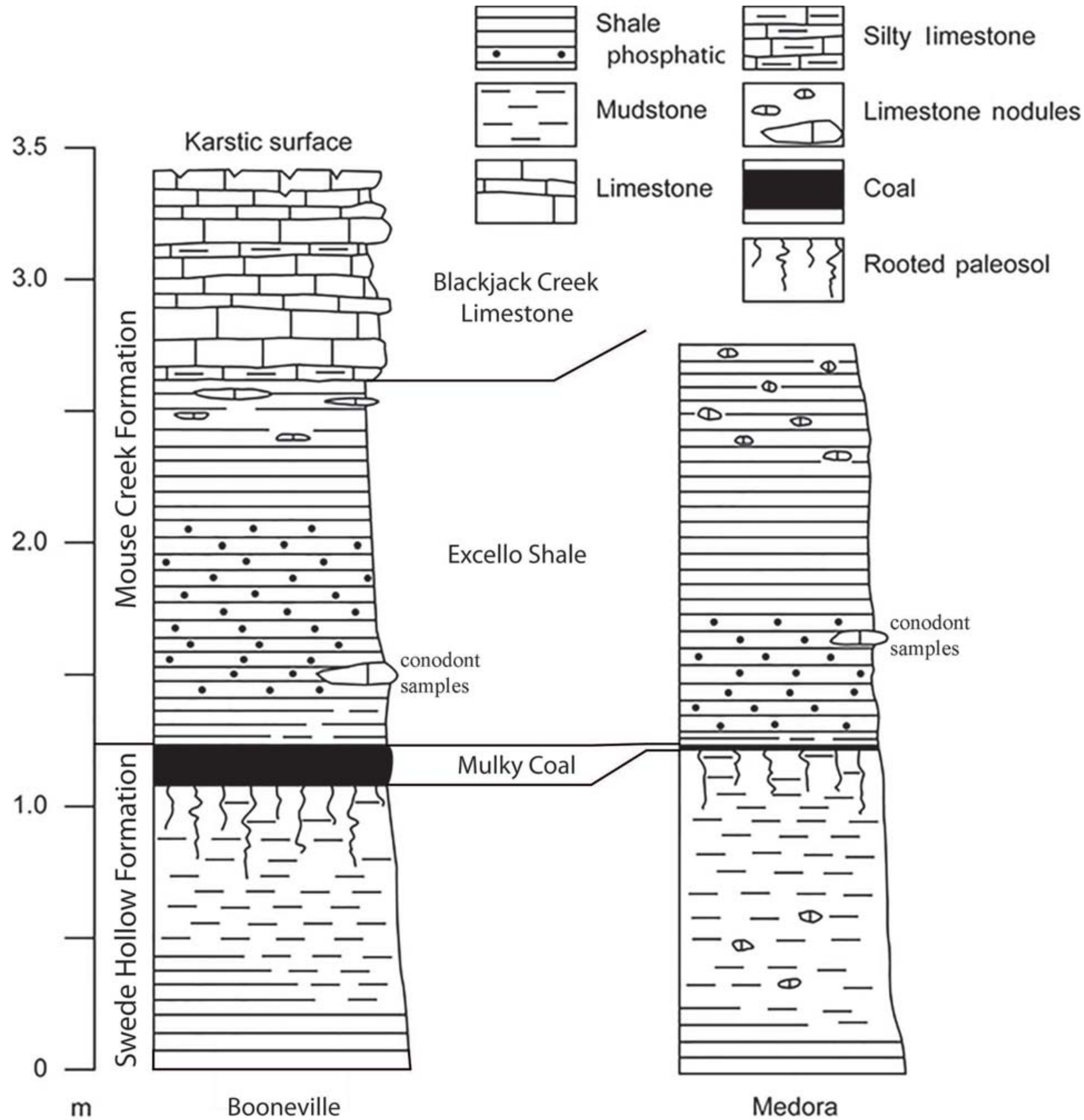
S1 element (pl. 1, fig. 5): dolabrate; basal cavity is under the second denticle (cusp), not the largest denticle (anticusp). Posterior three denticles erect, remaining anterior denticles reclined, posterior-most denticle is a large and wide "anticusp", the second denticle (cusp) is nearly as high as the first, but less wide, the third denticle is about half the size of the second, then there is a marked drop-off in denticle size; remaining denticles thin, evenly-spaced and decrease in size anteriorly.

S2 element (pl. 1, fig. 4): breviform digyrate; slightly reclined cusp with sharply pointed thin denticles; anterior process medium sized and sharply directed downward with evenly-spaced denticles that decrease in height anteriorly; posterior-lateral process with small evenly-spaced denticles that decrease in height posteriorly; process is slightly twisted and denticles are slightly recurved becoming procline posteriorly.

S3 element (pl. 1, fig. 7): breviform digyrate; cusp large; two short processes, anterior process with three medium sized denticles of subequal height; posterior-lateral process usually bearing 5-6 thin denticles, first two of subequal size, then decreasing in size distally.

S4 element (pl. 1, fig. 1): bipennate; cusp large erect; anterior process short, directed inwardly and bears a few medium sized sharply pointed denticles that decrease in size distally; posterior process medium sized with denticles of near equal height that increase in width posteriorly except posterior-most three which become less wide and the distal most is small.

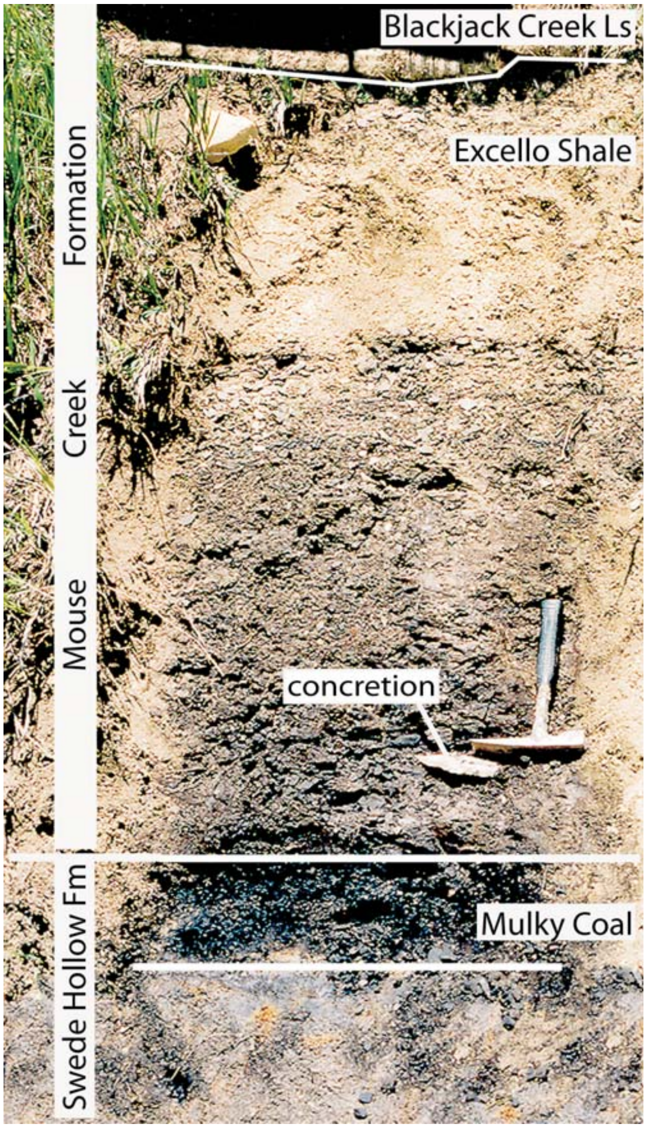
Remarks: Elements of *Idioprioniodus* are commonly twice the size of the elements of other genera in our material. In the available literature, most illustrated specimens of *Idioprioniodus* are broken and therefore are difficult to place taxonomically. Landing and Wardlaw (1981) and Von Bitter (1972) illustrated enough of the apparatus from Atokan and Virgilian strata, respectively, so that at least based on the P1 element, these specimens can be differentiated from our *Idioprioniodus conjunctus*. The type material of *Idioprioniodus conjunctus* (Gunnell 1931) is from the Little Osage Shale Member, the succeeding black shale above the Excello Shale Member (text-fig. 2). We agree with Merrill and Merrill (1974) that Von Bitter (1972) illus-



TEXT-FIGURE 3
Columnar measured sections of sample localities.

trated part of the apparatus of a different species of *Idioprioniodus* other than *Idioprioniodus conjunctus*, which they attributed to *Idioprioniodus typus*. Possibly with better preserved material many of the specimens attributed to *I. conjunctus* will be found to be different species. All the elements illustrated herein are unbroken, except the posterior process of the S0 element. This good preservation gives some new perspective to the position placement in the apparatus. The *Idioprioniodus* apparatus reconstruction presented herein represents the final ideas of Wardlaw, and the other authors were reluctant to make significant changes to it in the final drafts of the manuscript. Other workers may not agree with this reconstruction and they are encouraged to present their alternate reconstructions. Merrill et al. (1990) pointed out the difficulty of placing the elements of the *Idioprioniodus* apparatus in positional notation. In the author's opinions, the closest analogue for the *Idioprioniodus* apparatus is the "nude" platform *Gondolella* apparatus presented by Von Bitter and Merrill (1998). Stone and Geraghty (1994) modeled the apparatus architecture of *Idioprioniodus* based on broken and incomplete bedding plane assemblages.

