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# Ordovician conodonts from the Mithaka Formation (Georgina Basin, Australia). Regional and paleobiogeographical implications

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## ABSTRACT

The systematic analysis of conodonts from the previously unstudied Mithaka Formation (Georgina Basin) yielded 1366 identifiable elements, representing 25 species and 21 genera. One new species was recovered and identified, *Triangulodus mithakensis* n. sp. Four other new species are described in open nomenclature as *Bergstroemognathus*? n. sp. A, ?*Periodon* n. sp. A, *Phragmodus* n. sp. A and *Taoqupognathus* n. sp. A. The Mithaka Fm fauna shows similarity with conodonts from several previous Australian studies and lesser similarity with conodonts from North China and North America. Some species of North American Midcontinent (Laurentian Province) affinity include *Erismodus quadridactylus* (STAUFFER) and *Staufferella divisa* SWEET, whereas some species of North Chinese affinity include *Aurilobodus leptosomatus* AN, *Panderodus nogamii* (LEE) and ?*Serratognathus* sp. However, many species are distinctly Australian: *Bergstroemognathus*? n. sp. A, ?*Periodon* n. sp. A, *Phragmodus* n. sp. A, *Drucognathus yiranus* ZHANG, BARNES and COOPER, *Erismodus nicolli* ZHANG, BARNES and COOPER, *Yaoxianognathus*? *neonychodonta* ZHANG, BARNES and COOPER, *Triangulodus mithakensis* n. sp. and *Taoqupognathus* n. sp. A. These Australian species support the placement of the Mithaka Fm fauna within the proposed Australian Province. This new conodont fauna is correlated to the early Late Ordovician upper *Drucognathus yiranus* Zone of the Amadeus Basin, Central Australia and the late Gisbornian Stage. The conodont fauna indicates a shallow open lagoon depositional environment.

*KEYWORDS* **Ordovician. Conodonts. Mithaka Formation. Georgina Basin. Palaeobiogeography.**

## INTRODUCTION

Knowledge of Ordovician conodont faunas from the interior basins of Australia is still sparse, limiting biostratigraphic correlations and paleogeographic reconstructions. The late Proterozoic to lower Paleozoic strata of the Georgina Basin (Fig. 1) has been extensively studied, producing a 1:125,000 scale geological map of the area (Shergold and Druce, 1980). However, little work has been undertaken on the thin Mithaka Fm. The age of this Formation has been much debated, with early workers assigning a Middle Ordovician age (e.g. Casey in Smith, 1963). Shergold and Druce (1980) suggested an Early to Middle Ordovician age. This paper addresses the taxonomic study of conodont remains representing 25 species and 21 genera, including five new species, four of them described in open nomenclature. A general paleoenvironmental interpretation of the Mithaka Fm conodont assemblage is provided and its comparison with conodont assemblages from other Australian basins and from North China and North America is carried out.

## GEOLOGICAL SETTING

### The Georgina Basin

The Georgina Basin is a large intracratonic basin that straddles the Northern Territory – Queensland border northeast of Alice Springs (Figs. 1A and 1B). The basin contains a sedimentary and volcanic sequence spanning the late Proterozoic through Devonian age and covers an estimated 325000 sq km (Shergold and Druce, 1980). Deposition of shallow water successions in the Georgina Basin began in the Cambrian, and continued until the close of the Ordovician. Lower Paleozoic strata known collectively as the Toko Group are divided into six formations: in ascending order, the Kelly Creek Fm, Coolibah Fm, Nora Fm, Carlo Sandstone, Mithaka Fm, and Ethabuka Sandstone (Fig. 1C).

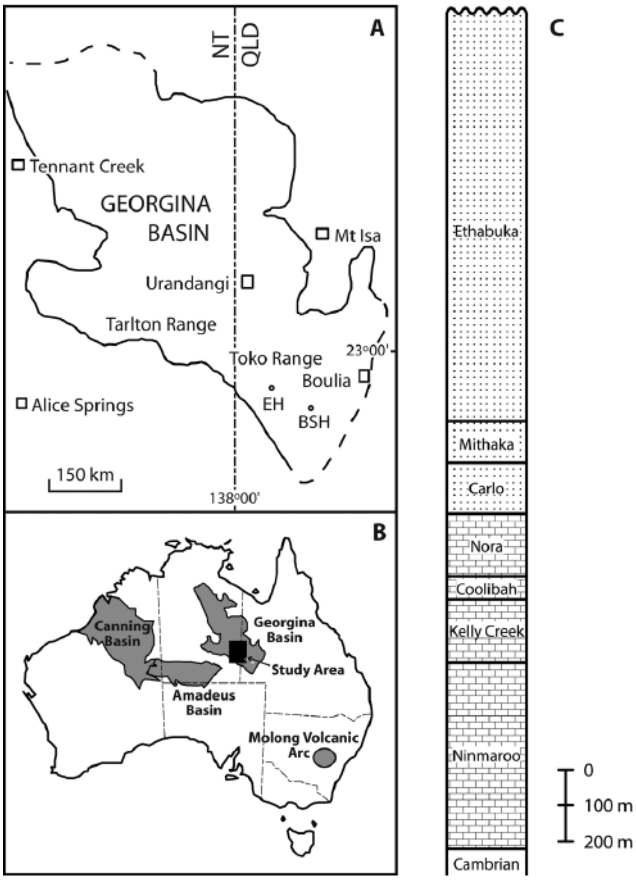



FIGURE 1 **A) Location map for the Georgina Basin, central Australia. Samples were collected from the Toko Range. Locations of the Ethabuka Hole 1 (EH; 138.425°E 23.689°S) and the Bedourie Scout Hole no. 1 (BSH; 139.111°E 24.067°S) are shown in the southeastern Georgina Basin (modified from Stait and Druce, 1993). B) Australian intracratonic basins (after Cook and Totterdell (1991) and Haines et al., (2001). C) A generalized stratigraphic sequence of uppermost Cambrian through Devonian strata of the Georgina Basin. This sequence contains numerous stratigraphic gaps, which have not been shown for simplicity of the figure (after Cook and Totterdell (1991) and Fortey and Cocks (1998)). The Stokes Siltstone (Amadeus Basin) is correlated with the upper Carlo Sandstone and lower Mithaka Fm. (Zhang et al., 2003 and this study). The Nita and Goldwyer formations (Canning Basin) are correlated with the Nora and lower Carlo sandstones (Cook and Totterdell, 1991). The Molong Volcanic Arc (Bowen Park Succession) is correlated with the Ethabuka Sandstone (Zhen et al., 1999).**

The Georgina Basin achieved its maximum extent during the Middle Ordovician, represented by deposition of the Coolibah Fm (Cook and Totterdell, 1991). Later, regressions began diminishing the size of the depocenter, producing a barrier – lagoon complex within the basin. The barrier – lagoon sequence is represented by the Carlo Sandstone and the Mithaka Fm, respectively. Marine deposition later changed to a prevailing fluvial dominated system, represented by the Ethabuka Sandstone (Fig. 1C).

### The Mithaka Formation

The Mithaka Fm is known from outcrop along the axial part of the Toko Syncline and from part of the plateau of the Toko Range (Fig. 1A). Outcrops are extensively lateritized and ferruginized (Shergold and Druce, 1980). Casey (in Smith, 1963) first described the Mithaka Fm that consists of a sequence of medium-bedded fine to very fine-grained sandstone with interbeds of massive siltstone and mudstone with rare limestone. The Mithaka Fm is generally estimated to be 60 m thick, although a maximum thickness of 127 m has been recorded in the Ethabuka No. 1 well of Alliance Oil Development Australia (Fig. 1A). Mudstones within the Mithaka Fm are gypsiferous and the sandstones are glauconitic.

The Mithaka Fm interfingers with the underlying Carlo Sandstone and the overlying Ethabuka Sandstone (Fig. 1C). The Mithaka Fm contains abundant fossils and ichnofossils, which support an open lagoon depositional environment. Trace fossils place the Mithaka Fm within the *Glossifungites* and *Skolithos* biofacies (Draper, 1980). Draper (1977) interpreted this sequence to represent an open lagoon (Mithaka Fm) with a breached barrier system (Carlo Sandstone).

## SAMPLING AND MATERIAL

The systematic analysis of conodonts from the Mithaka Formation was conducted using 106 samples collected from the Toko Range area, which were provided by Geoscience Australia, complemented with 6 samples from the Bedourie Scout Hole no. 1 (see location in Fig. 1A). The Geoscience Australia sample set includes sixteen geological outcrop grab samples. Poor outcrop conditions have prevented precise stratigraphic measurement of these samples, however all available information on sampling location is provided (GEO samples; see Tables 1 and 2 in the electronic version of this paper*). Moreover, ninety shot point samples (SP samples) recovered from the Mithaka Fm section thanks to the development of a seismic survey conducted by the French Petroleum Company in the 1960s were also examined (Table 3). Finally, six samples from the Bedourie Scout Hole no. 1, core 3, intermittently spanning from 959' to 998' depth (see location in Fig. 1A; Table 4).

The 112 samples studied from the Mithaka Fm yielded 1366 identifiable conodont elements that are assigned to 25 species representing 21 genera. The conodonts are very well preserved but commonly broken and have a CAI of 1.5 (Epstein et al., 1977).

## SYSTEMATIC PALEONTOLOGY

All elements are described in multielement taxonomy, following the notations of Sweet (1981, 1988). Because taxonomic relationships between genera are not well established for many Middle to Late Ordovician conodonts, the taxa are listed in alphabetical order rather than within a suprageneric classification. Eleven groups of conodonts (representing 4 new species, 5 undetermined species and 2 unknown genera and species) are described in open nomenclature due to the low recovery. Three species of conodonts (*Drepanoistodus suberectus*, *D. basiovalis* and *Staufferella divisa*) are not included in the systematic paleontology as they have been well described in previous papers (Zhang et al., 2003 for *D. suberectus*; Löfgren, 1978 for *D. basiovalis*; and Sweet, 1982 for *S. divisa*). Sample weights were not recorded; therefore no discussion of abundance per kilogram of sample is possible. Conodont element occurences are shown in Tables 2, 3 and 4, for GEO, SP and Bedourie Scout Hole samples, respectively.

**Phylum:** Craniata LINNAEUS, 1758
**Subphylum:** Vertebrata LINNAEUS, 1758
**Superclass:** Gnathostomata COPE, 1889
**Plesion:** Conodonta EICHENBERG, 1930

GENUS ***Aurilobodus*** XIANG and ZHANG, in An et al., 1983

*Type species*: *Tricladiodus*? *aurilobodus* LEE, 1975

***Aurilobodus leptosomatus*** AN et al., 1983
Figures 2.1 and 2.2

*Synonymy*:
1983 *Aurilobodus leptosomatus* n. sp., An and others, p. 72-73, pl. 21, figs. 14-17, pl. 22, Figs. 1
1988 *Juanognathus leptosomatus* (AN), Watson, p. 116, pl. 1, figs 1-3, 6
1993 *Aurilobodus*? *leptosomatus* AN, Stait and Druce, p. 302, figs, 17A-C

*Material*: 4 specimens: 2 Sa elements and 2 S elements recovered from SP samples. Figured specimens, CPC 37528 and CPC 37529, housed in the Commonwealth Palaeontological Collection, Geoscience Australia, Canberra, Australia.

*Description*: Only four elements of *Aurilobodus leptosomatus* were recovered. Sa element (Fig. 2.1) has a proclined cusp with rounded anterior margin and sharp posterior margin. Large lateral flanges extend from tip to past base of cusp. Lateral flanges are symmetrically disposed. Basal extension of lateral flanges meets lateral edge as a truncated triangle. Asymmetrical S element (Fig. 2.2) is fragmentary, with posterior ridge and basal area broken. Distinctive termination of lateral flange allows for assignment to this species.

*Occurrence*: *Aurilobodus leptosomatus* has been recovered from the lower Majiagou Fm of North China (An et al., 1983), the lower and middle Goldwyer Fm of the Canning Basin, Western Australia (Watson, 1988), the lower to middle Coolibah Fm of the Georgina Basin, central Australia and the Mithaka Fm.

*Discussion*: Although only one complete element was recovered the characteristics are distinctively those of *Aurilobodus* following An (in An et al., 1983). The sharp posterior keel, sharp lateral flange edges and triangular cusp cross section distinguish this species from *Juanognathus*.

Elements recovered from the Goldwyer Fm, Canning Basin were originally described as *Juanognathus leptosomatus* by Watson (1988). These elements possess more features in common with *Juanognathus* than do the Mithaka specimens, but were considered by Stait and Druce (1993) to be congeneric with *Aurilobodus*? *leptosomatus* recovered from the Coolibah Fm, Georgina Basin. These collections likely represent an evolutionary transition between *Juanognathus* and *Aurilobodus*, with the younger Mithaka collection representing true *Aurilobodus* specimens.

GENUS ***Baltoniodus*** LINDSTRÖM, 1955

*Type species*: *Prioniodus navis* LINDSTRÖM, 1955

***Baltoniodus***? sp. A
Figures 2.3 to 2.7

*All tables of this paper are available in the web page of the journal www.geologica-acta.com

*Synonymy*:
*Baltoniodus*? sp. A, Zhang et al., 2003, p. 11, pl. 2, figs. 1-9

*Material examined*: 15 specimens: 2 Pa, 10 Pb, 2 Sa and 1 Sb elements from the SP samples. 5 specimens: 5 P elements from the GEO samples. Figured specimens, CPC 37530 to CPC 37534, housed in the Commonwealth Palaeontological Collection, Geoscience Australia, Canberra, Australia.

*Description***:** The elements of this species appear similar to those described by Zhang et al. (2003) from the Stokes Siltstone, Amadeus Basin. No further revision to the open taxonomy of this species presented in that paper is possible from the limited collections from the Mithaka Fm.

*Occurrence***:** This species has only been described elsewhere from the Stokes Siltstone, Amadeus Basin.

GENUS ***Bergstroemognathus*** SERPAGLI, 1974

*Type species*: *Oistodus extensus* GRAVES and ELLISON, 1941

***Bergstroemognathus*** sp. A
Figures 2.8 to 2.10

*Material*: 5 specimens: 2 Pa and 3 Sb elements recovered from the SP samples. Figured specimens, CPC 37535 to CPC 37537, housed in the Commonwealth Palaeontological Collection, Geoscience Australia, Canberra, Australia.

*Description*: Pa element (Figs. 2.8 and 2.9) has a large, reclined, laterally compressed cusp with sharp anterior margin and rounded posterior margin. Anterior margin extends into a downwardly deflected antero-lateral process bearing one to three denticles compressed to the cusp. Process is twisted laterally. Posterior process is denticulate bearing several confluent reclined denticles. Denticles are separated from cusp by discrete space. White matter is present at tips of cusp and denticles.

Sb element (Fig. 2.10) has broad antero-posteriorly compressed cusp. Lateral flanges extend into posterior processes of unequal length. Long process has up to 13 denticles. A small adenticulate anterior anticusp is also present. White matter forms vertical bands through core of denticles of lateral processes. Angle between lateral processes in oral-aboral plane is ~120°.