Merrill and Merrill (1974) and Sweet (1988) interpreted the element positional notation for the *Idioprioniodus* apparatus based on discrete elements of incomplete specimens, very differently from our construction. They described the P1 element as



TEXT-FIGURE 4
Photograph of the road cut at the Booneville section. Rock hammer is 25 cm long.

digyrate (our S1, dolabrate) and the P2 element as digyrate. Herein, the S2 and S3 elements are digyrate with the S0 element alate, and the S4 element bipennate.

Family GNATHODONTIDAE Sweet 1988
Genus ***Idiognathodus*** Gunnell 1931

Idiognathodus acutus Ellison
Plate 2, figures 1-9; Plate 5, figures 1-2, 4-5, 7-11

Idiognathodus acutus ELLISON 1941, p. 137, pl. 23, figs. 21, 24. – NESTELL et al. 2012, pl. 7, figs. 5, 6, 8.
Idiognathodus/Neognathodus - POPE et al. 2011, pl. 1, figs. 5-6.

Description: P1 element (pl. 2, fig. 1): carminiscaphate; asymmetrical pair of platform elements; sinistral element slightly more robust, more denticulate and more variable than dextral element. Posterior transverse ridges are more continuous across the upper surface of the platform, and only break-up into nodes and short ridges near the posterior end of the carina in dextral elements. The transverse ridges are much less continuous and broken into nodes and short ridges for a longer distance of the platform in sinistral elements. Dextral elements have a much simpler ornamentation of nodes with an adcarinal ridge on the inner side, isolating a loose row of nodes with a few additional nodes on the side of the platform in larger specimens. The outer adcarinal ridge isolates a single loosely aligned row of nodes that lose definition near posterior end of the carina. In sinistral elements, both adcarinal ridges become indistinct posteriorly near the posterior end of the carina. The inner side has at least one loose row of nodes that is sub-parallel with the inner adcarinal ridge and can have as many as three very loosely aligned rows that become less parallel to the adcarinal ridge and straighter. The sinistral and dextral P1 elements both have a blade that is nearly as long as the platform, and whose inner and outer adcarinal ridges have a sharp decline and form a rib on the lower lateral side of the blade for most of its length. The inner adcarinal ridge of both elements is more flared than the outer. The blade bears 10-13 denticles that are closely-spaced and fused posteriorly and increase in size anteriorly, except the anterior-most 1-3 which decrease in size; posteriorly the blade becomes a fused carina with indistinct nodes on the platform and posteriorly ends with 1-4 discrete small, rounded nodes.

P2 element (pl. 2, fig. 2): angulate; medium sized cusp lightly bowed and anterior process of medium size with closely-spaced denticles that increase in size anteriorly (height and width) and become less fused except for distal-most which is smaller than the adjacent largest denticles; shorter posterior process bears three fused denticles of subequal size on the backside of the cusp, followed by denticles of alternating size. Very thin and short denticles alternate with larger, higher and wider "moderate" denticles of subequal size, slightly curved except last "moderate" denticle which is smaller and typically with a couple of minute denticles on the distal side of the last "moderate" denticle. The short, thin denticles number 1-2 between the "moderate" denticles, but occasionally are absent.

M element (pl. 2, fig. 5): dolabrate; cusp wide, short; basal cavity cup shaped; a short downward lateral process bears very short, stubby, closely spaced denticles on the edge of the cusp becoming more widely spaced laterally. The longer downward lateral process curves inward and bears denticles of alternating size. Larger thick denticles alternate with short and thin denticles. There are generally 1-3 thin denticles between each larger denticles. All the denticles on the long process are slightly recurved.

S0 element (pl. 2, figs. 3, 4): alate; cusp medium sized, erect, lateral process sharply downturned bearing sharply pointed medium sized denticles alternating with thin miniscule denticles. Medium sized denticles increase in height then decrease in height laterally and become medially wider laterally. A medium sized posterior process bears denticles of alternating size. Denticles of short to medium sized height alternate with thin shorter denticles; 1-5 thin denticles between short to medium sized denticles. Short to medium sized denticles increase in height posteriorly except distal-most and become medially wider and reclined posteriorly. All processes with a narrow groove on the underside.

S1 element (pl. 2, fig. 8): bipennate; "anterior" process short, upturned, laterally directed, backwards bending, and a long posterior process; The "anterior" process is gently upturned, orthogonal to the posterior process gently twisted backward and bears sharply pointed denticles of medium size. The posterior process bears denticles in a pattern of medium sized, sharply pointed denticles separated by 3-5 short, thin, sharply pointed denticles; denticles become more reclined posteriorly and the last 1-2 medium sized denticles separated by short, thin denticle sets decreasing in size. This element lacks a prominent denticle at or near the intersection of the processes that could be construed as a main cusp.

S2 element (pl. 2, fig. 7): bipennate; anterior process short, bent slightly downward and laterally, and bearing denticles of subequal size; long posterior process with a similar denticulation pattern as the S1. This element also lacks a prominent denticle at or near the intersection of the processes that could be construed as a main cusp.

S3 element (pl. 2, fig. 9): bipennate; antero-lateral process downward turned that bears a few thin short denticles next to the cusp before bearing larger denticles of subequal size laterally; long posterior process with a similar denticulation pattern to the S1, but with more thin denticles between medium sized denticles, generally 4-6.

S4 element (pl. 2, fig. 6): bipennate; cusp well developed, anterior process downward turned, only slightly inward turned bearing alternating thin and thick denticles that are at least partially fused; long posterior process with alternating thin and thick denticles, partially fused and of variable heights making a far less distinct pattern than the other S elements; more thin than thick denticles.

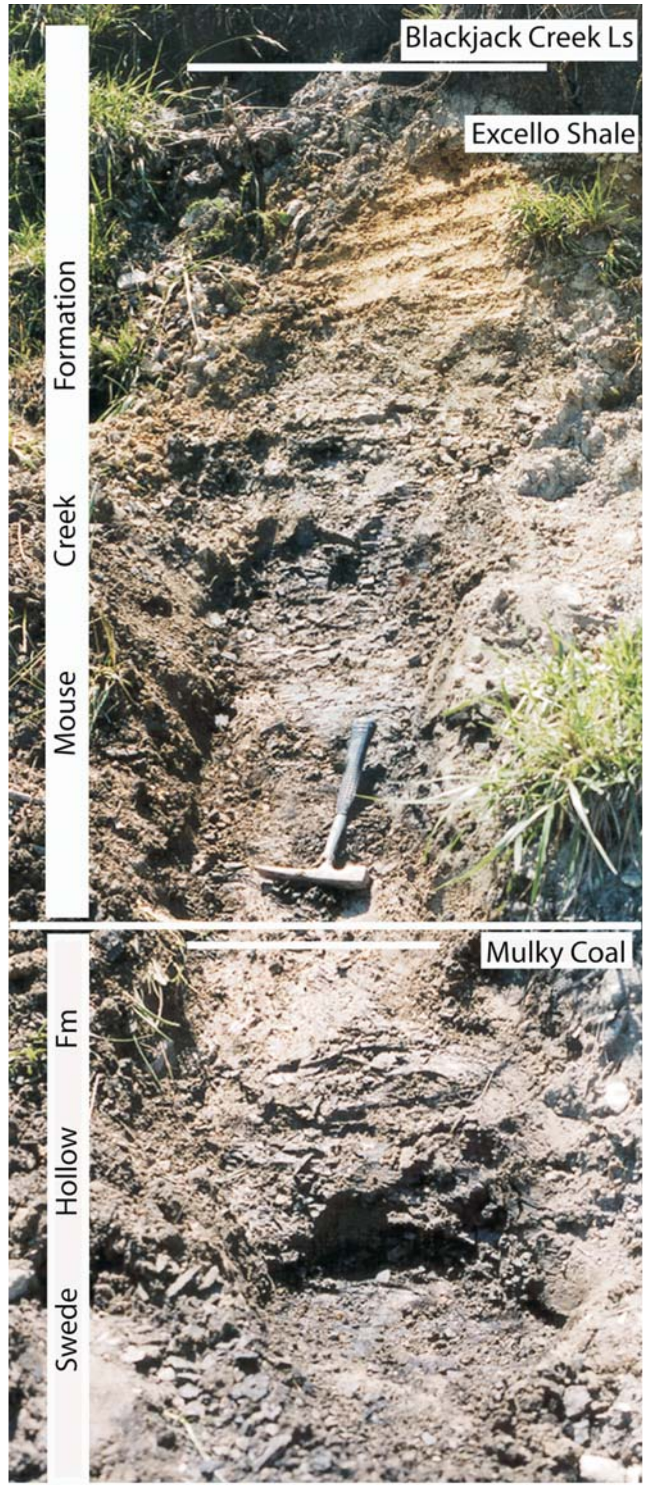
Remarks: Ellison (1941) misnumbered his specimens on plate 23; the holotype of *Idiognathodus acutus* should have read fig. 21 *not* fig. 22 and his other illustrated specimen should have read fig. 24 *not* fig. 25. Both specimens are from Sample 0117 E collected near Harrisburg, Boone County, Missouri below the lower part of Fort Scott Limestone and above the Mulky Coal, which is in the Excello Shale.

Idiognathodus and *Neognathodus* have very similar apparatuses. In our material *Idiognathodus* platforms far outnumber those of *Neognathodus*, as do the more denticulate ramiforms with shorter denticles which we place in the *Idiognathodus* apparatus. Purnell and Donoghue (1997) modeled the apparatus architecture of *Idiognathodus* based on bedding plane assemblages mostly from the Missourian Modesto Formation of Illinois. Illustrations of apparatus associations for discrete elements of *Idiognathodus* have been also proposed and illustrated by Grayson et al. (1990).

Idiognathodus tuberis Wardlaw, Nestell and Pope, **n. sp.**
Plate 5, figures 3, 6, 12

Idiognathodus acutus Ellison - POPE et al. 2011, pl. 1, fig. 1. – NESTELL et al. 2012, pl. 7, fig. 7.

Description: P1 element (pl. 5, figs. 3, 6, 12): carminiscaphate; subsymmetrical pairs of sinistral and dextral elements; diagnostic bulge developed halfway down the outer side of the element that generally bears one small node in both dextral and sinistral forms. Dextral elements with simpler ornamentation than sinistral elements with posterior ridges more consistently extended across the upper surface of the platform that only break-up into nodes and short ridges near the posterior end of the carina. Sinistral elements posteriorly similar in small to medium sized specimens, but posterior transverse ridges are almost completely broken-up in larger specimens. Adcarinal ridge be-



TEXT-FIGURE 5
Photograph of the road cut at the Medora section. Rock hammer is 25 cm long.

comes indistinct posteriorly near end of the carina; outer adcarinal ridge straight on dextral elements, slightly inwardly curved on sinistral elements, isolating a few small nodes on large specimens. Inner adcarinal ridge nearly straight on dextral elements, isolating a few nodes of variable size on the outside of the platform with nodes on the ridge of variable size. Inner adcarinal ridge on sinistral elements curves inward posteriorly and bears nodes that increase in size anteriorly to the declination of the ridge; may have one or two larger nodes at the posterior end of the ridge that decrease in size on the anterior declining part of the ridge and forms a barely perceptible rib along most of the blade. Isolated nodes on inner side outboard of the adcarinal ridge are of variable size and in no discernable pattern. Blade as long as the platform and bears 10-12 denticles that increase in size anteriorly, except anterior-most 1 or 2, and with at least one denticle of smaller size disrupting the increasing size pattern; becomes a fused carina on the platform that ends with 1-3 discrete small nodes posteriorly.

Designation of types: The specimen illustrated on plate 5, figure 12 (no. SUI 126542/1) is designated as the holotype.

Etymology: Named as tuberis because of the presence of rounded or wart like prominences or tubers.

Remarks: The rare forms that characterize *Idiognathodus tuberis* n. sp. have both dextral and sinistral P1 elements showing a lateral bulge or protuberance on the outer side of the element that bears one node. The closest form to the new species is *Idiognathodus acutus* Ellison, but in *Idiognathodus tuberis* n. sp. the inner node field bears fewer nodes of more variable size with no discernable pattern. Apparatus elements assigned to *I. acutus* could possibly belong to this new species. The only specimens recovered came from the Medora section.

Genus ***Neognathodus*** Dunn 1970

Neognathodus roundyi (Gunnell)
Plate 3, figures 1-9; Plate 6, figures 1-4, 6-11; Plate 8, figures 1-6

Gnathodus roundyi GUNNELL 1931, p. 249, pl. 29, figs. 19-20. – MERRILL 1971, p. 409, pl. 1, fig. 34.
Neognathodus roundyi (Gunnell) - MERRILL and KING 1971, p. 660, pl. 75, figs. 2-4. – MERRILL 1972, p. 826, pl. 2, figs. 11-16. – REXROAD et al. 2001, fig. 4.18-23. – STAMM and WARDLAW 2003, p. 119, pl. 5, figs. 8-10, 19. – NASCIMENTO et al. 2005, figs. 2D, H. – NESTELL et al. 2012, pl. 7, fig. 12. – BARRICK et al. 2013a, pl. 1, figs. 4-5. – BARRICK et al. 2013b, fig 8: 26.
Neognathodus dilatus Merrill - NESTELL et al. 2012, pl. 7, fig. 11.

Description: P1 element (pl. 3, fig. 2; pl. 6, figs. 1-4, 6-11, pl. 8, figs. 1-6): carminiscaphate, asymmetrically paired platform dextral and sinistral elements; sinistral elements have a denticulate inner parapet at all growth stages; inner parapet is ridged anteriorly and nodose posteriorly; denticles are wedge-shaped transverse ridges that become nodes posteriorly. Outer platform is smooth in the earliest growth stages and later develops a parapet with a small bump at its widest point, eventually becoming a rounded elongate denticle with growth. Dextral elements have a denticulate inner parapet at all growth stages; the denticles are shorter wedge-like transverse ridges than the sinistral elements and become rounded denticles both posteriorly and anteriorly. Outer dextral platform is smooth in the earliest growth stage. With growth a denticle forms at the posterior end of the outer parapet, first as a rounded denticle that become an elongate ridge. Carina in both sinistral and dextral elements merges posteriorly with the outer parapet first; there is a faint medial costae on each side of the denticles on the platform. Posterior-most carinal denticles are low and widely-spaced becoming higher and more closely spaced at the anterior end of the platform; a few denticles are partially to mostly fused on the anterior part of the platform; denticles on the blade increase in size and height except the anterior-most 2-3 which decrease in size and height; basal cavity is more outwardly flared on the outer side in both forms.

P2 element (pl. 3, fig. 1): angulate, with a medium sized and slightly reclined cusp; anterior process long, slightly downward curving and bearing short, reclined, pointed denticles that are partially fused next to the cusp and that increase slightly in height and width distally, except the distal-most 2 which decrease in size. Shorter posterior process curved downward, more so than the anterior process and bears medium sized sub-equal denticles about half the height of the cusp that increase in width slightly to the posterior, except distal-most 2-3 that decrease in size. A slightly flared basal cavity beneath the cusp becomes a groove under each process.

PLATE 1
Elements of the *Idioprioniodus conjunctus* apparatus ×50

1 S4 element, inner view, scan 164525, Medora section

2 P1 element, lateral view, MedB11-27, Medora section

3 M element, lateral view, MedB11-35, Medora section

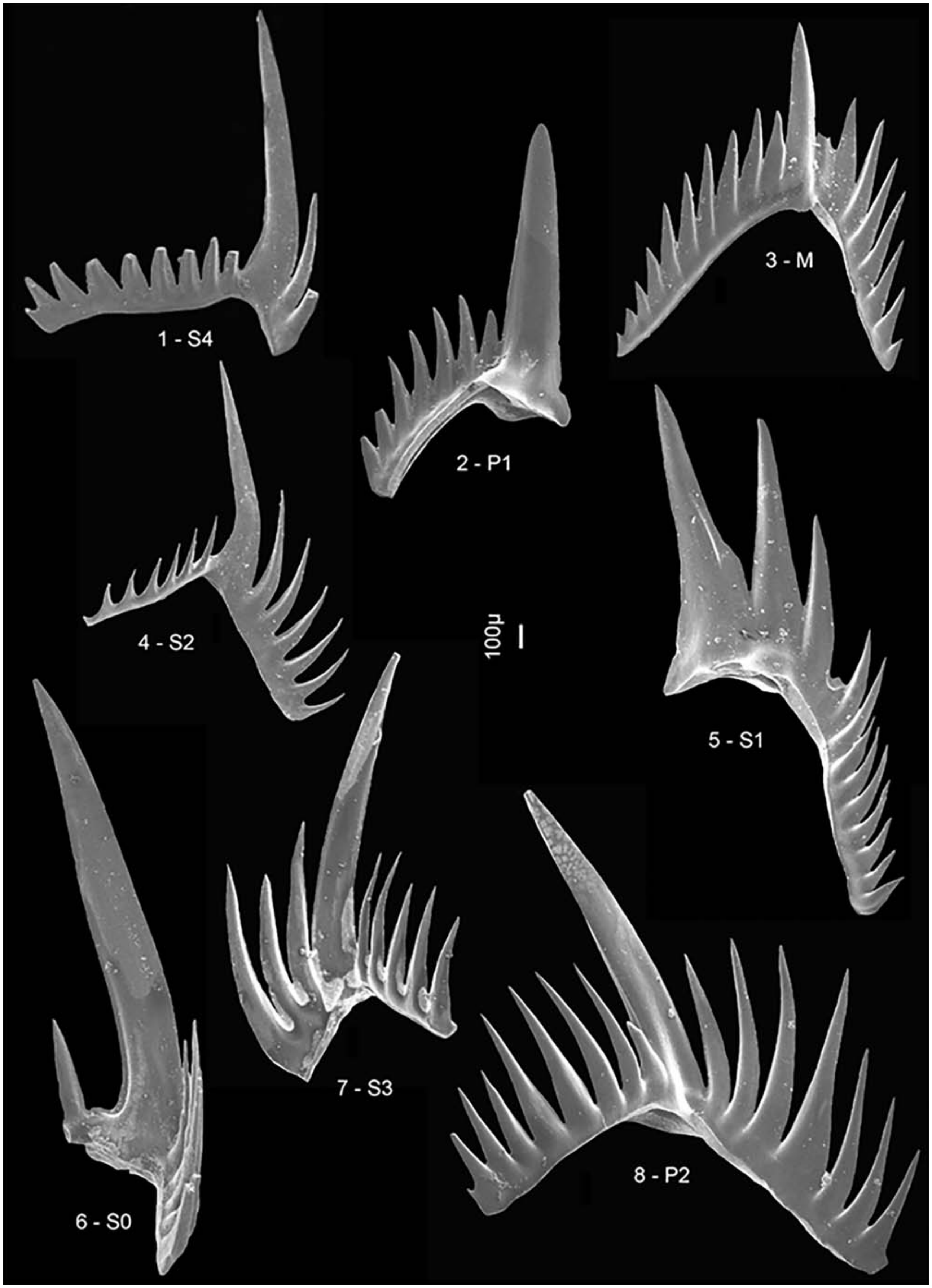
4 S2 element, lateral view, MedB11-30, Medora section