***Bergstroemognathus***? n. sp. A
Figures 2.11 and 2.12

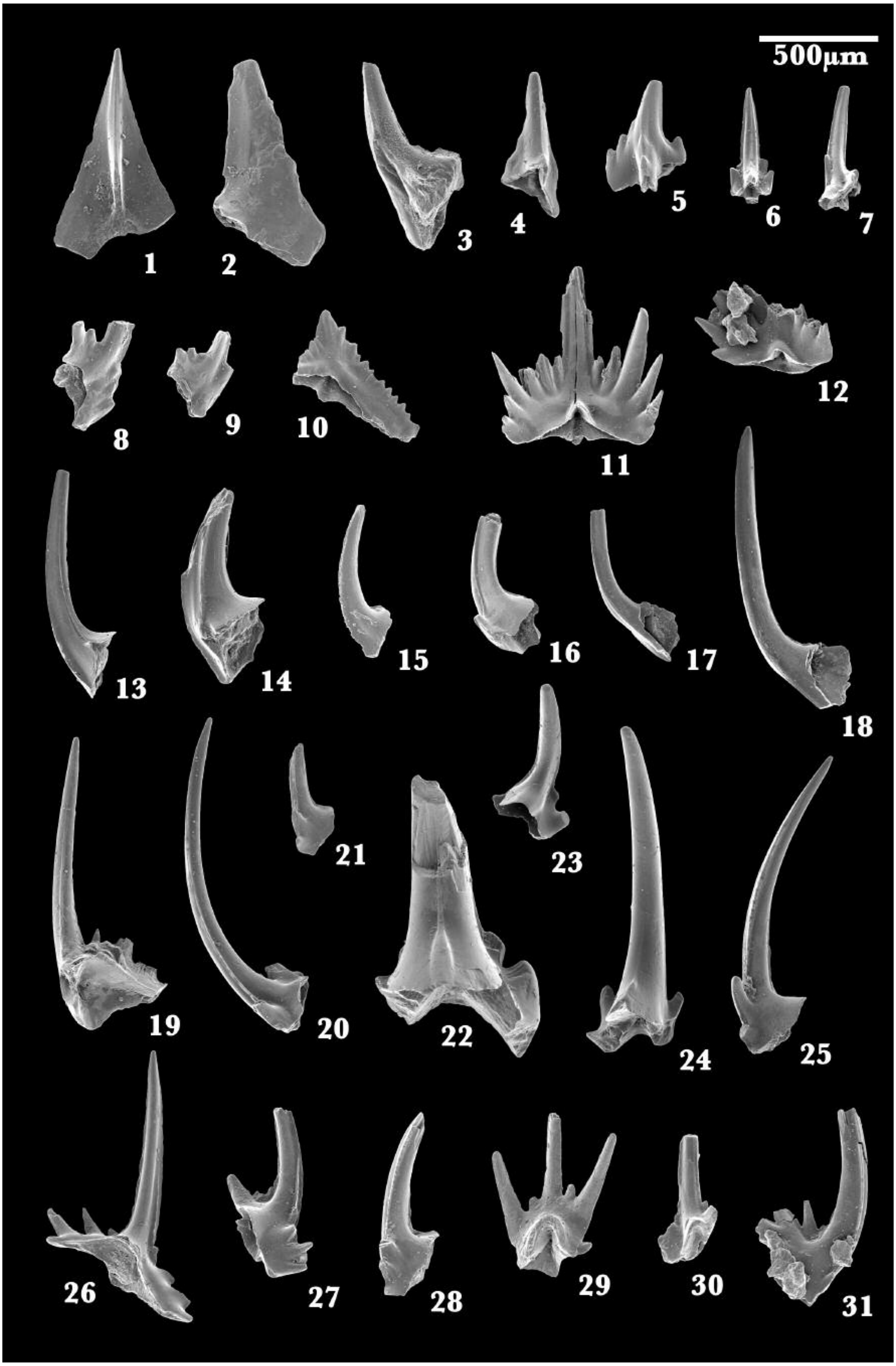
*Material*: 4 specimens: 4 Sb elements from the SP samples. 4 specimen: 2 Sa and 2 Sb elements recovered from the GEO samples. Figured specimens, CPC 37538 and CPC 37539, housed in the Commonwealth Palaeontological Collection, Geoscience Australia, Canberra, Australia.

*Diagnosis*: A species tentatively assigned to *Bergstroemognathus*, which is characterized by Sa elements with prominent anterior-posterior flattened cusp and denticles. Lateral processes are swept posteriorly, but denticles remain erect. A small oval basal cavity extends beneath lateral processes.

*Description*: Only Sa and Sb elements were recovered for this species. Sa element (Fig. 2.11) is symmetrical with anterior-posterior flattened cusp with two lateral flanges. Anterior margin is rounded and extends into a small anticusp. Posterior process is poorly developed representing posterior enlargement of basal cavity. Lateral processes are swept backwards with a sub-horizontal basal sheath connecting them. Lateral processes bear four to six antero-posteriorly flattened denticles. Angle between lateral processes in oral view is ~90°. Denticles are distinct but lateral flanges on denticles overlap near their base. Second or third denticle is largest, with following denticles reclined and decreasing in size distally. Basal cavity is small and extends partially beneath lateral processes as a shallow groove.

Sb element (Fig. 2.12) is similar to Sa element, representing the second stage of a transition series. One lateral process is deflected posteriorly.

FIGURE 2| **1-2) *Aurilobodus leptosomatus* AN, 1983. 1) Sa element, from SP 885, posterior view, CPC 37528; 2) S element, from SP 859, posterior view, CPC 37529. 3 to 7) Baltoniodus? sp. A. 3) Pb element, from SP 904, lateral view, CPC 37530; 4) Pb element, from SP 859, lateral view, CPC 37531; 5) Pa element, from SP 845, outer lateral view, CPC 37532; 6) Sa element, from SP 762, posterior view, CPC 37533; 7) Sb element, from SP 915, posterior view, CPC 37534. 8 to 10) *Bergstroemognathus* sp. A. 8) Pa element, from SP 854, inner lateral view, CPC 37535; 9) Pa element, from SP 854, lateral view, CPC 37536; 10) Sb element, from SP 854, posterior view, CPC 37537. 11- 12) *Bergstroemognathus*? n. sp. A. 11) Sa element, from GEO 048/2, posterior view, CPC 37538; 12) Sb element, from SP 867, posterior view, CPC 37539. 13 to 18) *Drucognathus yiranus* ZHANG, BARNES and cooper, 2003. 13) Pa element, from SP 790, inner lateral view, CPC 37540; 14) Pb element, from SP 777, inner lateral view, CPC 37541; 15) M element, from SP 866, inner lateral view, CPC 37542; 16) Sa element, from SP 790, postero-lateral view, CPC 37543; 17) Sb element, from SP 790, lateral view, CPC 37544; 18) Sc element, from SP 774, inner lateral view, CPC 37545. 19 to 25) *Erismodus nicolli* ZHANG, BARNES and COOPER, 2003. 19) Pa element, from SP 764, inner lateral view, CPC 37546; 20) Pb element, from SP 764, inner lateral view, CPC 37547; 21) M element, from SP 759, inner lateral view, CPC 37548; 22) Sa element, from SP 917, posterior view, CPC 37549; 23) Sa element, from SP 759, posterior view, CPC 37550; 24) Sb element, from SP 764, postero-lateral view, CPC 37551; 25) Sc element, from SP 764, inner lateral view, CPC 37552. 26 to 31) *Erismodus quadridactylus* (STAUFFER, 1935). 26) Pa element, from SP 753, inner lateral view, CPC 37553; 27) Pb element, from SP 764, inner lateral view, CPC 37554; 28) M element, from SP 763, inner lateral view, CPC 37555; 29) Sa element, from SP 763, posterior view, CPC 37556; 30) Sb element, from SP 764, posterior view, CPC 37557; 31) Sc element, from SP 763, inner lateral view, CPC 37558. All figured specimens at x 40.**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*Discussion*: This species is tentatively assigned to *Bergstroemognathus*. A larger collection is required to properly determine the generic assignment of this species.

GENUS ***Drucognathus*** ZHANG, BARNES and COOPER, 2003

*Type species*: *Drucognathus yiranus* ZHANG, BARNES and COOPER, 2003

***Drucognathus yiranus*** ZHANG, BARNES and COOPER, 2003
Figures 2.13 to 2.18

*Synonymy*:
?1973 *Dichognathus decipiens* BRANSON and MEHL, Moskalenko, pl. 15, figs. 7-12
2003 *Drucognathus yiranus* n. sp., Zhang et al., p. 12, pl. 6, figs. 1-14

*Material*: 76 specimens: 8 Pa, 9 Pb, 2 M, 13 Sa, 10 Sb and 34 Sc elements from the SP samples. 3 specimens: 1 Pa, 1 Pb and 1 Sc elements from the GEO samples. 31 specimens: 5 Pa, 2 Pb, 3 Sa, 3 Sb and 18 Sc elements from the Bedourie Scout Hole no. 1, core 3. Figured specimens, CPC 37540 to CPC 37545, housed in the Commonwealth Palaeontological Collection, Geoscience Australia, Canberra, Australia.

*Discussion*: This species has been figured and described in detail by Zhang et al. (2003). In the Mithaka Fm specimens are fragmentary. Denticles on processes are commonly broken.

*Occurrence*: *Drucognathus yiranus* was recently first described from the Upper Ordovician Stokes Siltstone (Zhang et al., 2003).

GENUS ***Erismodus*** BRANSON and MEHL, 1933

*Type species*: *Erismodus typus* BRANSON and MEHL, 1933

***Erismodus nicolli*** ZHANG, BARNES and COOPER, 2003
Figures 2.19 to 2.25

*Synonymy*:
2003 *Erismodus nicolli* n. sp., Zhang et al., p. 14, pl. 3, figs. 12-19

*Material*: 26 specimens: 2 Pa, 3 Pb, 2 M, 7 Sa, 3 Sb and 9 Sc elements from the SP samples. 2 specimens: 1 Sa and 1 Sc elements from the GEO samples. 1 specimen: 1 Sa element from the Bedourie Scout Hole no. 1, core 3. Figured specimens, CPC 37546 to CPC 37552, housed in the Commonwealth Palaeontological Collection, Geoscience Australia, Canberra, Australia.

*Description*: This species has been figured and described in detail by Zhang et al. (2003), however no Pb element was described for the species. A possible Pb element is identified here from the Mithaka Fm; it (Fig. 2.20) has a prominent cusp with posterior and antero-lateral processes. Anterior margin is rounded. A distinct lateral costa develops into antero-lateral process, which bears several small curved denticles. Posterior process has discrete proclined denticles and is deflected to outer-lateral side

*Discussion*: A more robust Sa element (Fig. 2.22) of *E. nicolli* is also recovered from the Mithaka Fm. This element is similar to the more delicate Sa elements from both the Stokes Siltstone (Zhang et al., 2003) and the Mithaka Fm, but is considerably more robust, suggesting a higher energy environment (Barnes et al., 1973).

*Occurrence*: *Erismodus nicolli* was only been observed elsewhere from the *Drucognathus yiranus* Zone of the Stokes Siltstone, Amadeus Basin (Zhang et al., 2003).

***Erismodus quadridactylus*** (STAUFFER, 1935)
Figures 2.26 to 2.31

*Synonymy*:
1935 *Chirognathus quadridactylus* n. sp., Stauffer, p. 138, pl. 9, fig. 35
1935 *Chirognathus invictus* n. sp., Stauffer, p. 137, pl. 9, fig. 43
1982 *Erismodus quadridactylus* (STAUFFER), Sweet, p. 1040, pl. 1, figs. 25-30 (includes synonymy to 1982)

*Erismodus quadridactylus* (STAUFFER), Zhang et al., p. 13, pl. 2, figs. 12-25 (includes synonymy to 2003)

*Material*: 242 specimens: 27 Pa, 41 Pb, 34 M, 30 Sa, 31 Sb, 61 Sc elements and 18 unassignable fragments from the SP samples. 29 specimens: 2 Pa, 10 Pb, 2 Sa, 4 Sb and 11 Sc elements from the GEO samples. 2 specimens: 2 Sa elements from the Bedourie Scout Hole no. 1, core 3. Figured specimens, CPC 37553 to CPC 37558, housed in the Commonwealth Palaeontological Collection, Geoscience Australia, Canberra, Australia.

*Description*: *Erismodus quadridactylus* was figured and described by Sweet (1982). Specimens from the Mithaka Fm have prominent cusps with lateral costae. Denticles of processes are antero-posteriorly compressed.

*Occurrence*: This species has also been reported from the Middle Ordovician Winnipeg Fm, South Dakota (Sweet, 1982), the Stokes Siltstone, Amadeus Basin (Zhang et al., 2003).

GENUS ***Erraticodon*** DZIK, 1978

*Type species*: *Erraticodon balticus* DZIK, 1978

***Erraticodon*** cf. ***E. patu*** COOPER, 1981
Figures 3.11 to 3.15

*Synonymy*:
1978 cf. Prioniodid conodont element, Müller, p. 276
1981 cf. *Erraticodon patu* n. sp., Cooper, p. 166, pl. 32, figs. 1-6, 8
1990 cf. *Erraticodon patu* COOPER, Nicoll, fig. 2.1
2003 cf. *Erraticodon patu* COOPER, Zhen et al., p. 195, figs. 16 A-K, 17 A-O

*Material*: 18 specimens: 1 Pa, 2 Sa, 3 Sb and 12 Sd elements from the SP samples. 4 specimen: 1 Sa and 3 Sb elements from the GEO samples. Figured specimens, CPC 37569 to CPC 37573, housed in the Commonwealth Palaeontological Collection, Geoscience Australia, Canberra, Australia.

*Description*: Zhen et al. (2003) reexamined *Erraticodon patu*, and made several revisions to the original descriptions of Cooper (1981), which are followed herein, in particular revised description of Pa and Pb elements. No Pb, M or Sc elements were recovered.

Pa element (Fig. 3.12) possesses anterior and posterior processes with large discrete denticles. Cusp is erect but only marginally larger than the largest denticle on the posterior process. Posterior process bears four denticles. Anterior process was broken on the only specimen recovered from the Mithaka Fm. Basal cavity is small and extends as a narrow groove beneath processes.

Sa element (Fig. 3.13) is symmetrical with two lateral and one posterior processes. Anterior margin extends into small anti-cusp. Cusp is distinct with sharp lateral edges, which extend into denticulated lateral processes. Denticles on lateral processes are antero-posteriorly compressed forming sharp v-shapes between denticles. Lateral processes commonly bear three denticles. Posterior process appears adenticulate although commonly broken near base of cusp.

Sb element (Figs. 3.14 and 3.15) is similar to Sa element, but has asymmetrically distributed lateral processes. Lateral processes are unequal in length bearing two to three and three to six denticles, respectively. Anterior margin extends into an anti-cusp. Posterior process is adenticulate. Basal cavity is small and extends beneath all processes as a narrow groove. A single Sb element recovered from the GEO samples (Fig. 3.15) has been tentatively grouped within this species; denticles of this element are more discrete, with a u-shape between distal denticles. Proximal denticles have a v-shape, more consistent with other Sb elements recovered from the SP samples.