5 S1 element, posterior lateral view, MedB11-28, Medora section

6 S0 element, lateral view, MedB11-39, Medora section

7 S3 element, lateral view, MedB11-26, Medora section

8 P2 element, lateral view, MedB11-27, Medora section.


1 - S4
2 - P1
3 - M
4 - S2
100µ
5 - S1
6 - S0
7 - S3
8 - P2

M element (pl. 3, fig. 5): dolabrate; cusp wide, short; cup-shaped basal cavity; two lateral processes of disparate length. A very short downward directed lateral process bearing very short widely spaced denticles, generally 4-5, that increase slightly in size except distal 1-2 which decrease. A long downward directed lateral process that curves slightly inward and bears alternating medium sized and thick denticles, and short and thin denticles, generally 1-2 thin denticles between each of the larger denticles; all denticles on the long process are slightly recurved.

S0 element (pl. 3, figs. 3, 4): alate; cusp long, slender, upright with costae running to each of the three processes; lateral processes are directed downward, slightly curved, forming about a 50^{o} angle to one another in posterior view, and bearing denticles of alternating size, one denticle thin, short, the other, thicker and medium sized. Medium sized denticles increase in size away from the cusp, then decrease in size and increase in spacing laterally; short denticles are very thin near the cusp and become thicker laterally, but decrease in height, becoming minute. Posterior process is relatively long and has an irregular pattern of alternating short and medium sized denticles, all sharply pointed; short denticles of variable size, generally numbering between 1-4 that occur between medium sized denticles that become more reclined and larger posteriorly, except posterior-most which is the most reclined, but slightly shorter than adjacent denticle.

S1 element (pl. 3, fig. 6): bipennate; cusp of subequal to lesser size of the process denticles; short anterior process that is directed laterally at 90^{o} angle to longer posterior process. Anterior process slightly downward turned bears 3-4 denticles, first two of sub-equal size, 2/3 the height of the cusp, and distal-most 1-2 decreasing in size; long, straight posterior process bears reclined alternating thin and thicker denticles, thin denticles variable, some fused, and in a more random pattern of 1-6 thin denticles between thicker denticles; thicker denticles higher than thin denticles by about 1/3, generally increasing slightly in height posteriorly, except posterior-most one.

S2 element (pl. 3, fig. 7): bipennate; cusp medium sized with a short anterior process and long posterior process. Short anterior process turns inward and downward that bears 2 thin denticles next to the cusp, highest denticle next, then denticles decrease in height distally; posterior process bearing reclined alternating thin and thicker denticles in more ordered pattern, but variable with 2-6 thin denticles between thicker denticles and of variable heights. S2 element is similar to the S4 element, but is considered herein to differ in the shorter denticle pattern.

S3 element (pl. 3, fig. 9): bipennate; cusp medium sized to short with short anterior process and long posterior process. Short anterior process turns inward and downward that bears 2 thin denticles next to the cusp; highest denticle next, then process turns sharply inward bearing 4-5 denticles decreasing in size. A long straight posterior process bears slightly reclined alternating thin and thicker denticles in an ordered pattern of 2-4 thin denticles between thicker denticles; 3-4 posterior-most denticles thin and thicker denticles alternating one for one; thin denticles of more equal size becoming higher in middle of process; thicker denticles high, several are higher than the cusp; denticles on the middle of the process of sub-equal height and decreasing in height both anteriorly and posteriorly.

S4 element (pl. 3, fig. 8): bipennate; cusp medium sized with short anterior process and long posterior process. Short anterior process turns inward and downward and bears 3 thin denticles next to the cusp, highest denticle next, then the process turns inward bearing 3-4 denticles decreasing in size. Long, nearly straight posterior process bears slightly reclined alternating thin and thicker denticles in an ordered pattern of 2-4 thin denticles between thicker denticles; thin denticles when not broken of subequal height on anterior and middle part of process, then decreasing in height posteriorly; thicker denticles increasing in height to anterior middle of process, then decrease in size posteriorly.

Remarks: Late Moscovian *Neognathodus* species have been suggested to show a tendency toward paedomorphosis as observed in the P1 elements by retention of juvenile features into adult sizes in younger species (Stamm and Wardlaw 2003, Rosscoe and Barrick 2013). Small specimens typically have a smooth outer parapet and this smooth outer parapet is retained in larger specimens through time. This type of growth pattern has resulted in a plethora of species names and a method of counting species to tell time. Until there is standardization of a

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PLATE 2

Elements of the *Idiognathodus acutus* apparatus ×60

1 P1 element, sinistral upper view, MedB11-5, Medora section

2 P2 element, lateral view, MedA-10, Medora section

3 S0 element, lateral view, MedA-2, Medora section

4 S0 element, posterior view, MedA-8, Medora section

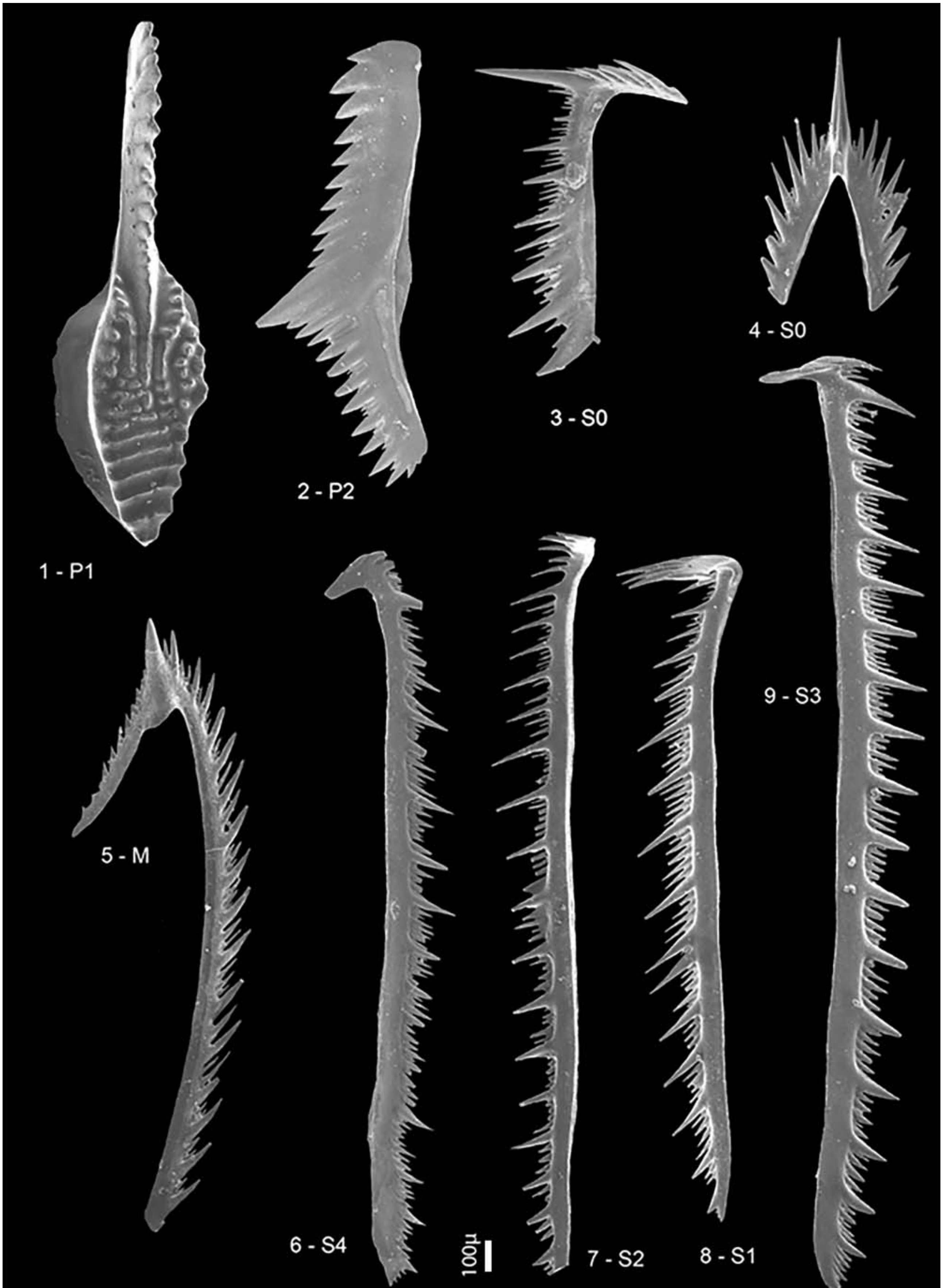
5 M element, posterior lateral view, MedB11-19, Medora section

6 S4 element, inner lateral view, NEMed3-29, Medora section

7 S2 element, inner lateral view, MedB12-5, Medora section

8 S1 element, inner lateral view, MedB12-10, Medora section

9 S3 element, inner lateral view, MedB12-2, Medora section.


1 - P1
2 - P2
3 - S0
4 - S0
5 - M
6 - S4
100µ
7 - S2
8 - S1
9 - S3

proxy for growth to compare species, this methodology is meaningless. Further, as demonstrated by our material, sinistral and dextral P1 elements differ, dextral having a smoother outer parapet than sinistral elements. The apparatus of *Neognathodus* is very similar to that of *Idiognathodus* and Merrill and Von Bitter (1977) discuss some of the subtle differences.

A P1 element is illustrated (pl. 6, fig. 5) as part of the fauna recovered and is referred to *N.* cf. *N. roundyi*. This species name is tentative and a correct specific assignment would require more specimens.

Family GONDOLELLIDAE Lindstrom 1970
Genus ***Gondolella*** Stauffer and Plummer 1932

Gondolella wardlawi Nestell and Pope, **n. sp.**
Plate 4, figures 1-7, 8; Plate 7, figures 1-4

Gondolella sp. 2 - SWADE 1985, fig. 18, no. 35.
Gondolella bella Stauffer and Plummer - MERRILL and GRAYSON 1989, pl. 1, figs. 19-30.
Gondolella magna Stauffer and Plummer - STAMM and WARDLAW 2003, p. 106, pl. 3, fig. 13.
Gondolella bella? Stauffer and Plummer - POPE et al. 2011, pl. 1, fig. 8. – NESTELL et al. 2012, pl. 7, figs. 9-10.
Gondolella cf. *G. bella* Stauffer and Plummer - BARRICK et al. 2013a, pl. 1, fig 13.

Description: P1 element (pl. 4, fig. 8) : segminiplanate; terminal cusp large, posteriorly reclined, heavily crenulated lateral margins (rugose), a medial carina of low denticles circular in cross section, a few anteriormost denticles form a blade, cusp and denticles generally connected along the length of the element. Carina bordered by a smooth furrow of variable width, lower side with elevated keel with medial v-shaped groove, tapering at the anterior end, with a large, flared loop and deep pit posteriorly beneath the cusp.

P2 element (pl. 4, fig. 7): angulate; cusp medium sized, reclined and pointed; posterior process short, slightly inwardly turned bearing 3-4 thin, sharply pointed denticles, the first partially fused to the cusp decreasing in medial width posteriorly, generally decreasing in height, but variable; anterior process long, bearing sharply-pointed, laterally compressed, but medially wide denticles of near equal height, except anterior-most which is small; denticles reclined near the cusp becoming erect near anterior end, a prominent lateral ridge at the base of the denticles occurs along the entire anterior process; medial costa developed on all denticles and cusp; both processes with a groove on the underside, and a small basal pit is present beneath the cusp.

M element (pl. 4, fig. 2): breviform digyrate; cusp moderately high and slightly recurved: a short lateral process bearing 3 pointed denticles decreasing in size distally, a longer lateral process bearing typically 5 pointed denticles of near equal size that are laterally compressed and medially wide; denticles and cusp with lateral costae; a distinct posterior cup to the basal cavity forms a thick costa extending up half the cusp.

S0 element (pl. 4, fig. 3): alate; cusp medium sized, slightly reclined; a very short posterior process bearing 2-3 denticles decreasing in height posteriorly; medium sized lateral processes greatly downturned and bearing sharply pointed, laterally compressed, medium sized, slightly reclined denticles of near equal height; all denticles medially costate, and cusp with costae leading to all three processes; all processes with narrow groove on underside and a small basal pit beneath cusp.

S1a element (pl. 4, fig. 5): digyrate; cusp high recurved with a lateral costa leading to a short lateral process bearing 2-3 denticles, medially costate; posterior costa leading to a short, downward turned posterior process bearing relatively low, medially wide denticles, medially costate; a narrow groove under each process and a small basal cavity under the cusp

S1b element (pl. 4, fig. 6): digyrate; cusp high nearly erect with a costa that leads to the lateral process that is lateral near the base that twists to the anterior going up the cusp; lateral process bears 2 denticles; posterior process short, sharply downturned bearing 4-5 denticles, first two of medium size; all denticles medially costate, posterior costa (not twisted) on posterior of cusp leading to posterior process, tip of cusp may be slightly recurved; a relatively wide groove occurs under the posterior pro-

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PLATE 3
Elements of the *Neognathodus roundyi* apparatus x60

1 P2 element, inner lateral view, MedA-11, Medora section

2 P1 element, upper sinistral view, SUI 126549, MedA-17, Medora section

3 S0 element, oblique upper lateral view, scan 150104, Medora section

4 S0 element, posterior view, MedA-23, Medora section

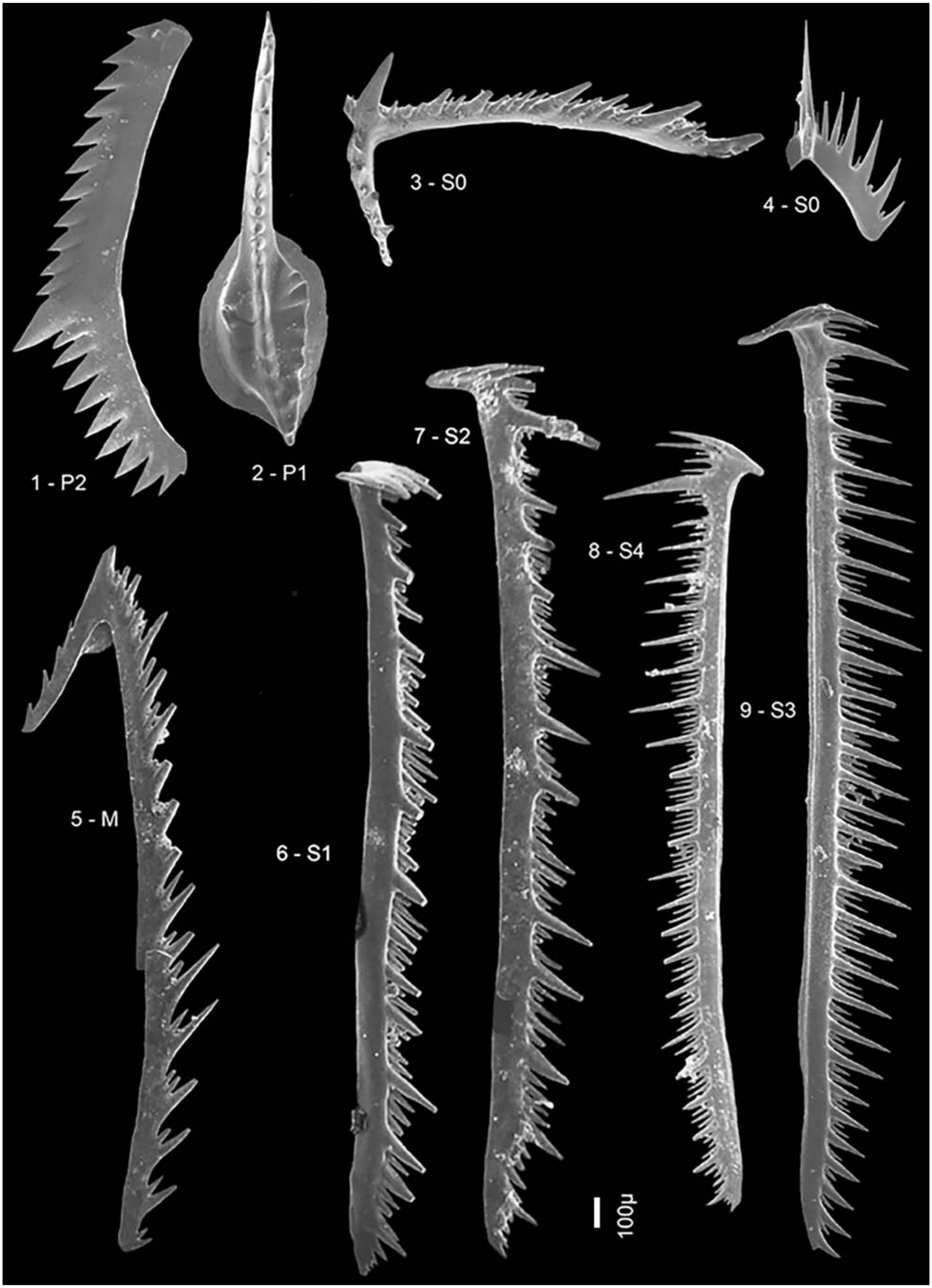
5 M element, anterior lateral view, scan 144237, Medora section

6 S1 element, inner lateral view, scan 155216, Medora section

7 S2 element, inner lateral view, scan 160925, Medora section

8 S4 element, inner lateral view, scan 144412, EBV-1, Booneville section

9 S3 element, inner lateral view, MedA-41, Medora section.


1 - P2
2 - P1
3 - S0
4 - S0
5 - M
6 - S1
7 - S2
8 - S4
9 - S3
100µ

cess leading to a medium sized basal cavity, slightly flared under the cusp.

S2 element (pl. 4, fig. 1): angulate; cusp medium sized, nearly erect to slightly proclined; short posterior process bearing 3 denticles that decrease in height posteriorly; a medium length to long downturned anterior process bearing denticles of near equal medium height, first two denticles proclined then becoming slightly recurved, distal-most denticle small; all denticles and cusp medially costate; a flared basal cavity below the cusp becomes a groove under each process.