Sd element (Fig. 3.11) has a large erect cusp with sharp anterior and posterior margins. Cusp has distinct costae, which extend into posteriorly deflected lateral processes. Anterior margin extends into denticulated anterior process bearing one to two indistinct denticles. Posterior process is adenticulate. Lateral processes vary from symmetrically disposed to asymmetrical, bearing two to four denticles. Second denticle on each lateral process is usually the largest, approaching size of the cusp. Denticles are antero-posteriorly compressed with sharp lateral margins.

*Occurrence*: *Erraticodon patu* has also been reported from the Horn Valley Siltstone, Amadeus Basin (Cooper, 1981), the Mount Arrowsmith and Koonenberry Gap sections, Western New South Wales (Zhen et al., 2003).

*Discussion*: These elements have been described as cf. *E. patu* for several reasons. The Pb element of *E. patu* is the most distinctive element within the apparatus, but no Pb elements were recovered from the Mithaka Fm. There are also several differences between the Mithaka specimens and those described by Cooper (1981) and Zhen et al. (2003). The primary difference is the lack of a denticulated posterior process. It is unclear from the limited number of elements recovered whether this difference warrants the distinction of a new species or represents morphological variability within the *E. patu*.

The single M element described by Zhang et al. (2003) may represent *E. patu* not the suggested *E. balticus*, however, the M element lacks the single denticle on the anterior process characteristic of *E. patu*. More specimens would be required to clarify this relationship.

GENUS ***Juanognathus*** SERPAGLI, 1974

*Type species*: *Juanognathus variabilis*, SERPAGLI, 1974

***Juanognathus*** sp. A
Figures 4.20 to 4.23

*Material*: 8 specimens: 8 S elements from the SP samples. Figured specimens, CPC 37604 to CPC 37607, housed in the Commonwealth Palaeontological Collection, Geoscience Australia, Canberra, Australia.

*Description*: Several elements of *Juanognathus* were recovered from the Mithaka Fm; all represent asymmetrical S elements. Elements are highly variable, but have two distinct variations: unicostate and bicostate. In bicostate variant (Figs. 4.20 and 4.21), costae are antero-lateral and postero-lateral. Antero-lateral costa develops into a broad flange. Cusp cross section is approximately elliptical.

The unicostate variant (Figs. 4.22 and 4.23) has single antero-lateral costa that develops into downwardly deflected adenticulate antero-lateral process. This process varies greatly in morphology.

GENUS ***Onyxodus*** WATSON, 1988

*Type species*: *Onyxodus acuoliratus* WATSON, 1988

***Onyxodus acuoliratus*** WATSON, 1988
Figures 3.16 and 3.17

*Synonymy*:
1973 aff. *Distacodus vernus* MOSKALENKO, Moskalenko, p. 29-30, pl. 2, figs 4a, b
1973 aff. *Drepanodus inventum* MOSKALENKO, Moskalenko, p. 32-33, pl. 2, figs 7, 8a, b
1973 aff. *Scandodus dulkumaensis* MOSKALENKO, Moskalenko, p. 40, pl. 23, figs 8a, b, 9
1973 aff. *Scandodus notabilis* MOSKALENKO, Moskalenko, p. 41, pl. 3, figs 10a, b, 11, 12
1988 *Onyxodus acuoliratus* n. sp., Watson, p. 120, pl. 2, figs 9a, b, 10a, b, 11

*Material*: 5 specimens: 1 Sa (symmetrical) and 4 S (asymmetrical) elements from the SP samples. 4 specimens: 2 Sa (symmetrical) and 2 S (asymmetrical) elements from the Bedourie Scout Hole no. 1, core 3. Figured specimens, CPC 37574 and CPC 37575, housed in the Commonwealth Palaeontological Collection, Geoscience Australia, Canberra, Australia.

*Description*: Symmetrical and asymmetrical elements (Figs. 3.16 and 3.17, respectively), following the description of Watson (1988), were recovered. These elements all display characteristic slender cone shaped basal cavity, which terminates at point of maximum curvature of the cusp.

*Occurrence*: *Onyxodus acuoliratus* has also been observed from Siberia (Moskalenko, 1973) and the Nita and Goldwyer formations, Canning Basin (Watson, 1988).

GENUS ***Oulodus*** BRANSON and MEHL, 1933

*Type species*: *Cordylodus serratus* STAUFFER, 1930

?***Oulodus*** sp.
Figure 3.18

*Material*: 19 specimens: 19 unidentifiable fragments from the SP samples. 4 specimens: 4 unidentifiable fragments from the Bedourie Scout Hole no. 1, core 3. Figured specimen, CPC 37576, housed in the Commonwealth Palaeontological Collection, Geoscience Australia, Canberra, Australia.

*Description*: Several fragments were recovered from the Mithaka Fm, and have been tentatively ascribed to *Oulodus* sp. due to similarities with denticles of *Oulodus*. Ends of denticles, which are commonly broken, show abundant white matter. Denticles are antero-posteriorly compressed with sub-spherical cross sections and sharp lateral margins.

GENUS ***Panderodus*** ETHINGTON, 1959

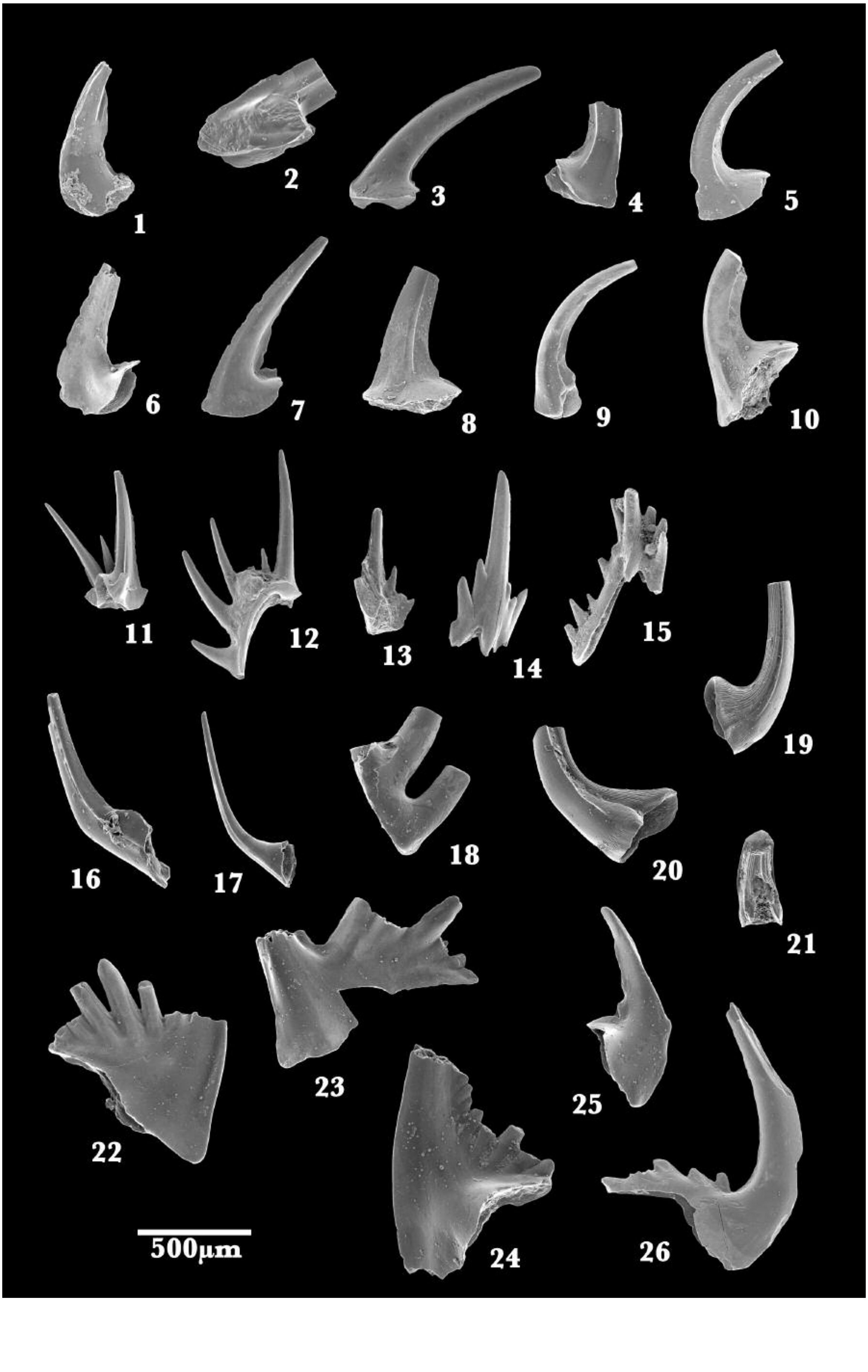
*Type species*: *Paltodus unicostatus* BRANSON and MEHL, 1933

***Panderodus nogamii*** (LEE, 1975)
Figures 3.19 to 3.21

*Synonymy*:
1975 *Scolopodus nogamii* n. sp., Lee, p. 179, p. 2, Fig. 13; text-fig. L
1983 *Scolopodus nogamii* LEE, An et al., p. 144, pl. 13, figs 20-25
1983 *Scolopodus euspinus* n. sp., Jiang and Zhang *in* An et al., p. 140, pl. 13, fig. 27, pl. 14, Fig. 1-8
1988 *Protopanderodus nogamii* (LEE), Watson, p. 124, pl. 3, figs. 1a, 1b, 6a, 6b
2003 *Panderodus nogamii* LEE, Zhang et al., p. 16, pl. 5, figs. 1-5
2003 *Protopanderodus nogamii* (LEE), Zhen et al., p. 207-209, fig. 23A-P, ?Q

*Material*: 30 specimens: 6 M, 7 Sa and 17 S elements from the SP samples. 3 specimens: 1 Sa and 2 S elements

FIGURE 3 | **1 to 5) *Drepanoistodus basiovalis* (SERGEEVA, 1963). All figured specimens from SP 763. 1) P element, inner lateral view, CPC 37559. 2) M element, inner lateral view, CPC 37560. 3) Sa element, lateral view, CPC 37561. 4) Sb element, inner lateral view, CPC 37562. 5) Sc element, outer lateral view, CPC 37563. 6 to 10) *Drepanoistodus suberectus* (BRANSON and MEHL, 1933). All specimens from GEO 048/4. 6) P element, inner lateral view, CPC 37564; 7) M element, inner lateral view, CPC 37565; 8) Sa element, lateral view, CPC 37566; 9) Sb element, outer lateral view, CPC 37567; 10) Sc element, outer lateral view, CPC 37568. 11 to 15. *Erraticodon* cf. *E. patu* COOPER, 1981. 11) Sd element, from SP 753, inner lateral view, CPC 37569; 12) Pa element, from SP 749, lateral view, CPC 37570; 13) Sa element, from SP 915, postero-lateral view, CPC 37571; 14) Sb element, from SP 917, antero-lateral view, CPC 37572; 15) Sb element, from GEO 046/34, posterior view, CPC 37573. 16-17) *Onyxodus acuoliratus* WATSON, 1988. 16) S-symmetrical element, from SP 765, lateral view, CPC 37574; 17) S-asymmetrical element, from SP 772, inner lateral view, CPC 37575. 18) ?*Oulodus* sp. Unidentified fragment, from SP 790, anterior view, CPC 37576. 19 to .21. *Panderodus nogamii* (LEE, 1975). 19) S-asymmetrical element, from SP 850, lateral view, CPC 37577; 20) M element, from SP 762, lateral view, CPC 37578; 21) Sa-symmetrical element, from SP 850, posterior view, CPC 37579. 22 to 25) ?*Periodon* n. sp. A. 22) Pa element, from SP 761, inner lateral view, CPC 37580; 23) Pb element, from SP 761, inner lateral view, CPC 37581; 24) M element, from SP 763, inner lateral view, CPC 37582; 25) M element, from SP 763, inner lateral view, CPC 37583. 26) Gen. et sp. indet. B. Sc element, from SP 913, outer lateral view, CPC 37584. All figured specimens at x 40.**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from the GEO samples. Figured specimens, CPC 37577 to CPC 37579, housed in the Commonwealth Palaeontological Collection, Geoscience Australia, Canberra, Australia.

*Description*: No P elements were recovered from the Mithaka Fm M, symmetrical and asymmetrical S elements were recovered. M element (Fig. 3.20) has a large reclined cusp with two lateral costae. Strong curvature is observed at the tip of the basal cavity. Anterior margin is rounded and smooth. Faint striations are apparent at anterior basal margin. Posterior margin is distinctly striated between lateral costae. Posterior basal margin is expanded.

Symmetrical S elements (Fig. 3.21) have a large proclined cusp with two symmetrically disposed lateral grooves. Anterior margin is rounded and smooth, with no striations. Antero-basal margin possesses faint striations. The posterior margin is distinctly striated between lateral grooves.

Asymmetrical S element (Fig. 3.19) is similar to S-symmetrical in all respects, except lateral grooves are not symmetrically distributed.

*Occurrence*: This species has also been described from North China (e.g. An et al., 1983) and several locations in Australia, including the Nita and Goldwyer formations, Canning Basin (Watson, 1988) and the Stokes Siltstone, Amadeus Basin (Zhang et al., 2003).

*Discussion*: The generic taxonomy of this species has been much debated. The presence of white matter within elements of this species and its distinctive striation pattern distinguish it from previously used genera, *Scolopodus* and *Protopanderodus*, respectively.

GENUS ***Periodon*** HADDING, 1913

*Type species*: *Periodon aculeatus* HADDING, 1913

?***Periodon*** n. sp. A
Figures 3.22 to 3.25

*Material*: 31 specimens: 8 Pa, 5 Pb and 18 M elements from the SP samples. 2 specimens: 2 M elements from the Bedourie Scout Hole no. 1, core 3. Figured specimens, CPC 37580 to CPC 37583, housed in the Commonwealth Palaeontological Collection, Geoscience Australia, Canberra, Australia.

*Diagnosis*: A species tentatively assigned to *Periodon*, which is characterized by large laterally compressed cusps on P and M elements. The posterior margin of P and M elements bear large reclined laterally compressed denticles with white matter cores.

*Description*: M elements tentatively assigned to *Periodon* are highly variable. P elements show a more constant morphology. No S elements were recovered from the Mithaka Fm, although a possible Sc element was recovered from sample SP 913. This specimen is herein referred to gen. et sp. indet. B.

Pa element (Fig. 3.22) has a large laterally compressed reclined cusp with sharp anterior and posterior margins. Anterior margin extends into adenticulate indistinct anterior process. Posterior margin extends into denticulated posterior process. Denticles on posterior process are reclined, with middle denticles being the largest and most discrete. Denticles are laterally compressed with sharp anterior and posterior edges. In oral view, the element is linear, with slight inner flare of basal margin. Basal cavity is deep, and bears a distinctive "sickle-shaped" termination. White matter is present within cores of denticles, extending to tip of basal cavity.

Pb element (Fig. 3.23) is similar to Pa element. Anterior process is better developed and twists outwardly. Posterior process has a well-developed sinuosity in oral view.

M element (Figs. 3.24 and 3.25) is highly variable with posterior process that varies continuously from strongly denticulated to adenticulate. Cusp is large, reclined and laterally compressed with sharp anterior and posterior margins. Anterior margin extends into a thin sharp corner. Posterior margin extends into a posterior process and varies from adenticulate to denticulate. Denticulation extends onto posterior process. Adenticulate elements show furrows and white matter development that is suggestive of denticle formation. Basal cavity is similar in shape to that of P elements, although sickle curvature is subdued. Base is flared on inner side.

*Discussion*: This element shows generic level similarity with *Periodon flabellum* reported from Jämtland, Sweden (Löfgren, 1978) and from the Hubei Province (An et al., 1985a), but represents a distinct species.

The specimen herein referred to gen. et sp. indet B may be the Sc element of this species of ?*Periodon*. The low recovery (a single Sc element) has prevented determination of this relationship. The basal cavity of gen. et sp. indet. B is similar in shape to the distinctive P element basal cavity.

GENUS ***Phragmodus*** BRANSON and MEHL, 1933

*Type species*: *Phragmodus primus* BRANSON and MEHL, 1933

***Phragmodus polystrophos*** WATSON, 1988
Figures 4.1 to 4.6

*Synonymy*:

1988 *Phragmodus polystrophos* n. sp., Watson, p. 121, pl. 6, figs. 20, 21, 24-27, pl. 7, figs. 10, 12-16 (includes detailed synonymy to 1988)

*Material*: 34 specimens: 4 Pa, 1 Pb, 7 M, 2 Sa, 7 Sb and 13 Sc elements from the SP samples. 34 specimens: 5 Pa, 3 Pb, 6 M, 4 Sa, 8 Sb and 8 Sc elements from the GEO samples. 14 specimens: 4 Pa, 3 M, 2 Sb and 5 Sc elements from the Bedourie Scout Hole no. 1, core 3. Figured specimens, CPC 37585 to CPC 37590, housed in the Commonwealth Palaeontological Collection, Geoscience Australia, Canberra, Australia.

*Description*: This species is similar in most respects to that described by Watson (1988), but M element differs slightly.

Pa element (Fig. 4.1) has erect cusp, which has white matter distally. Anterior and posterior margins are sharp. A distinctive serrated denticulation occurs on basal portion of anterior margin. Posterior margin extends into a short adenticulate posterior margin. Small adenticulate inner-lateral process is also present.

Pb element (Fig. 4.2) is similar to Pa element, with distinctive serrated denticulation on basal anterior margin. Posterior process is denticulated. A broad basal flange extends horizontally between lateral and posterior processes.

M element (Fig. 4.3) has a distinct reclined cusp with sharp anterior and posterior margins. Anterior margin, as with P elements, has the defining serrated denticulation on basal portion. M element however varies from those described by Watson (1988) in lacking an extended adenticulate posterior process.

Sa element (Fig. 4.4) has a distinct erect cusp with two symmetrical lateral costae. Anterior margin is rounded, and is inwardly deflected at basal end. Posterior margin is sharp and extends into denticulated posterior process. Denticles are reclined and increase in size distally. Posterior process is slightly curved. Lateral costae extend into short adenticulate lateral processes. Lateral costae and processes are anteriorly positioned on the cusp.

Sb element (Fig. 4.6) is similar to Sa element, except cusp is proclined and lateral processes are asymmetrically distributed. Inner lateral process is located at anterior edge of cusp.

Sc element (Fig. 4.5) is similar to Sa and Sb elements, with the exception of having no lateral processes.

*Occurrence*: This species has also been found in the Nita and Goldwyer Formations, Canning Basin (Watson, 1988). A detailed discussion of synonymous global occurrences is presented by Watson (1988).

*Discussion*: This species represents the smallest conodont elements recovered from the Mithaka Fm. It is the main constituent of the deeper water fauna observed within the Mithaka Fm.

The presence of *Phragmodus polystrophos* within the Gisbornian age Mithaka Fm represents the latest known occurrence of *P. polystrophos*. This may be a result of the Georgina Basin (and possibly other basins) acting as a refugium, which lacks *P. flexuosus* to replaces *P. polystrophos*, as in later strata of Siberia and North America.

***Phragmodus*** n. sp. A
Figures 4.7 to 4.12

*Material*: 22 specimens: 5 Pa, 2 Pb, 2 M, 1 Sa, 7 Sb and 5 Sc elements from the SP samples. 2 specimens: 1 Pa and 1 Pb elements from the GEO samples. 10 specimens: 1 M, 1 Sa, 4 Sb and 4 Sc elements from the Bedourie Scout Hole no. 1, core 3. Figured specimens, CPC 37591 to CPC 37596, housed in the Commonwealth Palaeontological Collection, Geoscience Australia, Canberra, Australia.

*Diagnosis*: A species of *Phragmodus* with Pa, Pb, M, Sa, Sb, Sc elements, characterized by P elements bearing two to four large denticles on the anterior processes, and posterior process of Pb element. Denticles are flattened against the cusp.

*Description*: This species is represented by Pa, Pb, M, Sa, Sb and Sc elements. These elements are considerably larger than those of *Phragmodus polystrophos*.

Pa element (Fig. 4.7) has a broad laterally compressed erect cusp with sharp anterior and posterior margins. Anterior margin extends into denticulated anterior process with two to three indistinct denticles. Denticles are flattened against cusp. Posterior margin extends into short adenticulate posterior process. Basal cavity flares to both sides.

Pb element (Fig. 4.8) is similar to Pa element but anterior process is better developed, bearing three to four denticles. Anterior process is twisted to inner-lateral side. Posterior process is denticulate with two to three denticles. Basal cavity flares to the outside.

M element (Fig. 4.9) has a large laterally compressed cusp with sharp anterior and posterior margins. Cusp is curved slightly to inside. Posterior margin extends into denticulated posterior process, bearing two to three reclined denticles. Basal cavity flares on both sides.

Sa element (Fig. 4.10) has a distinct proclined cusp with sharp anterior and posterior margins. Two symmetrically distributed lateral costae fade distally. Anterior margin extends into large anti-cusp-like projection that is inwardly deflected. Posterior margin is denticulated. Denticles are not strongly reclined (less than Sa element of *P. polystrophos*). Denticles increase in size distally. Both lateral costae extend into downwardly projecting adenticulate lateral processes. These processes are located in middle of the cusp and extend beyond the basal cavity. Basal cavity is deep and extends beneath all processes.

Sb element (Fig. 4.11) is similar to Sa element except lateral costae are asymmetrically distributed. Sc element (Fig. 4.12) is similar, but lacks lateral costae and processes.

*Occurrence*: This species is only known from the Mithaka Fm.

*Discussion*: The elements of this species are much larger than those of *P. polystrophos*. This species is found within the shallower water fauna of the Mithaka Fm. The second transition series of the this species shows similarity to the unnamed new *Phragmodus* species described by Zhang et al. (2003) from the Stokes Siltstone, Amadeus Basin. The first transition series (Pa, Pb and M elements) are significantly different, resulting in the present interpretation of this *Phragmodus* species as different from *P.* n. sp. A of Zhang et al. (2003).

GENUS ***Polycaulodus*** BRANSON and MEHL, 1933

*Type species*: *Polycaulodus bidentatus* BRANSON and MEHL, 1933

***Polycaulodus bidentatus*** BRANSON and MEHL, 1933
Figure 4.15
*Synonymy*:
1933 *Polycaulodus bidentatus* n. sp., Branson and Mehl, p. 106, pl. 8, figs, 1-3

*Material*: 1 specimen: 1 unassigned element from the GEO samples. Figured specimen, CPC 37599, housed in the Commonwealth Palaeontological Collection, Geoscience Australia, Canberra, Australia.

*Description*: Only one element (Fig. 4.15) of *P. bidentatus* was recovered from the Mithaka Fm. Specimen has 2 distinct denticles, central one is slightly larger than the other. Both are inclined to one side. Base is roughly elliptical with the length approximately twice the width. Base is shallowly excavated.

GENUS ***Serratognathus*** LEE, 1970

*Type species*: *Serratognathus bilobatus* LEE, 1970

***Serratognathus***? sp.
Figure 4.13

*Material*: 2 specimens: 2 Sa elements from the SP samples. Figured specimen, CPC 37597, housed in the Commonwealth Palaeontological Collection, Geoscience Australia, Canberra, Australia.

*Description*: Two fragmentary elements of *Serratognathus*? were recovered from the Mithaka Fm Sa element (Fig. 4.13) has a triangular shape in posterior view. Lateral margins are extended into flanges with rough edges. Anterior margin is broad and smooth. Posterior margin is irregular and broken. A distinct protrusion occurs at the tip of cusp.

GENUS ***Taoqupognathus*** AN *in* An et al., 1985b

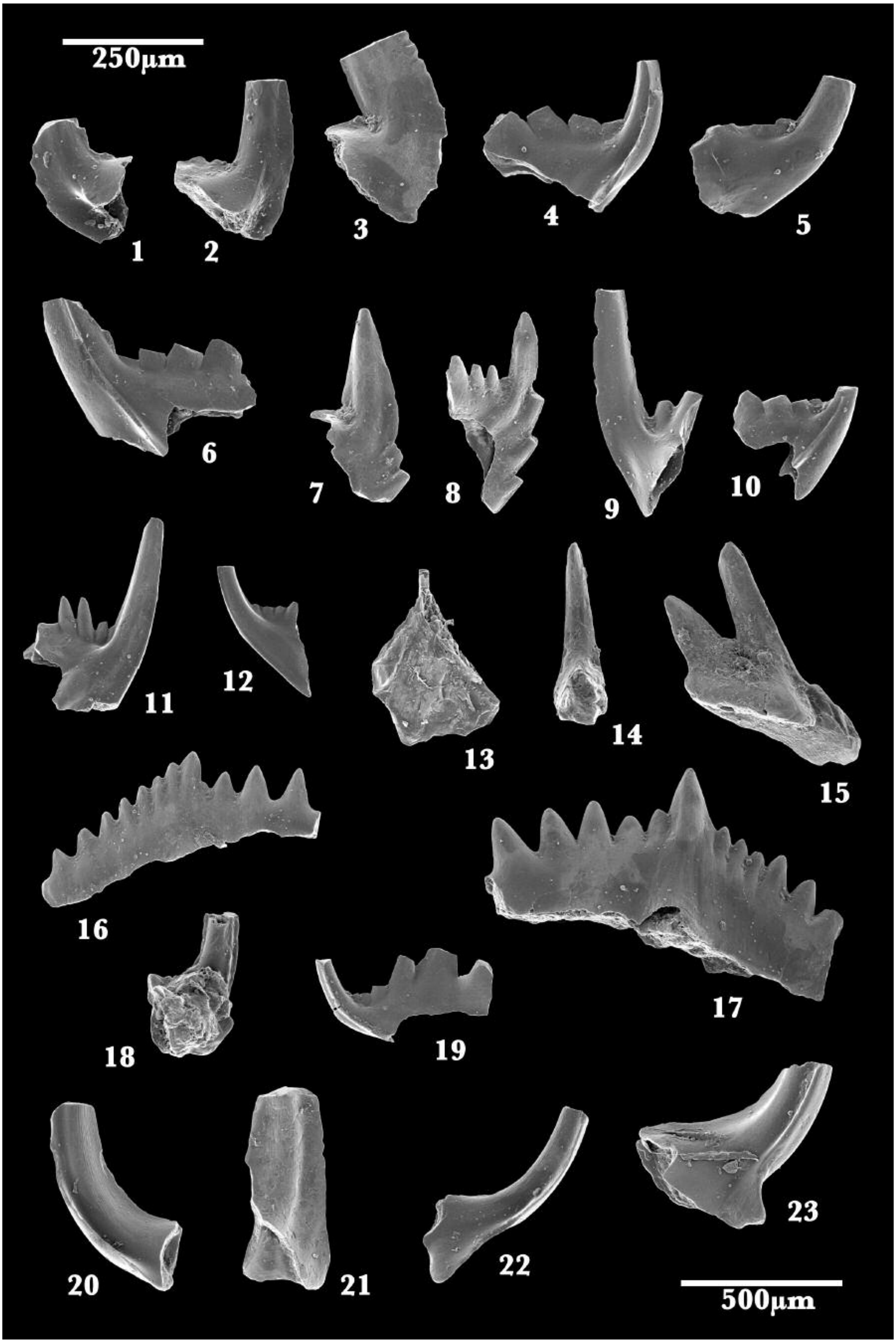
*Type species*: *Taoqupognathus blandus* AN in An et al., 1985b

***Taoqupognathus*** n. sp. A
Figures 5.14 and 5.15

*Material*: 1 specimen: 1 P element from the SP samples. Figured specimen, CPC 37621, housed in the Commonwealth Palaeontological Collection, Geoscience Australia, Canberra, Australia.

*Diagnosis*: A species of *Taoqupognathus* characterized by a distinctly denticulated posterior margin with

FIGURE 4| **All specimens at x 55, unless otherwise noted. 1 to 6) *Phragmodus polystrophos* WATSON, 1988. All figured specimens from GEO 038/11 and at x 95. 1) Pa element, inner lateral view, CPC 37585; 2) Pb element, from GEO 038/35, inner lateral view, CPC 37586; 3) M element, inner lateral view, CPC 37587; 4) Sa element, lateral view, CPC 37588; 5) Sc element, lateral view, CPC 37589; 6) Sb element, inner lateral view, CPC 37590. 7 to 12. *Phragmodus* n. sp. A. 7) Pa element, from SP. 762, inner lateral view, CPC 37591; 8) Pb element, from SP 764, inner lateral view, CPC 37592; 9) M element, from 764, inner lateral view, CPC 37593; 10) Sa element, from 764, lateral view, CPC 37594; 11) Sb element, from SP 762, inner lateral view, CPC 37595; 12) Sc element, from SP 762, lateral view, CPC 37596. 13) ?*Serratognathus* sp. Sa element, from SP 774, posterior view, CPC 37597. 14) *Staufferella divisa* SWEET, 1982. Sa element, from SP 795, posterior view, CPC 37598. 15) *Polycaulodus bidentatus* BRANSON and MEHL, 1933. ? element, from GEO 046/34, posterior view, CPC 37599. 16 to 19) *Yaoxianognathus*? *neonychodonta* ZHANG, BARNES and COOPER, 2003. 16) Pa element, from SP 833, outer lateral view, CPC 37600; 17) Pa element, from SP 833, inner lateral view, CPC 37601; 18) Pb element, from SP 854, inner lateral view, CPC 37602; 19) Sc element, from SP 784, lateral view, CPC 37603. 20 to 23. Juanognathus sp. A. 20) S element, from SP 764, inner lateral view, CPC 37604; 21) S element, from SP 764, posterior view, CPC 37605; 22) S element, from SP 764, inner lateral view, CPC 37606; 23) S element, from SP 763, inner lateral view, CPC 37607.**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numerous small pits at the denticle – cusp interface. No concentrically ridged basal flange is present.

*Description*: The apparatus of *Taoqupognathus* contains 4 elements (with 10 morphotypes) (Zhen and Webby, 1995). A single P element of a new species of *Taoqupognathus* is recognized from the Mithaka Fm. P element (Figs. 5.14 and 5.15) has broad cusp with distinct curvature at distal end. Tip of the cusp curves nearly horizontal. Anterior margin is rounded. Antero-basal margin extends forwards beyond line of anterior margin of cusp. Posterior margin is denticulated with denticulated posterior process; denticulation ends just passed maximum extension of the posterior margin. At denticle – cusp interface are numerous small pits. Some small pits are also present near anterior margin. Basal margin differs from previously described species.