S3 element (pl. 4, fig. 4): angulate; cusp medium sized to short, reclined; posterior process short, downturned bearing 5 denticles of near equal height; anterior process short, bearing 5 denticles of near equal height, anterior denticles higher than posterior denticles; denticles laterally compressed and medially costate, as is the cusp; basal cavity slightly flared below the cusp.

Designation of types: The specimen illustrated on plate 4, figure 8 (no. SUI 126547) is designated as the holotype; plate 7, figure 2a (no. SUI 126546) as a paratype. Barrick et al. (2013a) illustrated the holotype specimen under the incorrect number SUI 134874.

Etymology: The authors considered this form as a new species and planned to use a different species name. However, Nestell and Pope decided to name the species *Gondolella wardlawi* to honor Wardlaw after his sudden and untimely death in March, 2016.

Remarks: The apparatus architecture of *Gondolella* was first modelled by Von Bitter and Merrill (1998) from bedding plane assemblages of the middle Desmoinesian Oak Grove Member of the Spoon Formation, Illinois. They recognized two similar S1 elements (their Sb1, Sb2) in their reconstruction of *G. pohli*. The apparatus assemblage of the new species presented herein follows their model. The 13 element apparatus for *Gondolella* illustrated by Von Bitter and Merrill (1998) includes both paired and unpaired elements. Herein, *G. wardlawi* is considered to be a 15 element apparatus of both paired and unpaired elements. If the highly similar S1a and S1b elements of *G. wardlawi* were not separated, but would be considered to occupy the same S1 element position, then the apparatus would have 13 elements. Orchard (personal communication, May 2016) in commenting about the apparatus construction of *Gondolella* presented on Pl. 4 suggested a possible alternative construction could be made with the S1a and S1b elements interchanged with the S2 element.

The oldest crenulated gondolellid illustrated is referred to *G. magna* as reported in Stamm and Wardlaw (2003, pl. 3, fig. 13) from the Chimney Rock Shale, Paradox Formation in the Rapee Anticline section in Utah. The age is considered to be generally equivalent to that of strata of the early part of the middle Desmoinesian Lower Kittanning cyclothem of the Appalachian Basin. The latter specimen appears to be an immature one, but is very similar to *Gondolella wardlawi* in general shape, development of the crenulations, and the shape of the denticles. This occurrence in the Desmoinesian is just slightly older in stratigraphic position (Verdigris cyclothem in the Midcontinent region and upper part of the Brannon Bridge Limestone in north-central Texas) than that of Excello Shale (Lower Fort Scott cyclothem in Kansas and Santo Limestone interval in north-central Texas) (Boardman et al. 1990, p. 331; Heckel 2013).

Merrill and Von Bitter (2007) discuss thoroughly the taxonomic problems associated with the type specimens of several species of Pennsylvanian gondolellids named by Stauffer and Plummer (1932). Their final conclusions are that there are two distinct species, *G. bella* from the latest Desmoinesian East Mountain Shale and *G. elegantula* from the early Missourian Posideon Shale with a number of synonyms. In particular, *G. magna* is considered to be more properly referred to *G. bella* (Merrill and Von Bitter 2007). *Gondolella wardlawi* n. sp. is quite different from *Gondolella elegantula* in the structure of the crenulations and general shape, especially in the narrower width of the latter species. There is also a significant difference in age.

Gondolella wardlawi n. sp. is somewhat similar to *G. bella*, but differs in several critical points. First, there is a distinct difference in overall shape with *G. bella* being narrower in the anterior than *G. wardlawi* n. sp. Second, the denticles of *G. bella* are rounder. Third, many of the platform crenulations of *G. bella*

PLATE 4

Elements of the *Gondolella wardlawi* n. sp. apparatus ×105

1 S2 element, lateral view, NMed3-3b, Medora section

2 M element, posterior lateral view, NEMed3-7, Medora section

3 S0 element, anterior lateral view, NEMed3-15, Medora section

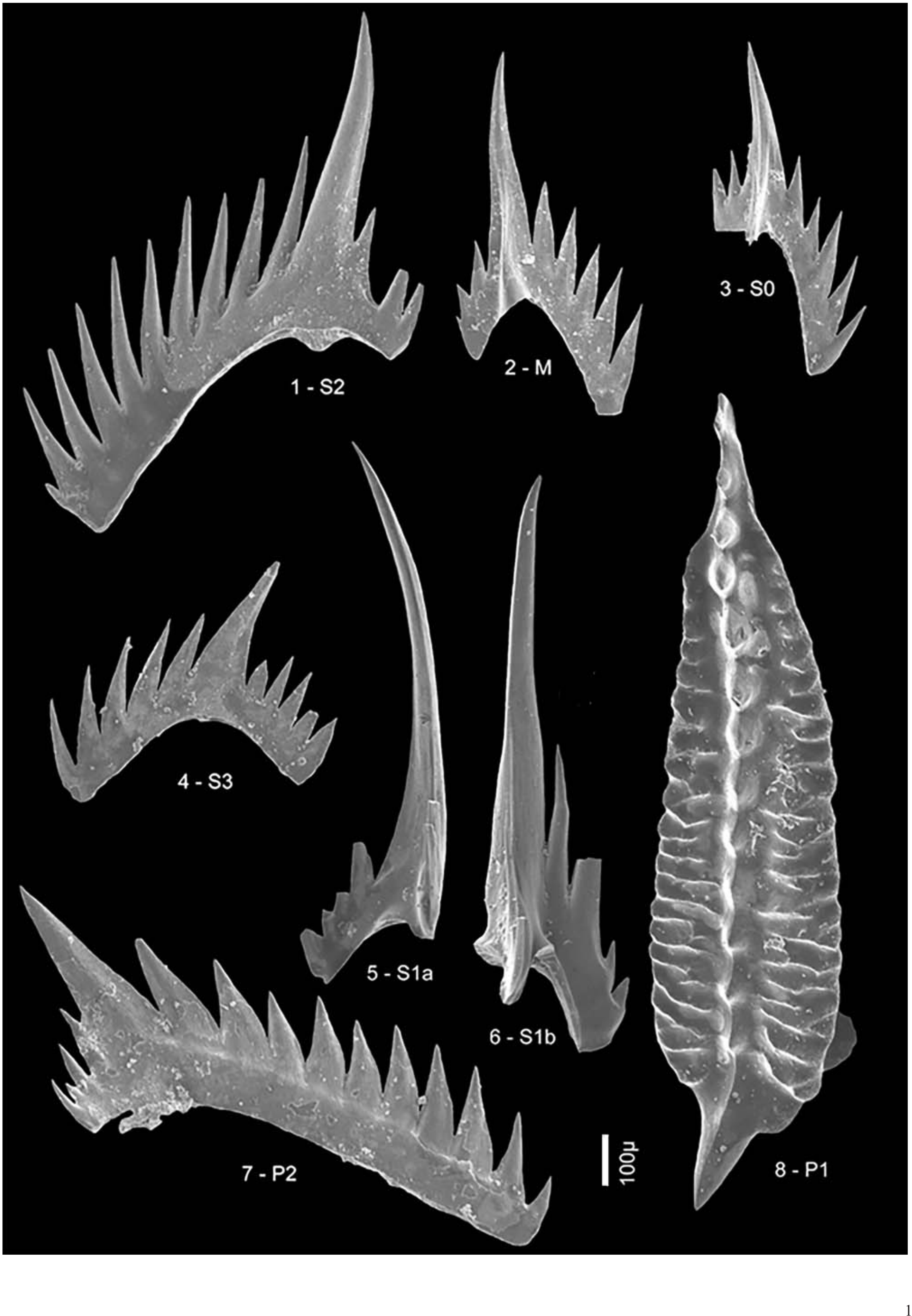
4 S3 element, lateral view, NEMed3-13, Medora section

5 S1a element, posterior lateral view, NEMed3-10, Medora section

6 S1b element, posterior lateral view, NEMed3-23, Medora section

7 P2 element, lateral view, NEMed3-11, Medora section.

8 P1 element, oblique upper view, holotype, SUI 126547, NEMedB-4, Medora section.


1 - S2
2 - M
3 - S0
4 - S3
5 - S1a
6 - S1b
7 - P2
8 - P1
100µ

extend to the denticles. Lastly, unlike in *G. bella*, a distinct furrow on each side of the denticles separates them from the crenulations.

CONCLUDING REMARKS

Proposed apparatus reconstructions for *Gondolella wardlawi* (new species), *Idiognathodus acutus, Idioprioniodus conjunctus,* and *Neognathodus roundyi* are presented as recovered from a few concretions in the lower part of the Excello Shale (Middle Pennsylvanian) at the Booneville and Medora localities in Iowa. Rare specimens of a proposed new species *Idiognathodus tuberis* are also present in the assemblage. The selection of specimens for a conodont apparatus reconstruction is a very subjective exercise at best. Wardlaw and Nestell had many lively discussions as to which elements to choose from our collections and how they should be assigned. The descriptions of the conodonts and their apparatus reconstructions were mostly written by Wardlaw and Nestell during the last visit of Wardlaw to the University of Texas at Arlington's Department of Earth and Environmental Sciences a few months before his death. Several versions of the various apparatus constructions were discussed at that time, preliminary drafts of the plates were constructed, and descriptions written. Wardlaw took the text back to Reston, Virginia to make the final decisions as to which specimens were to be illustrated in the apparatus reconstructions presented in this paper. A draft of the last version of the manuscript was received by Nestell near the end of February of 2016.