*Discussion*: This specimen represents the oldest known occurrence of *Taoqupognathus* in Australia. The genus has been recovered primarily from the Molong Volcanic Belt, New South Wales (e.g. Zhen et al., 1999). This element had a higher CAI (2.5) than other elements from the same sample and from all other samples had a lower CAI (1.5). This new species may represent an early form of *Taoqupognathus*, but a larger sample number is required to clarify this suggestion.

GENUS ***Triangulodus*** VAN WAMEL, 1974

*Type species*: *Paltodus volchovensis* SERGEEVA, 1963

***Triangulodus mithakensis*** n. sp.
Figures 5.1 to 5.13

*Material*: 342 specimens: 39 Pa, 42 Pb, 62 M, 49 Sa, 43 Sb, 71 Sc and 36 Sd elements from the SP samples. 72 specimens: 9 Pa, 12 Pb, 19 M, 6 Sa, 9 Sb, 11 Sc and 6 Sd elements from the GEO samples. 25 specimens: 4 Pa, 3 Pb, 4 M, 1 Sa, 7 Sb, 5 Sc and 1 Sd elements from the Bedourie Scout Hole no. 1, core 3. Figured specimens, CPC 37608 to CPC 37620, housed in the Commonwealth Palaeontological Collection, Geoscience Australia, Canberra, Australia.

*Diagnosis*: A species of *Triangulodus* with Pa, Pb, M, Sa, Sb, Sc and Sd elements, characterized by elements of the second transition series with distinct lateral processes that form a small but distinct lateral arch. P and M elements have broad sharp anterior and posterior flanges. The base is commonly jagged.

*Description*: Pa element (Figs. 5.1 and 5.2) has a proclined to erect cusp with sharp anterior and posterior edges. Cusp is twisted so that anterior and posterior margins form antero-lateral and postero-lateral flanges. Anterior margin extends to sharp corner at its basal extent. Posterior corner is commonly broken. Base opens to both sides. Basal cavity is large with a slightly curved drawn out termination beneath center of cusp.

Pb element (Fig. 5.3) is similar to Pa element except cusp is erect to reclined and antero-lateral and postero-lateral flanges are better developed. Anterior margin of cusp has a sudden curvature above posterior margin termination.

M element (Figs. 5.4 and 5.5) has broad laterally compressed cusp with sharp anterior and posterior margins. Anterior and posterior margins develop into small flanges, which have less lateral component than flanges of P elements. Basal cavity is similar in shape to that of P elements. Base is prominently flared to inside, while only slightly flared to outer side.

Sa element (Figs. 5.6 and 5.7) is symmetrical with two lateral and one posterior costae. Anterior margin is round and deflected inwards. Lateral costae extend into lateral processes with a subdued but distinctive lateral arch. Cusp is triangular in cross section near the base. Basal cavity is deep and forms an equilateral triangle when viewed laterally.

Sb element (Figs. 5.8 and 5.9) is similar to Sa element, except that lateral costae are not symmetrically disposed. Lateral arch is still present, but more subdued.

Sc element (Figs. 5.10 and 5.11) has large proclined cusp with one posterior and one antero-lateral costae. Anterior margin is downwardly deflected and extends into a sharp corner. Posterior margin and process can have a small lateral flange. Basal cavity is triangular in shape when viewed laterally.

Sd element (Figs. 5.12 and 5.13) has a large proclined cusp with four pronounced costae. Cusp is twisted such that costae are arranged anterior, posterior and two lateral at distally end of cusp and two postero-lateral, two antero-lateral at base of cusp. Antero-lateral costae extend into sharp corners.

*Etymology*: From the Mithaka Fm, where this species is first described

*Type*: Holotype: Sa element, Fig. 5.6; all others paratypes

*Occurrence*: This species has only been observed in the Mithaka Fm.

*Discussion*: This species shows close similarity with *Triangulodus brevibasis* (in van Wamel, 1974, and Stait and Druce, 1993). However, there is sufficient difference in the elements to warrant designation as a new species, which likely evolved from *T. brevibasis*. This new species has a more abbreviated basal cavity than *T. brevibasis* as figured by van Wamel (1974). The opening of the basal cavity of the P and M elements is much more vertical than that of *T. brevibasis*. The elements described as *T.* cf. *T. brevibasis* by Stait and Druce (1993) likely represent the transition between *T. brevibasis* and *T. mithakensis* n. sp..

GENUS ***Yaoxianognathus*** AN et al., 1985b

*Type species*: *Yaoxianognathus yaoxianensis* AN et al., 1985b

***Yaoxianognathus*? *neonychodonta*** ZHANG, BARNES and COOPER, 2003
Figures 4.16 to 4.19

*Synonymy*:
2003 *Yaoxianognathus*? *neonychodonta* n. sp., Zhang et al., p. 19, pl. 7, figs, 1-12

*Material*: 14 specimens: 2 Pa, 7 Pb, 1 M, and 4 Sc elements from the SP samples. 7 specimens: 2 Pa, 4 Pb and 1 Sc elements from the GEO samples. 8 specimens: 4 Sc and 4 unassignable fragments from the Bedourie Scout Hole no. 1, core 3. Figured specimens, CPC 37600 to CPC 37603, housed in the Commonwealth Palaeontological Collection, Geoscience Australia, Canberra, Australia.

*Description*: This species has been well described by Zhang et al. (2003). Because of the small sample size, little can be added to this description from the specimens of the Mithaka Fm.

*Occurrence*: This species has been observed in the Stokes Siltstone, Amadeus Basin (Zhang et al., 2003) and the Mithaka Fm.

**Gen. et sp. indet. A**
Figure 5.16

*Material*: 1 specimen: 1 Sb element from the SP samples. Figured specimen, CPC 37622, housed in the Commonwealth Palaeontological Collection, Geoscience Australia, Canberra, Australia.

*Description*: A single Sb element of this indeterminate genus and species was recovered. It (Fig. 5.16) has a large erect cusp with rounded anterior and posterior margins. Anterior process is deflected inwardly so that at its termination the margin is nearly horizontal. Posterior process bears several small discrete denticles that are widely spaced from cusp. Denticulated antero-lateral process bears four small indistinct denticles. Basal cavity is deep and extends beneath all processes. Lateral and posterior processes are connected by thin basal flange, which is broken in this specimen.

**Gen. et sp. indet. B**
Figure 3.26

*Material*: 3 specimen: 3 Sc element from the SP samples. Figured specimen, CPC 37584, housed in the Commonwealth Palaeontological Collection, Geoscience Australia, Canberra, Australia.

*Description*: Sc element (Fig. 3.26) has a large distinct recurved cusp that has sharp anterior margin and rounded posterior margin. Anterior margin is inwardly deflected basally. A long slender posterior process extends from posterior margin. Posterior process bears five reclined denticles. Basal cavity is distinctly sickle-shaped at its termination and extends beneath posterior process.

*Discussion*: This specimen is described as gen. et sp. indeterminate but is similar to ?*Periodon* n. sp. A in the curved nature of the termination of the basal cavity. A larger collection would be required to determine if this element represents the Sc element of ?*Periodon* n. sp. A.

## MITHAKA FORMATION CONODONT FAUNA

Of the 25 species recognized from the Mithaka Fm, five represent new species, one represents a variation of a previously described species and two more represent unknown genera and species. The limited conodont abundance of this study has only allowed one of the five suggested new species to be formally named. Several specimens are tentatively assigned to known genera, but may represent new genera (*Bergstroemognathus*? n. sp. A) when a larger collection clarifies their entire apparatus.

Two faunas are recognized within the Mithaka Fm. Within the GEO (outcrop grab) samples (Table 2 in electronic version), two distinctive faunas are observed: a low diversity deeper water fauna dominated by *Phragmodus polystrophos* WATSON and a shallower water fauna dominated by *Triangulodus mithakensis* n. sp. and *Erismodus quadridactylus* STAUFFER. The deeper water fauna is composed of very small elements representing only a few species. *Triangulodus mithakensis* n. sp. is present within the deeper water fauna, but elements are considerably smaller than those found within the shallower water fauna. Within the SP samples (Table 3 in electronic version), and Bedourie Scout Hole samples (Table 4 in electronic version), the deeper fauna representative *P. polystrophos* is sparse, representing only a few specimens in several samples and the deeper water – shallower water faunal pattern is less evident, although samples SP 774 through

SP 795 do show the characteristic small specimens of a less diverse assemblage of conodonts. A larger sample base would be required to better establish the shallow water – deep water distribution pattern.

The dominant species in the Mithaka Fm belongs to the shallow water fauna assemblage and is a new species of *Triangulodus* (*T. mithakensis* n. sp.). Two erismodid species comprised another significant portion of the fauna. *Erismodus* has, in North America, been considered characteristic of nearshore, restricted environments (Barnes et al., 1973). Nevertheless, two species of *Phragmodus* (*P. polystrophos* and *P.* n. sp. A) are also relatively abundant within the Mithaka Fm. *Phragmodus polystrophos* in particular appears in restricted samples, but when present is commonly abundant (usually the dominant species within that sample). Middle to Late Ordovician sequences from North America (Midcontinent or Laurentian Province) (e.g. Sweet, 1982, 1984) and the Molong Volcanic Arc sequences from central New South Wales (Zhen and Webby, 1995; Zhen et al., 1999) contain abundant *Plectodina* and *Phragmodus* in deeper subtidal environments (Figs. 1 and 7). Consequently the conodont faunas recorded here suggest a more open shallow subtidal environment over the earlier open lagoonal setting.

## REGIONAL CORRELATION AND IMPLICATIONS

The Mithaka fauna differs from that of the nearby Stokes Siltstone (Zhang et al., 2003) in several characteristics and shows more similarity with faunas recovered from the Canning Basin (e.g. Watson, 1988) and the island arc sequences of central New South Wales (Zhen and Webby, 1995).

Correlations between the Georgina, Amadeus and Canning basins and the Molong Volcanic Arc do little to determine a precise age of the Mithaka Fm as no similar aged sections have been described (Fig. 1B). The Mithaka Fm shares five genera and species in common with the Nita and Goldwyer formations from the Canning basin: *Aurilobodus leptosomatus*, *Drepanoistodus basiovalis*, *Onyxodus acuoliratus*, *Phragmodus polystrophos* and *Juanognathus* sp (Watson, 1988). All of these, with the exception of *A. leptosomatus*, are open water, widespread species. *Aurilobodus leptosomatus* is considered a zonal species (late Early Ordovician to Middle Ordovician) in North China (An et al., 1983), however its upper stratigraphic limit is uncertain.

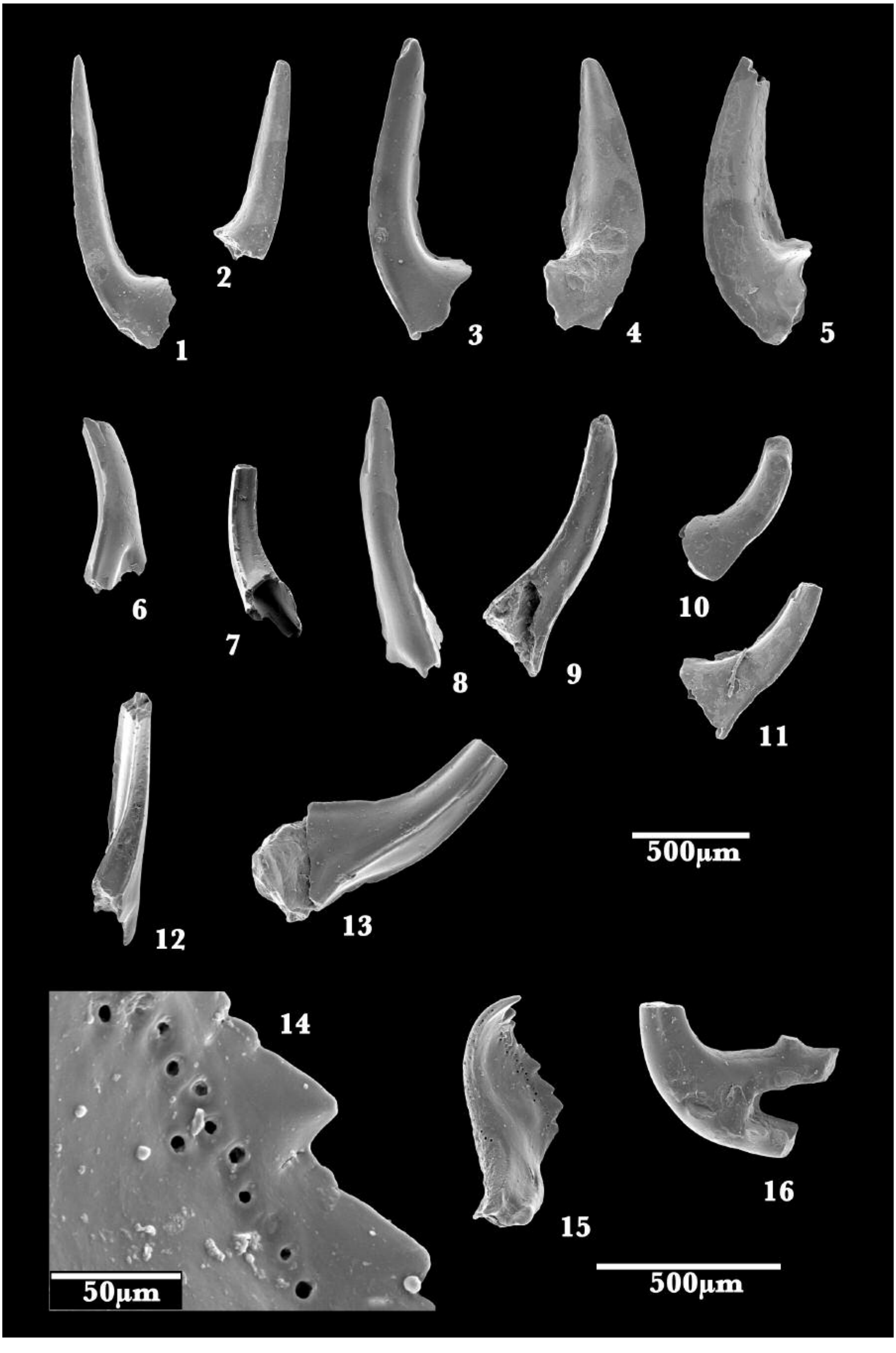
The Mithaka Fm shows some similarity with the Middle Ordovician fauna of the Coolibah Fm, Georgina Basin (Stait and Druce, 1993). One species appears in both faunas, *Aurilobodus leptosomatus*, although there has been significant evolutionary change between both representatives. *Triangulodus mithakensis* n. sp. is believed to have evolved from *T. brevibasis*, which is present in the Coolibah Fm. However, the Coolibah form, which is only tentatively described as representing *T. brevibasis*, may actually be the earliest form of *T. mithakensis* n. sp.