Holotypes of the two new species have SUI numbers and are deposited in the Paleontological Repository of the Department of Earth and Environmental Sciences of the University of Iowa. All other figured specimens are to be deposited with the holotype of *Gondolella wardlawi* under the numbers presented in the plate descriptions. The numbers SUI 126542, SUI 126542/1, SUI 126546, and SUI 126547 refer to University of Iowa Department of Earth and Environmental Sciences Paleontological Museum collection numbers. Scan xxxxxx refers to the original SEM scan registry number. Med A, B, NEMed, NMed also refer to original SEM scans.

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PLATE 5

P1 elements of *Idiognathodus* all specimens ×60 except 1a ×300

1a,b *I. acutus*, sinistral element, enlargement of surface micro-ornament (x300) at posterior end of the carina to the inner platform margin and oblique upper view, MedB11-7, Medora section

2 *I. acutus*, sinistral element, oblique upper view, NEMedB-5, Medora section

3 *I. tuberis*, n. sp., sinistral element, oblique upper view, SUI 126544, MedA-15, Medora section

4 *I. acutus*, dextral element, oblique upper view, NEMedB-6, Medora section

5 *I. acutus*, sinistral element, upper view, MedB11-5, Medora section

6 *I. tuberis*, n. sp., dextral element, oblique upper view, MedA-16, Medora section

7 *I. acutus*, dextral element, oblique upper view, scan 133436, Medora section

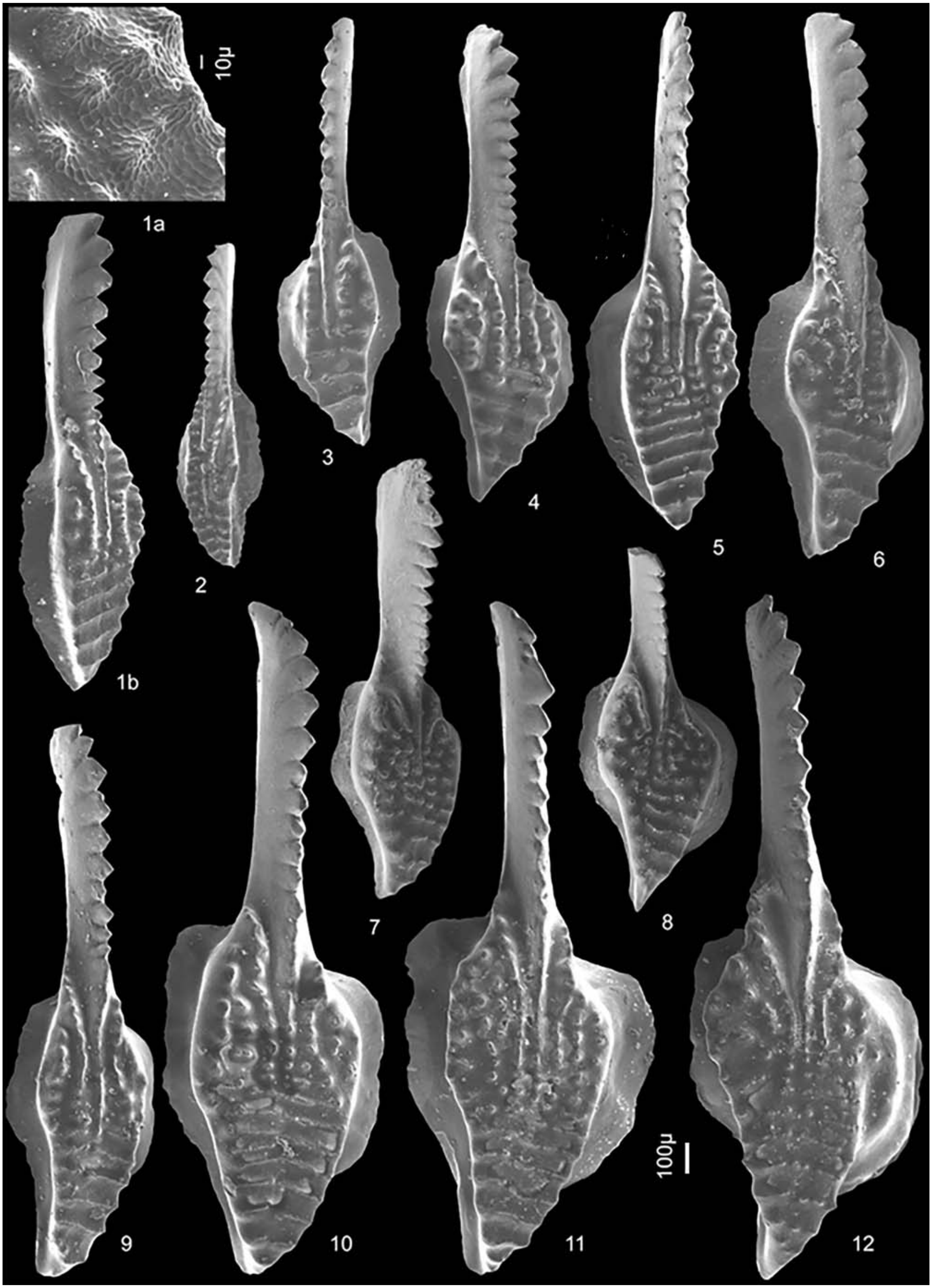
8 *I. acutus*, dextral element, upper view, scan 133238, Medora section

9 *I. acutus*, dextral element, upper view, MedB11-6, Medora section

10 *I. acutus*, dextral element, upper view, MedB11-4, Medora section

11 *I. acutus*, dextral element, upper view, MedB11-3, Medora section

12 *I. tuberis*, n. sp., dextral element, upper view, holotype (SUI 126542/1), MedB11-2, Medora section.


10µ
1a
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2
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100µ

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PLATE 6

P1 elements of *Neognathodus roundyi ×80*

1 sinistral element, upper view, MedA-13, Medora section

2 sinistral element, upper view, SUI 126548, MedA-14, Medora section

3 sinistral element, upper view, SUI 126549, MedA-17, Medora section

4 sinistral element, upper view, MedA-19, Medora section

5 N. cf. *N. roundyi*, sinistral element, upper view, MedB11-8, Medora section

6 sinistral element, upper view, scan 135029, Medora section

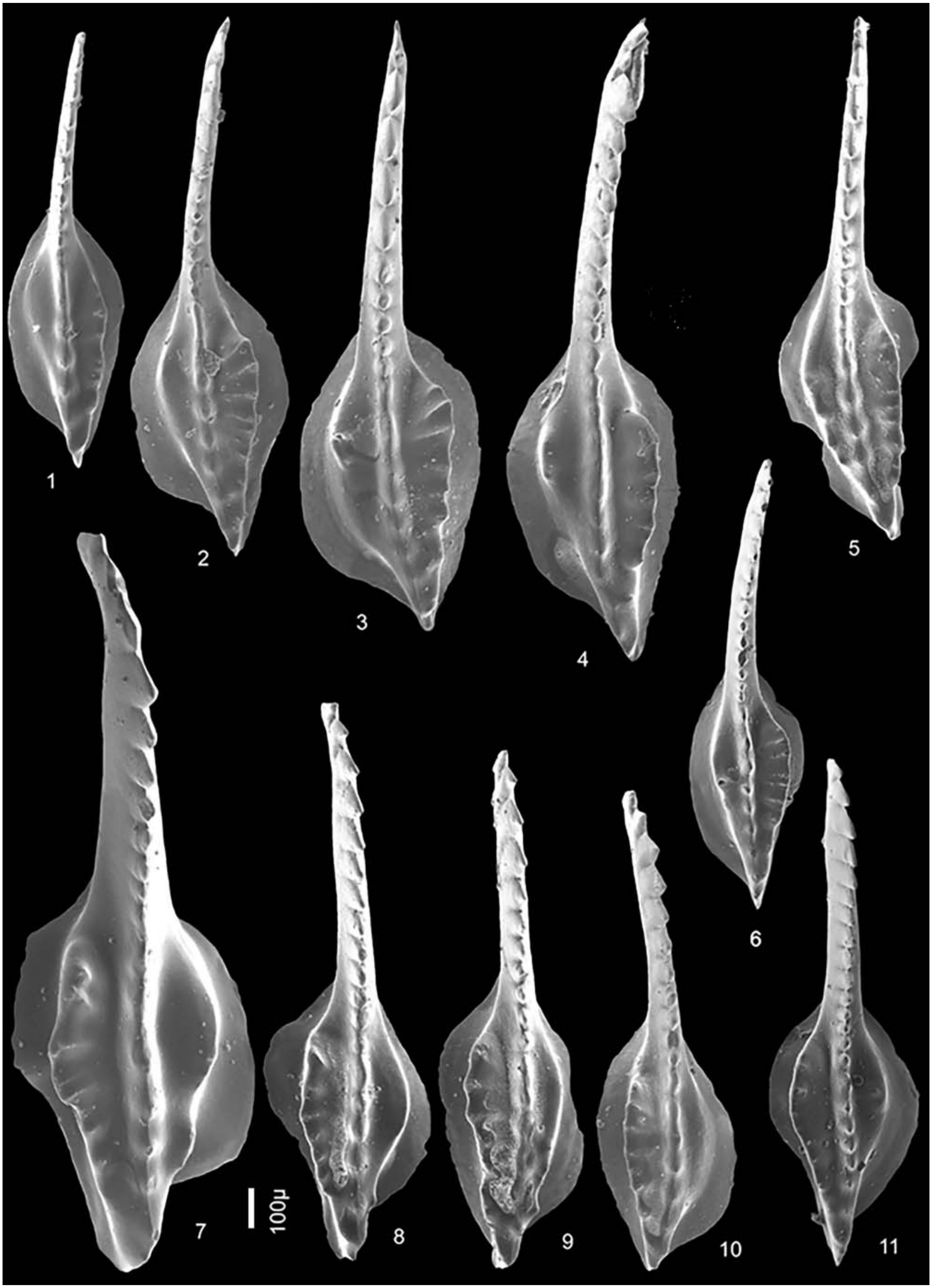
7 dextral element, upper view, MedB11-1, Medora section