Several species are common between the Mithaka Fm and the Stokes Siltstone (Zhang et al., 2003). In particular, the presence of *Erismodus quadridactylus* and *Drucognathus yiranus*, as well as lesser amounts of *Yaoxianognathus*? *neonychodonta* are important for correlation between these two units. The presence of *D. yiranus* and the lack of any *Erismodus typus*, allows correlation of the Mithaka Fm with the upper *D. yiranus* Zone (Fig. 6; Zhang et al., 2003).

The presence of *Drepanoistodus basiovalis* and *Taoqupognathus* n. sp. A poses some interesting questions. It is difficult to rule out the possibility of reworking, as stratigraphic control on sample locations is limited. *Drepanoistodus basiovalis* is generally considered an Early to Middle Ordovician species, making its presence within the Mithaka Fm the youngest known occurrence of this species. There is some difference between these and elements assigned to *D. suberectus*, which is generally considered the younger species, arising from the later. The primary distinction is on the hyaline nature of *D. basiovalis* compared to the more white matter in *D. suberectus*. Morphological differences in the M elements support the two species designation.

*Taoqupognathus* n. sp. A is a characteristic Late Ordovician form, for example in central New South Wales (Zhen and Webby, 1995; Zhen et al., 1999). It is unclear from the Mithaka sample (1 P element was recovered) whether this new species represents an earlier form of previously identified (and younger) species or should be considered a new species. The single P element was excluded from biostratigraphic interpretation.

FIGURE 5| **1 to 13) *Triangulodus mithakensis* n. sp. All figured specimens at x 40. 1) Pa element, paratype, from SP 757, inner lateral view, CPC 37608; 2) Pa element, paratype, from SP 763, inner lateral view, CPC 37609; 3) Pb element, paratype, from SP 757, inner lateral view, CPC 37610; 4) M element, paratype, from SP 757, inner lateral view, CPC 37611; 5)M element, paratype, from SP 913, inner lateral view, CPC 37612; 6) Sa element, holotype, from SP 763, antero-lateral view, CPC 37613; 7) Sa element, paratype, from SP 759, postero-lateral view, CPC 37614; 8) Sb element, paratype, from SP 757, antero-lateral view, CPC 37615; 9) Sb element, paratype, from SP 760, postero-lateral view, CPC 37616; 10) Sc element, paratype, from SP 757, inner lateral view, CPC 37617; 11) Sc element, paratype, from SP 761, inner lateral view, CPC 37618; 12) Sd element, paratype, from SP 757, posterior, CPC 37619; 13) Sd element, paratype, from SP 761, inner lateral view, CPC 37620. 14-15) *Taoqupognathus* n. sp. A. 14) P element, from SP 846, enlargement of posterior denticulation showing small pits, x 430, CPC 37621; 15) P element, inner lateral view, same element as Fig. 14, x 63. 16) Gen. et sp. indet. A. Sb element, from SP 853, inner lateral view, x 63, CPC 37622.**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500μm

Regional correlation between Australian basins provides support for the recent tectonic history of central Australia proposed by Haines et al. (2001). They suggested that a period of extensional deformation occurred during the Early and Middle Ordovician, followed by a switch to a compressional regime, known as the Alice Springs Orogeny, during the Late Ordovician. Isotopic dating of metamorphism related to the Alice Springs Orogeny provided an age of 450-443 Ma within the Amadeus Basin (Haines et al., 2001) and was contemporaneous with the beginning of deposition of the Carmichael Sandstone. The Ethabuka Sandstone is believed to be analogous and contemporaneous with the Carmichael Sandstone, providing an upper age limit of 450 Ma for the Mithaka Fm. The late Gisbornian age suggested for the Mithaka Fm in this paper supports the isotopic age interpretation.

Similarities between the Canning and Georgina basin faunas do not provide firm proof of a Larapinta Seaway connection contemporaneous with the Mithaka Fm, but suggest that the seaway was open and providing dispersal pathways for several open water conodont species during or shortly before deposition of the Mithaka Fm. This provides further evidence that a ~ 450 Ma initiation of the Alice Springs Orogeny, which closed the Larapinta Seaway, is plausible and consistent with conodont faunal evidence.

## PROVINCIALISM AND GLOBAL CORRELATION

Many of the species present in the Mithaka Fm appear to be endemic to Australia. They belong to the newly proposed Australian Province, of the Tropical Domain, within the Shallow-Sea Realm (Fig. 7; Zhen and Percival, 2003). The Tropical Domain, Shallow-Sea Realm is roughly equivalent to the broadly defined Midcontinent Realm (Pohler and Barnes, 1990). The Tropical Domain is characterized by high diversity and high endemism. Several other species within the Mithaka Fm are related to the Laurentian and North Chinese Shallow-Sea provinces, and the Open-Sea Realm (Zhen and Percival, 2003). *Erismodus quadridactylus* and *Staufferella divisa* represent Laurentian (Midcontinent) Province species. *Aurilobodus leptosomatus*, *Panderodus nogamii*, and ?*Serratognathus* sp. represent North China Province species. *Drepanoistodus suberectus*, *Drepanoistodus basiovalis* and *Onyxodus acuoliratus* represent more cosmopolitan deeper water species (Open-Sea Realm). *Baltoniodus*? sp. A shows affinity with the North Atlantic (Open-Sea Realm), but is distinctively Australian in characters.

*Erismodus quadridactylus* has been described from the Laurentian (Midcontinent) Province, and ranges from the base of the *E. quadridactylus* Zone to the base of the *Plectodina tenuis* Zone (Sweet, 1984). This is consistent with the placement of the Mithaka Fm within the Gisbornian to Eastonian Stages (early Caradocian Stage; Fig.

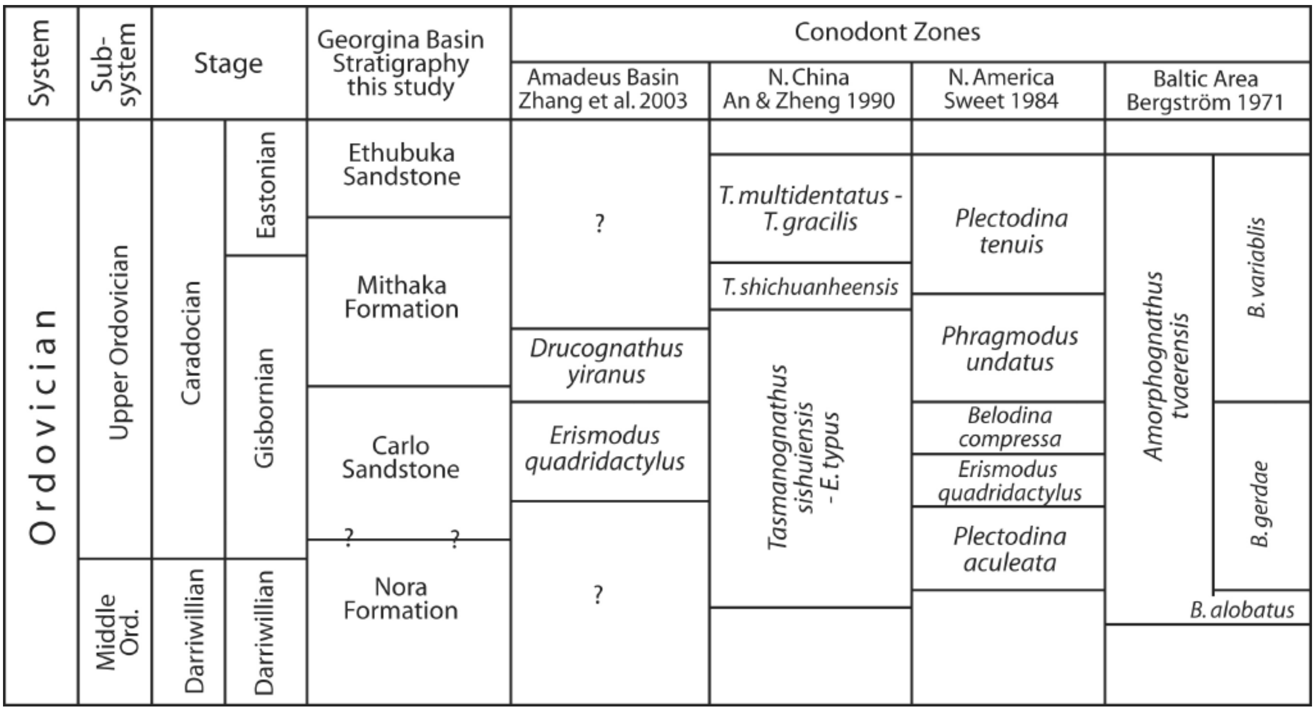


FIGURE 6 | **Darriwilian and Caradocian stratigraphy of the Georgina Basin, with comparative conodont biozonations for the Amadeus Basin, north China, North America and the Baltic area. Baltic Area stratigraphy of Bergström (1971) modified by Pyle and Barnes (2002). Modified from Zhang et al. (2003).**

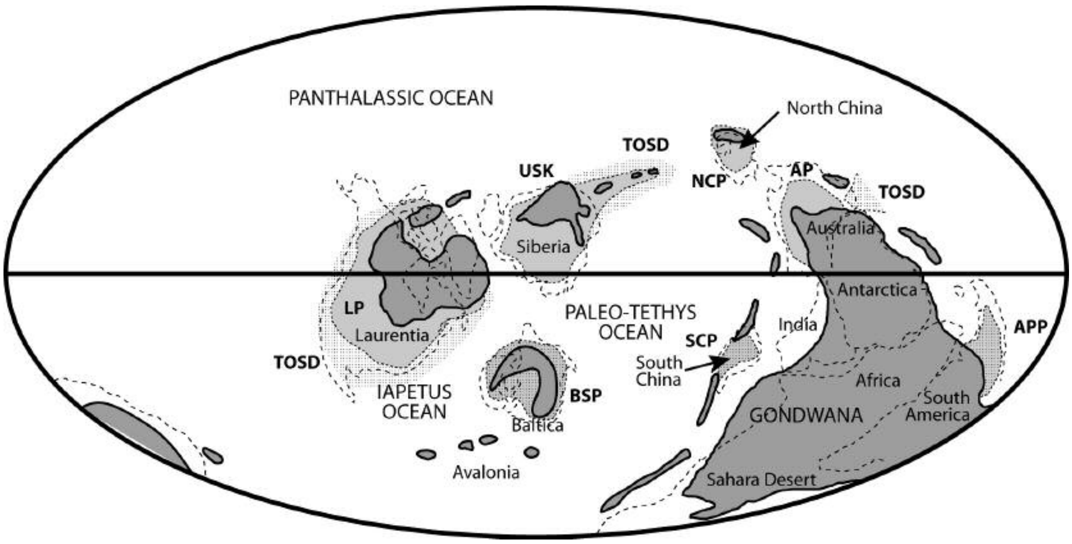


FIGURE 7 | **A paleogeographic reconstruction (modified from Scotese, 2004) showing plate configurations, including the equatorial position of Australia at 458 Ma, and proposed conodont biogeographic regions. Dark grey: paleolandmass, light grey: tropical shallow-sea provinces (LP: Laurentian Province; USK: unknown Siberian and Kazakhstan provinces; NCP: North China Province; AP: Australian Province). Light grey stippled: temperate and cold water shallow-sea provinces (BSP: Balto-Scandian Province; SCP: South China Province; APP: Argentine Precordillera Province) and stippled: Tropical open-sea Domain (TOSD; shown only were data is available). Synthesized from Barnes et al. (1973) and Zhen and Percival (2003).**

6). *Erismodus typus* is present in the *Tasmanognathus sishuiensis – E. typus* Zone of North China (An and Zheng, 1990). The lack of *E. typus* within the Mithaka Fm supports the late Gisbornian age suggested by the presence of the zonal species *Drucognathus yiranus*.

## CONCLUDING REMARKS

Australia's intracratonic basins contain extensive Paleozoic sedimentary sequences, however correlation between basins and with well studied strata from other parts of the world can still be improved. This systematic study of conodonts from the Mithaka Fm, Georgina Basin allows improved correlations of the Mithaka conodont fauna with several other recent Australian conodont studies (e.g. Stait and Druce, 1993; Zhen et al., 1999; Zhang et al., 2003). It supports current paleogeographic interpretations for an open Larapinta Seaway across central Australia near the time of Mithaka deposition. This study also confirms the recent suggestion of Zhen and Percival (2003) that a distinct Australian Province existed within the Ordovician conodont paleobiogeographic provinces.

Twenty-five species, representing 21 genera were recovered from the Mithaka Fm. These have allowed for correlation of the Mithaka Fm with the upper *Drucognathus yiranus* Zone from the Stokes Siltstone, Amadeus Basin (Zhang et al., 2003). The Mithaka Fm is inferred to be of late Gisbornian age, although the upper age limit of the Mithaka Fm – Ethabuka Sandstone boundary is not precisely delineated. This new early Late Ordovician age is younger than the previous Early to Middle Ordovician age associated with the Mithaka Fm (Casey in Smith, 1963; Shergold and Druce, 1980).

Of the 25 species recovered from the Mithaka Fm, five represented new species, with only one sufficiently abundant to be named (*Triangulodus mithakensis* n. sp.). Another three species represent previously described endemically Australian forms, bringing the total Australian species to eight. Two Laurentian Province species, three North China Province species and two Open-Sea Realm species were also present within the Mithaka Fm. This relatively high number of endemic forms supports the recent suggestion of Zhen and Percival (2003) that the Australian region should be considered a separate province within the Tropical Domain, Shallow-Sea Realm. There are, however, enough broadly distributed species within the tropical and temperate provinces to correlate the Mithaka Fm with the upper *Tasmanognathus sishuiensis – Erismodus typus* and *T. schichuanheensis* zones of North China, the *Phragmodus undatus* Zone of North America and the upper *Amorphognathus tvaerensis* Zone of the Baltic area.

Further studies of the conodont faunas of Australian intracratonic basins should provide greater stratigraphic control over the deposition and tectonic history of this region, as well as provide valuable information on the degree of endemism and faunal provincialism with Ordovician conodonts of Australia and elsewhere. Large conodont samples of contemporaneous strata within the Australian Province may also provide answers to some of the unresolved questions surrounding taxonomy and biostratigraphic ranges of several conodont genus and species described in this paper (e.g. *Taoqupognathus* n. sp. A, ?*Periodon* n. sp. A and *Bergstroemognathus*? n. sp. A).

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# APPENDIX

## Sampling location and Ocurrence and abundance of conodont specimens

TABLE 1 **Sampling location information for Australian Geological Survey Organization geological grab samples (GEO samples). Samples were collected by J.J. Draper in June-July 1975.**

| Sample No. | Registered Number | Formation Name | Area | Map sheet name | Map sheet number | Airphoto Reference |
|---|---|---|---|---|---|---|
| GEO 033/008 | 74710299 | MITHAKA FM | Toko | Mt Whelan | SF54/13 | AL02 |
| GEO 033/012 | 74710303 | MITHAKA FM | Toko | Mt Whelan | SF54/13 | AL02 |
| GEO 033/024 | 74710315 | MITHAKA FM | Toko | Mt Whelan | SF54/13 | AL02 |
| GEO 033/025 | 74710316 | MITHAKA FM | Toko | Mt Whelan | SF54/13 | AL02 |
| GEO 038/011 | 74710396 | MITHAKA FM | Toko | Tobermorey | SF53/12 | TO13/0024 |
| GEO 038/035 | 74710420 | MITHAKA FM | Toko | Glenormiston | SF54/09 | NH12/0048 |
| GEO 038/041 | 74710426 | MITHAKA FM | Toko | Tobermorey | SF53/12 | TO13/0022 |
| GEO 038/055 | 74710440 | MITHAKA FM | Toko | Tobermorey | SF53/12 | TO |
| GEO 038/056 | 74710441 | MITHAKA FM | Toko | Tobermorey | SF53/12 | TO |
| GEO 038/057 | 74710442 | MITHAKA FM | Toko | Tobermorey | SF53/12 | TO |
| GEO 042/001 | 74710467 | MITHAKA FM | Toko | Tobermorey | SF53/12 | TO12 |
| GEO 046/034 | 74710529 | MITHAKA FM | Toko | Tobermorey | SF53/12 | TO08/0230 |
| GEO 048/001 | 74710543 | MITHAKA FM | Toko | Tobermorey | SF53/12 | TO08/0230 |
| GEO 048/002 | 74710544 | MITHAKA FM | Toko | Tobermorey | SF53/12 | TO08/0230 |
| GEO 048/004 | 74710546 | MITHAKA FM | Toko | Tobermorey | SF53/12 | TO08/0230 |
| GEO 048/005 | 74710547 | MITHAKA FM | Toko | Tobermorey | SF53/12 | TO08/0230 |

TABLE 2 **Occurrence and abundance of conodont specimens from GEO samples.**

| species | sample # / element | GEO 033/8 | GEO 033/12 | GEO 033/24 | GEO 033/25 | GEO 038/11 | GEO 038/35 | GEO 038/41 | GEO 038/55 | GEO 038/56 | GEO 038/57 | GEO 042/1 | GEO 046/34 | GEO 048/1 | GEO 048/2 | GEO 048/4 | GEO 048/5 | Total | Species Total | % species |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Baltoniodos? sp. A* | P | | | | | | | | 2 | | | | | | | 3 | | 5 | 5 | 2.63 |
| *Bergstroemognathus n. sp. A* | Sa | | | | | | | | 1 | | | | | | 1 | | | 2 | | |
| | Sb | | | | | | | | 1 | | 1 | | | | | | | 2 | 4 | 2.11 |
| *Drepanoistodus suberectus* | P | | | | | | | | | | 1 | | | | | 1 | | 2 | | |
| | M | | | | | | | | | | | | | | | 3 | | 3 | | |
| | Sa | | | | | | | | 1 | 2 | | | 1 | | | 2 | | 6 | | |
| | Sb | | 2 | | | | | | | 1 | | | 5 | | | 1 | | 9 | | |
| | Sc | | | | | | | | | 1 | | | | | | 1 | | 2 | 22 | 11.58 |
| *Drucognathus yiranus* | Pa | | 1 | | | | | | | | | | | | | | | 1 | | |
| | Pb | | | | | | 1 | | | | | | | | | | | 1 | | |
| | Sc | | | | | | | | 1 | | | | | | | | | 1 | 3 | 1.58 |
| *Erismodus quadridactylus* | Pa | | | | | | | | | 1 | | | | | | 1 | | 2 | | |
| | Pb | | | | | | 1 | | 2 | 2 | | | 2 | | 1 | 1 | 1 | 10 | | |
| | Sa | | | | | | | | | | | | | | 1 | | 1 | 2 | | |
| | Sb | | | | | | | | | 1 | 1 | | | | | 2 | | 4 | | |
| | Sc | | | | | | | 2 | 2 | 1 | | | | | 3 | 2 | 1 | 11 | 29 | 15.26 |
| *Erismodus nicolli* | Sa | | | | | | | | | | | | | | | 1 | | 1 | | |
| | Sc | | | | | | | | 1 | | | | | | | | | 1 | 2 | 1.05 |
| *Erraticodon* cf. *E. patu* | Sa | | | | | | | | | 1 | | | | | | | | 1 | | |
| | Sb | | | | | | | | 1 | 1 | | | 1 | | | | | 3 | 4 | 2.11 |
| *Panderodus nogamii* | Sa | | | | | | | | | | | | | | | 1 | | 1 | | |
| | S | | | | | | | | | | | | | | | 2 | | 2 | 3 | 1.58 |
| ?*Periodon* n. sp. A | M | | | | | | | | 1 | 1 | | | | | | | | 2 | 2 | 1.05 |
| *Phragmodus polystrophos* | Pa | | | | | 3 | 2 | | | | | | | | | | | 5 | | |
| | Pb | | | | | 1 | 2 | | | | | | | | | | | 3 | | |
| | M | | | | | 5 | 1 | | | | | | | | | | | 6 | | |
| | Sa | | | | | 2 | 2 | | | | | | | | | | | 4 | | |
| | Sb | | | | | 7 | 1 | | | | | | | | | | | 8 | | |
| | Sc | | | | | 8 | | | | | | | | | | | | 8 | 34 | 17.89 |
| *Phragmodus* n. sp. A | Pa | | | | | | | | | | | | | | | 1 | | 1 | | |
| | Pb | | | | | | | | | | | | | | | 1 | | 1 | 2 | 1.05 |
| *Polycaulodus bidentatus* | | | | | | | | | | | | | 1 | | | | | 1 | 1 | 0.53 |
| *Triangulodus mithakensis* | Pa | | | | | | | | 2 | 2 | | | | | 1 | 3 | 1 | 9 | | |
| | Pb | | 5 | 1 | | | | 1 | 1 | 2 | | | 1 | | | 1 | | 12 | | |
| | M | | | 1 | | | | 1 | 2 | 2 | | | 4 | | | 6 | 3 | 19 | | |
| | Sa | | | | | | | | 2 | 2 | | | | 1 | | 1 | | 6 | | |
| | Sb | | 1 | | | 1 | 1 | | 1 | 2 | 1 | | | | | 1 | 1 | 9 | | |
| | Sc | | | | | 1 | 1 | 1 | | 2 | | | | | 1 | 3 | 2 | 11 | | |
| | Sd | | | | | | | | 1 | 1 | | | 1 | | | 3 | | 6 | 72 | 37.89 |
| *Yaoxianognathus?* | Pa | | | | | | | | 1 | 1 | | | | | | | | 2 | | |
| *neonychodonta* | Pb | | | | | | | | 1 | 2 | | | | | | | 1 | 4 | | |
| | Sc | | | | 1 | | | | | | | | | | | | | 1 | 7 | 3.68 |
| *Total* | | 0 | 9 | 2 | 1 | 28 | 12 | 5 | 24 | 28 | 4 | 0 | 16 | 1 | 8 | 41 | 11 | 190 | 190 | 100 |

TABLE 3 **Occurrence and abundance of conodont specimens from the SP samples.**

| species | sample # / element | S.P. 703 | S.P. 704 | S.P. 726 | S.P. 728 | S.P. 729 | S.P. 734 | S.P. 749 | S.P. 752 | S.P. 753 | S.P. 754 | S.P. 755 | S.P. 757 | S.P. 758 | S.P. 759 | S.P. 760 | S.P. 761 | S.P. 762 | S.P. 763 | S.P. 764 | S.P. 765 | S.P. 770 | S.P. 772 | S.P. 773 | S.P. 774 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Aurilobodus leptosomatus* | Sa | | | | | | | | | | | | | | | | | | | | | | | | |
| | S | | | | | | | | | | | | | | | | | | | | | | | | |
| *Baltoniodus? sp. A* | Pa | | | | | | | | | 1 | | | | | | | | | | | | | | | |
| | Pb | | | | | | | | | | | | | | | | | | | | | | | | |
| | Sa | | | | | | | | | | | | | | | | | 1 | | | | | | | |
| | Sb | | | | | | | | | | | | | | | | | | | | | | | | |
| *Bergstroemognathus sp. A* | Pa | | | | | | | | | | | | | | | | | | | | | | | | |
| | Sb | | | | | | | | | | | | | | | | | | | | | | | | |
| *Bergstroemognathus? n. sp. A* | Sb | | | | | | | | | | | | | | | | | | | | | | | | |
| *Drepanoistodus basiovalis* | P | | | | 1 | | | | | 1 | | | | | | | | | 1 | 1 | | | | | |
| | M | | | | | | 1 | | | | | | | | | | | | 1 | 2 | | | | | |
| | Sa | | | | 2 | | | | | 2 | 1 | | | | | | | 1 | 2 | | | | | | |
| | Sb | | | | | | 1 | | | 1 | | | | | | | | | 1 | | | | | | |
| | Sc | | | | | | 1 | | | 2 | | | | | | | | 1 | 1 | | | | | | |
| *Drepanoistodus suberectus* | P | | | | | | | | | | | | | 1 | | 3 | | | 2 | 1 | | | | | |
| | M | | | | | | | | | | | | 1 | | | | | | 2 | | | | | | |
| | Sa | | | | | | | | | | | | | | | | | | 2 | 1 | 1 | 1 | | | |
| | Sb | | | | | | | | | | | | | | | | 1 | 1 | 2 | | | | | | |
| | Sc | | | | | | | | | | | | 1 | | | | | | 1 | | | | | | |
| *Drucognathus yiranus* | Pa | | | | | | | | | | | | | | | | | | | | | | | | |
| | Pb | | | | | | | | | | | | 1 | | | | | | | | | | | | |
| | M | | | | | | | | | | | | | | | | | | | | | | | | |
| | Sa | | | | | | 1 | | | | | | | | | | | | | | | | 1 | | 1 |
| | Sb | | | | | | | | | | | | | | | | | | | | | | | | |
| | Sc | | | | | 1 | | | | | | | 3 | | | | | | 1 | | | | | 1 | 3 |
| *Erismodus nicolli* | Pa | | | | | | | | | | | | | | 1 | | | | | 1 | | | | | |
| | Pb | | | | | | | | | | | | 1 | | 1 | | | | | 1 | | | | | |
| | M | | | | | | | | | | | | | | 2 | | | | | | | | | | |
| | Sa | | | | | | | | 1 | | | | | | 1 | | | | | | | | | 1 | |
| | Sb | | | | | | | | | | | | 1 | | | | | | | 1 | | | | | |
| | Sc | | | | | | | | | | | | 2 | | | | | | | 1 | | | | | |
| *Erismodus quadridactylus* | Pa | | | | | | | | | 3 | 1 | | 2 | | | 1 | | 1 | 2 | 4 | | | | | |
| | Pb | | | | | | | | 1 | 1 | 1 | | 2 | | | 1 | 1 | 2 | 3 | 9 | | | | | |
| | M | | 1 | | | | | | 1 | 1 | | | | 1 | | | | 1 | 4 | | | | | | |
| | Sa | | | | | 1 | | 1 | | | 1 | 1 | | 1 | | 1 | 2 | | 2 | 1 | | | | | |
| | Sb | | | | | 1 | | | | 1 | | | | 1 | | 1 | | | 2 | 2 | | | | | |
| | Sc | | | | | | | 1 | | 1 | 2 | 1 | 2 | 1 | | 4 | 3 | 1 | 4 | 4 | | | | | |
| | frags | | | | | | | | 2 | | | | | | 1 | 1 | | | 2 | 2 | | | | | |
| *Erraticodon cf. E. patu* | Sd | | | | | 1 | | | | 1 | | | | | | 2 | | 1 | | | | | | | |
| | Pa | | | | | | | 1 | | | | | | | | | | | | | | | | | |
| | Sa | | | | | | | | | | 1 | | | | | | | | | | | | | | |
| | Sb | | | | | | 1 | | | | | | | | | | | | | | | | | | |
| *Onyxodus acuoliratus* | S-sym | | | | | | | | | | | | | | | | | | | | 1 | | 1 | 1 | |
| | S-asym | | | | | | | | | | | | | | | | | | | 1 | | | | | |
| *?Oulodus sp.* | frag | | | | | | | | | | | | | | | | | | | | | | | 1 | 1 |
| *Panderodus nogamii* | M | | | | | | | | | | | | | | | | | 1 | | | | | | | |
| | Sa | | | | | | | | | | | | | | | 1 | | | 1 | | | | | | |
| | S | | | | | | | | | | 1 | | | | | | | 1 | 1 | | | | | | |

TABLE 3| **Continued.**

| species | sample # / element | S.P. 703 | S.P. 704 | S.P. 726 | S.P. 728 | S.P. 729 | S.P. 734 | S.P. 749 | S.P. 752 | S.P. 753 | S.P. 754 | S.P. 755 | S.P. 757 | S.P. 758 | S.P. 759 | S.P. 760 | S.P. 761 | S.P. 762 | S.P. 763 | S.P. 764 | S.P. 765 | S.P. 770 | S.P. 772 | S.P. 773 | S.P. 774 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *?Periodon* n. sp. A | Pa | | | | | | | 1 | | | | | | | | | 1 | | | 1 | | | | | |
| | Pb | | | | | | | 1 | | | | | | | | | 1 | | | 1 | | | | | |
| | M | | | | | | | 1 | | | | | 1 | | 1 | | 1 | | 3 | 1 | | | | | |
| *Phragmodus polystrophos* | Pa | | | | | | 1 | | 1 | | | | | | | | | | | | | | | | |
| | Pb | | | | | | | | | | | | | | | | | | | | | | | | |
| | M | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| | Sa | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| | Sb | | | | | | 2 | | | | | | | | | | | | | | | | | | |
| | Sc | | | | | | 2 | | | | | | | | | | | | | | | | | | |
| *Phragmodus* n. sp. A | Pa | | | | | | | | | | | | | | | | | 1 | | | | | | | |
| | Pb | | | | | | | | | | | | | | | | | | 1 | 1 | | | | | |
| | M | | | | | | | | | | | | | | | | | | | 1 | | | | | |
| | Sa | | | | | | | | | | | | | | | | | | | 1 | | | | | |
| | Sb | | | | | | | | | | | | | | | | | 1 | 1 | 1 | | 1 | | | |
| | Sc | | | | | | | | | | | | | | | | | 2 | | | | | | | |
| *?Serratognathus* sp. | Sa | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| *Stauferella divisa* | Sa | | | | | | | | | | | | | | | | | | | | | | | | |
| *Triangulodus mithakensis* | Pa | | | | | | | | | 1 | | | 4 | | 1 | | 3 | 2 | 2 | 2 | | | | | |
| | Pb | 1 | | | | | | | | 2 | | 2 | 5 | 1 | 1 | | 1 | 1 | 3 | 2 | | | | 1 | |
| | M | | | 1 | | | | | 1 | 3 | | | 4 | | 2 | 1 | 1 | 3 | 2 | 1 | | | | 1 | 1 |
| | Sa | | 2 | | | | 1 | | | 2 | | 3 | 1 | 2 | 2 | 3 | 1 | 1 | 2 | 3 | | | | | |
| | Sb | | 1 | | | | 1 | | 1 | 4 | | 2 | 1 | | | 2 | | 1 | 1 | 3 | | | | | |
| | Sc | | 1 | | | 1 | 2 | 1 | | 4 | | | 5 | 1 | 1 | | 3 | 2 | 3 | 5 | | | | | 1 |
| | Sd | | 1 | | | | | | | 3 | | | 6 | 2 | | 2 | 1 | | 2 | | | | | | 1 |
| *Yaoxianognathus? neonychodonta* | Pa | | | | | | | | | | | | | | | | | | | | | | | | |
| | Pb | | | | | | | | | | | | | | | | | | | | | | | | |
| | M | | | | | | | | | | | | | | | | | | | 1 | | | | | |
| | Sc | | | | | | | | | | | | | | 1 | | | | | | | | | | |
| *Juanognathus* sp. A | S | | | | | | | | | | | | | | | 1 | | | 1 | 5 | | | | | |
| *Taoqupognathus* n. sp. A | P | | | | | | | | | | | | | | | | | | | | | | | | |
| gen et sp indet A | Sb | | | | | | | | | | | | | | | | | | | | | | | | |
| gen et sp indet B | Sc | | | | | | | | | | | | | | | | | | | | | | | | |
| *Total* | | 1 | 6 | 1 | 3 | 5 | 14 | 7 | 8 | 34 | 8 | 9 | 43 | 11 | 15 | 24 | 20 | 26 | 58 | 61 | 2 | 2 | 2 | 6 | 11 |