8 dextral element, upper view, MedB11-10, Medora section

9 dextral element, upper view, MedB11-9, Medora section

10 dextral element, upper view, MedB11-11 Medora section

11 dextral element, upper view, scan 134820, Medora section.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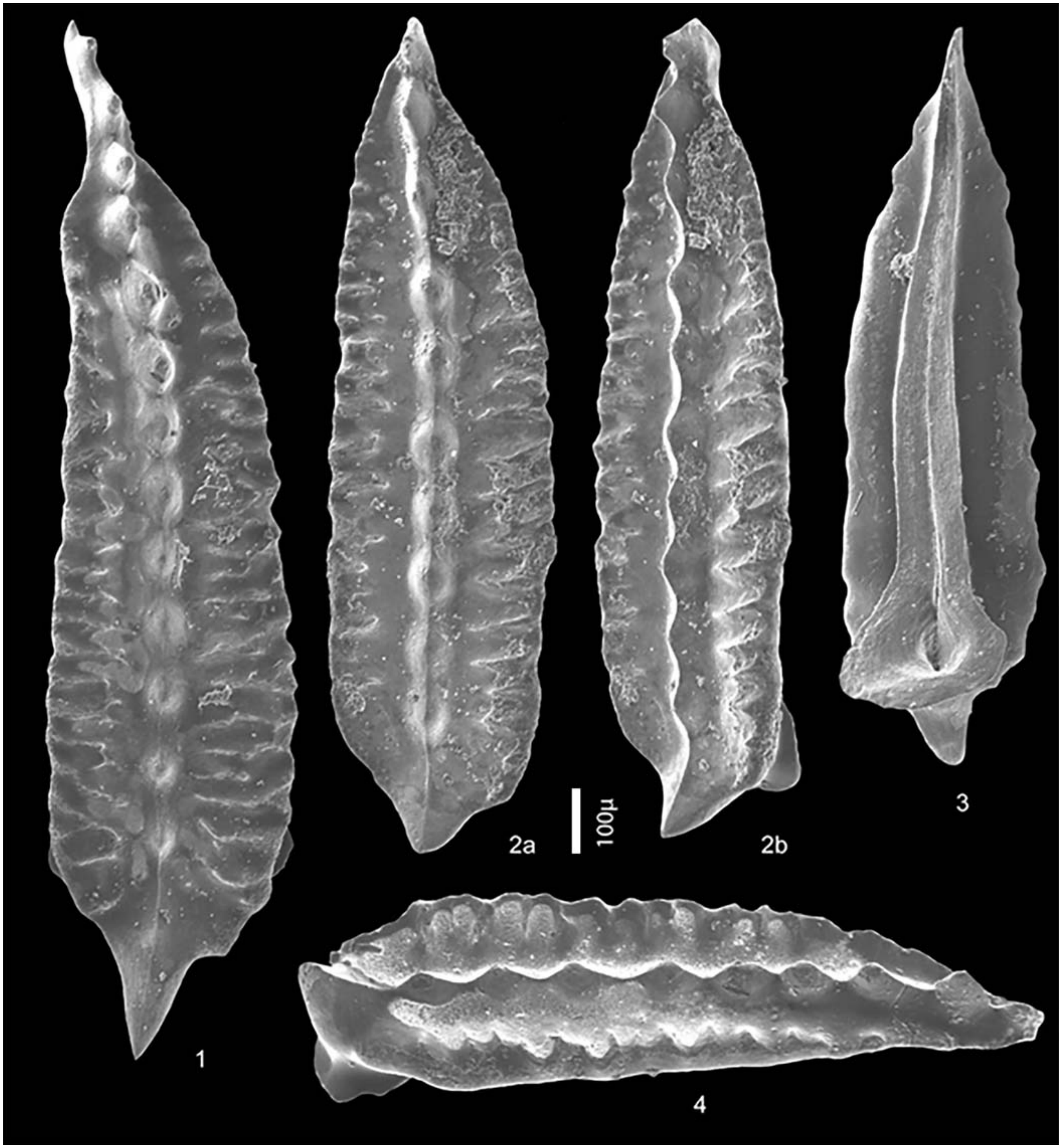

PLATE 7
P1 elements of *Gondolella wardlawi* n. sp. ×110

1 dextral element, upper view, holotype, SUI 126547, NEMedB-4, Medora section

2a,b dextral element, upper and oblique upper views, paratype, SUI 126546, NEMedB-3, Medora section

3 dextral element, lower view, NEMedB-1, Medora section

4 sinistral element, oblique upper view, NEMedB-2, Medora section.

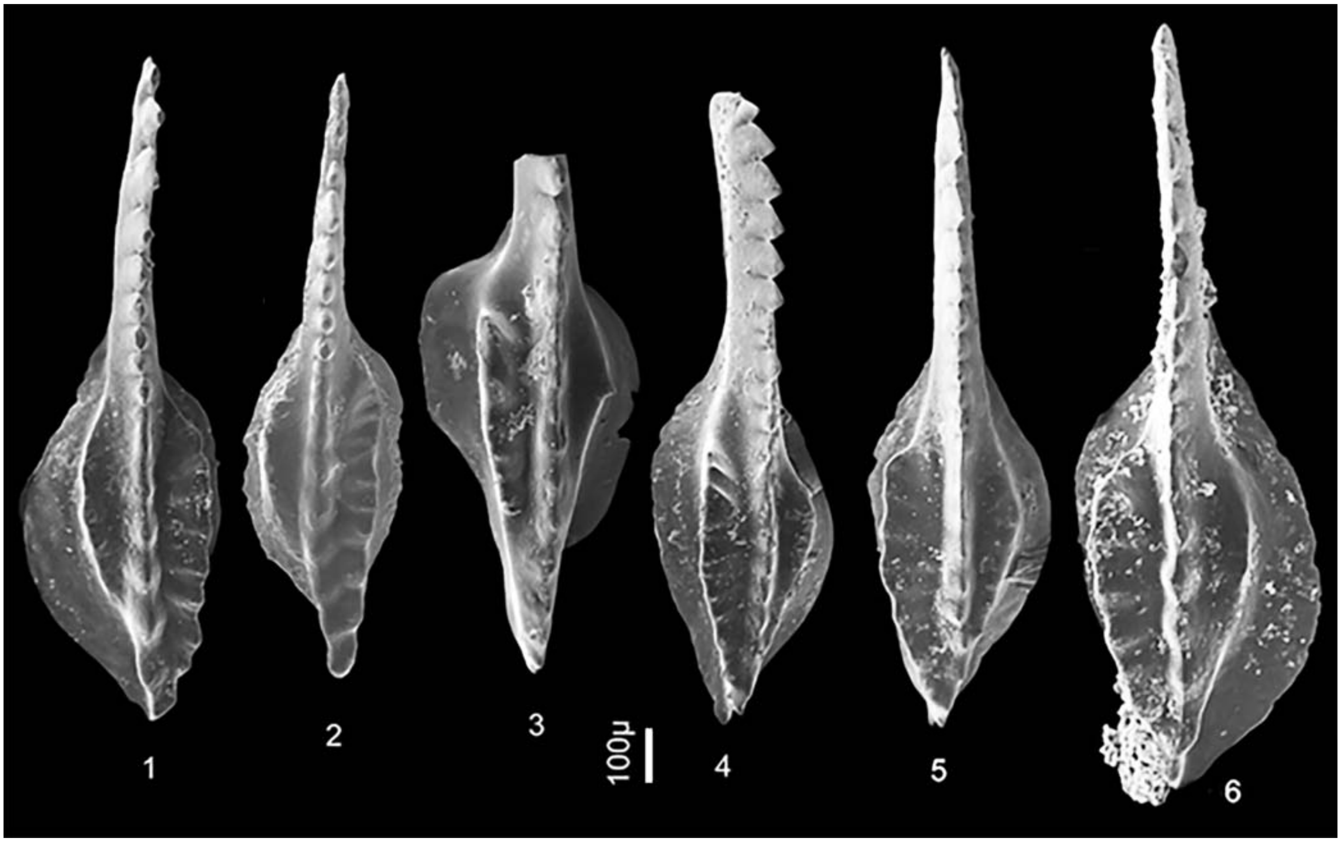

PLATE 8
Upper views of P1 elements of *Neognathodus roundyi ×80*

1 sinistral element, scan 145121, Booneville section
2 sinistral element, MedA-22, Medora section
3 dextral element, scan 134416, Medora section
4 dextral element, scan 135223, Medora section
5 dextral element, scan 134625, Medora section
6 dextral element, scan 145323, Booneville section.

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