TABLE 3 **Continued.**

| species | element | S.P. 776 | S.P. 777 | S.P. 778 | S.P. 780 | S.P. 782 | S.P. 783 | S.P. 784 | S.P. 787 | S.P. 790 | S.P. 792 | S.P. 794 | S.P. 795 | S.P. 797 | S.P. 804 | S.P. 807 | S.P. 815 | S.P. 817 | S.P. 831 | S.P. 833 | S.P. 841 | S.P. 842 | S.P. 844 | S.P. 845 | S.P. 846 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Aurilobodus leptosomatus* | Sa | | | | | | | | | | | | | | | | | | | | | | | | |
| | S | | | | | | | | | | | | | | | | | | | | | | | | |
| *Baltoniodus? sp. A* | Pa | | | | | | | | | | | | | | | | | | | | | | | 1 | |
| | Pb | | | | | | | | | | | | | | | | | | | | | | | | |
| | Sa | | | | | | | | | | | | | | | | | | | | | | | | |
| | Sb | | | | | | | | | | | | | | | | | | | | | | | | |
| *Bergstroemognathus sp. A* | Pa | | | | | | | | | | | | | | | | | | | | | | | | |
| | Sb | | | | | | | | | | | | | | | | | | | | | | | | |
| *Bergstroemognathus? n. sp. A* | Sb | | | | | | | | | | | | | | | | | | | | | | | | |
| *Drepanoistodus basiovalis* | P | | | | | | | | | | | | | | | | | | | | | | | | |
| | M | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| | Sa | | | | | | | | | | | | | | | | | | | | | | | | |
| | Sb | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| | Sc | | | | | | | | | | | | | | | | | | | | | | | | |
| *Drepanoistodus suberectus* | P | 1 | | 1 | | | | | | | | | 1 | | 1 | | | | | | | | | | 1 |
| | M | | 1 | | | | | | | | | | 1 | | | | | | 1 | | | 1 | | | 1 |
| | Sa | 1 | 1 | | | | 1 | | | | | | | | | | | | | | 1 | | | 2 | 1 |
| | Sb | 1 | | 1 | | 1 | | | | 1 | | | 3 | | 2 | | | | | | | | | | 1 |
| | Sc | | | | | | | | | | | | | | | | | | | | | | | | |
| *Drucognathus yiranus* | Pa | | 2 | | | | | 1 | | 1 | | | | | 1 | | | | | | | | 1 | | |
| | Pb | | 3 | 1 | | | | | | 1 | | | | | | | | | | | | | | | |
| | M | | | | | | | 1 | | | | | | | | | | | | | | | | | |
| | Sa | | | 1 | | | | | | 1 | | | 1 | | | | | | | | | | | | |
| | Sb | | 1 | | | | | 2 | 1 | 2 | | | 1 | | | | | | | | | | | | |
| | Sc | | 1 | 2 | | | | 4 | | 2 | | 1 | 2 | | | | | | | | 1 | | 2 | 1 | |
| *Erismodus nicolli* | Pa | | | | | | | | | | | | | | | | | | | | | | | | |
| | Pb | | | | | | | | | | | | | | | | | | | | | | | | |
| | M | | | | | | | | | | | | | | | | | | | | | | | | |
| | Sa | | | | | | | | | | | | | | | | | | | | | | | | |
| | Sb | | | | | | | | | | | | | | | | | 1 | | | | | | | |
| | Sc | | | | | | | | | | | | | | | | | | | | 2 | | | | |
| *Erismodus quadridactylus* | Pa | | | | | | | | | | | | | | | | | | | | | | | 1 | |
| | Pb | | | | | | | | | | | | | | | | | | | | | | 1 | | 2 |
| | M | | | | | | | | | | | | | | | | | | | | | | 3 | | |
| | Sa | | | | 1 | | | | | | | | | | | | | | | | | | | 1 | 1 |
| | Sb | | | | | | | 1 | | | | | | | | | | | | | | | 1 | 3 | 1 |
| | Sc | | | | | | | | | | | | | | | | | | | | | | 3 | 1 | |
| | frags | | | | | | | | | | | | | | | | | | | | | | 1 | | |
| *Erraticodon cf. E. patu* | Sd | | | | | | | | | | | | | | | | | | | | | | 2 | | |
| | Pa | | | | | | | | | | | | | | | | | | | | | | | | |
| | Sa | | | | | | | | | | | | | | | | | | | | | | | | |
| | Sb | | | | | | | | | | | | | | | | | | | | | | | | |
| *Onyxodus acuoliratus* | S-sym | | | | | | | | | | | | | | | | | 1 | | | | | | | |
| | S-asym | | | | | | | | | | | | | | | | | | | | | | | | |
| *?Oulodus sp.* | frag | | 1 | 1 | | | | | | 4 | | | | | 2 | | 2 | 2 | | | | | | | |
| *Panderodus nogamii* | M | | | | | | | 1 | | | | | | | | | | | | | | | | | 2 |
| | Sa | | | | | | | | | | | | | | | | | | | | | | 1 | | 1 |
| | S | | | | | | | | | | | | | | | | | | | 2 | | | 2 | | |

TABLE 3 **Continued.**

| species | element (sample #) | S.P. 776 | S.P. 777 | S.P. 778 | S.P. 780 | S.P. 782 | S.P. 783 | S.P. 784 | S.P. 787 | S.P. 790 | S.P. 792 | S.P. 794 | S.P. 795 | S.P. 797 | S.P. 804 | S.P. 807 | S.P. 815 | S.P. 817 | S.P. 831 | S.P. 833 | S.P. 841 | S.P. 842 | S.P. 844 | S.P. 845 | S.P. 846 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *?Periodon* n. sp. A | Pa | | | | | | | | | | | | | | | | | | 1 | 1 | | | 1 | | |
| | Pb | | | | | | | | | | | | | | | | | | | 1 | | | | | |
| | M | | | | | | | | | | | | | | | | | | 1 | 2 | | | 1 | | |
| *Phragmodus polystrophos* | Pa | | | | 1 | | | | | | | | | | | | | | | | | | | | |
| | Pb | | | | 1 | | | | | | | | | | | | | | | | | | | | |
| | M | | | | | | | | | | | | | | | | | | | 2 | | | | | |
| | Sa | | | | | | | | | | | | 1 | | | | | | | | | | | | |
| | Sb | | | | 1 | | | | | | | | 1 | | | | | | | | | | | | 1 |
| | Sc | | | | 3 | | | 2 | | | | | | | | | | | | 2 | | | | | |
| *Phragmodus* n. sp. A | Pa | | | | | | | | | | | | | | | | | | | | | | | | |
| | Pb | | | | | | | | | | | | | | | | | | | | | | | | |
| | M | | | | | | | | | | | | | | | | | | | | | | | | |
| | Sa | | | | | | | | | | | | | | | | | | | | | | | | |
| | Sb | | | | | | | | | | | | | | | | | | | | | | | | |
| | Sc | | | | | | | | | | | | | | | | | | | | | | | | |
| *?Serratognathus* sp. | Sa | | | | | | | | | | | | | | | | | | | | | | | | |
| *Stauferella divisa* | Sa | | | | | | | | | | | | 1 | | | | | | | | | | | | |
| *Triangulodus mithakensis* | Pa | | | | | | | | | | | | | | 1 | | 1 | | | | | | | | |
| | Pb | | | | | 1 | | | | | | | | | | | | | | | | | 1 | | |
| | M | | | | | | | | | | | | | | | | | | | | | | 1 | 3 | |
| | Sa | | 1 | | | 1 | | | | | | 1 | | | | | | | | | | | 1 | 1 | 1 |
| | Sb | | | | | 1 | | | | | | | | | | | | | | | | | 2 | 2 | |
| | Sc | | 1 | | | 1 | | | | | 1 | 1 | | | 3 | | 1 | 1 | | | | | 1 | | 1 |
| | Sd | | | | | | | | | | | | | | | | | | | | | | | | |
| *Yaoxianognathus? neonychodonta* | Pa | | | | | | | | | | | | | | | | | | | 2 | | | | | |
| | Pb | | | | | | | | | | | | | | | | | | | 1 | | | | | |
| | M | | | | | | | | | | | | | | | | | | | | | | | | |
| | Sc | | | | 1 | | | 2 | | | | | | | | | | | | | | | | | |
| *Juanognathus* sp. A | S | | | | | | | | | | | | | | | | | | | | | | | | |
| *Taoqupognathus* n. sp. A | P | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| gen et sp indet A | Sb | | | | | | | | | | | | | | | | | | | | | | | | |
| gen et sp indet B | Sc | | | | | | | | | | | | | | | | | | | | | | | | |
| *Total* | | 3 | 12 | 7 | 8 | 5 | 1 | 14 | 1 | 12 | 1 | 3 | 12 | 0 | 10 | 0 | 4 | 5 | 3 | 13 | 4 | 1 | 25 | 16 | 17 |

TABLE 3 **Continued.**

| | sample # | S.P. 847 | S.P. 848 | S.P. 850 | S.P. 852 | S.P. 853 | S.P. 854 | S.P. 856 | S.P. 857 | S.P. 859 | S.P. 864 | S.P. 865 | S.P. 866 | S.P. 867 | S.P. 868 | S.P. 873 | S.P. 882 | S.P. 884 | S.P. 885 | S.P. 889 | S.P. 890 | S.P. 891 | S.P. 892 | S.P. 893 | S.P. 894 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| species | element | | | | | | | | | | | | | | | | | | | | | | | | |
| *Aurilobodus leptosomatus* | Sa | | | | | | | | | 1 | | | | | | | | | 1 | | | | | | |
| | S | | | 1 | | | | | | 1 | | | | | | | | | | | | | | | |
| *Baltoniodus? sp. A* | Pa | | | | | | | | | | | | | | | | | | | | | | | | |
| | Pb | | | | | 2 | | 1 | 2 | 1 | 1 | | | 2 | | | | | | | | | | | |
| | Sa | | | | | | | | | | | | | 1 | | | | | | | | | | | |
| | Sb | | | | | | | | | | | | | | | | | | | | | | | | |
| *Bergstroemognathus sp. A* | Pa | | | | | | 2 | | | | | | | | | | | | | | | | | | |
| | Sb | | | | | | 2 | | | | | | | | | | | | | | | | | | |
| *Bergstroemognathus? n. sp. A* | Sb | | | | | | | | | | | | | 4 | | | | | | | | | | | |
| *Drepanoistodus basiovalis* | P | | | | | | | | | | | | | | | | 1 | | | | | | | | |
| | M | | | | | | | | | | | | | | | | 1 | 1 | | | | | | | |
| | Sa | | | 1 | | 1 | | 3 | 1 | 2 | | | 1 | | | | | | | | | | | | |
| | Sb | | | 1 | | | | | 1 | | | | | | | | | | | | | | | | |
| | Sc | | | 1 | | | | | | 1 | | | | | | | | | | | | | | | |
| *Drepanoistodus suberectus* | P | | | | | | | | | 1 | | | | 1 | | | | | | | | | 1 | | |
| | M | | | | | | | | | | | | | | | | | | | | | | | | |
| | Sa | | | | | | 2 | 1 | 2 | | 1 | 2 | | 2 | | | | | | | | | | | |
| | Sb | | | | | | 3 | 2 | | 3 | 1 | | | 1 | | | | | | | | | 2 | 1 | |
| | Sc | | | | | | | | | | | 1 | | | | | | | | | | | | | |
| *Drucognathus yiranus* | Pa | | | | | | | | | | | | | | | | 1 | | | | | | | | |
| | Pb | | | | | | | | | | | | | | | | | | | | | | | | |
| | M | | | | | | | | | | | | 1 | | | | | | | | | | | | |
| | Sa | | | | | | | 1 | | | | | | | 1 | | | | | | | | | | |
| | Sb | | | | | | | 1 | | | | | | | | | | | | | | | | | |
| | Sc | | | | | | 1 | 1 | | | | | 1 | 1 | | | | | | | | | | | |
| *Erismodus nicolli* | Pa | | | | | | | | | | | | | | | | | | | | | | | | |
| | Pb | | | | | | | | | | | | | | | | | | | | | | | | |
| | M | | | | | | | | | | | | | | | | | | | | | | | | |
| | Sa | | | | | | 1 | | | | | | | | | | | | | | | | | | |
| | Sb | | | | | | | | | | | | | | | | | | | | | | | | |
| | Sc | | | | | | | | | | | | | | | | | | | | | | | | |
| *Erismodus quadridactylus* | Pa | | | | | 1 | | 1 | | 1 | | | 1 | 2 | | | | | | | | | | | |
| | Pb | | | | | | 1 | 1 | 1 | 3 | 1 | | | 3 | | | | | | | | 1 | | | |
| | M | | | | | 1 | 2 | 2 | 1 | 2 | 1 | | | 6 | | | | | 1 | | | | | | |
| | Sa | | | | | 4 | | 3 | 2 | 1 | | | | 3 | | | | | | | | | | | |
| | Sb | | | | | 2 | 3 | 1 | | 1 | | | | 2 | | | | | | | | | | | |
| | Sc | 2 | 1 | 1 | 2 | 1 | 2 | 3 | 3 | 3 | 1 | | | 4 | | | | | | | | | | | |
| | frags | | | | | | | 1 | 4 | 1 | | | | | | | | | | | | | | | |
| *Erraticodon cf. E. patu* | Sd | | | 2 | | | | | | 2 | | | | | | | | | | | | | | | |
| | Pa | | | | | | | | | | | | | | | | | | | | | | | | |
| | Sa | | | | | | | | | | | | | | | | | | | | | | | | |
| | Sb | | | | | | | | | 1 | | | | | | | | | | | | | | | |
| *Onyxodus acuoliratus* | S-sym | | | | | | | | | | | | | | | | | | | | | | | | |
| | S-asym | | | | | | | | | | | | | | | | | | | | | | | | |
| *?Oulodus sp.* | frag | | | | | | | | | | | | | | | | | | | | | | 3 | 1 | 1 |
| *Panderodus nogamii* | M | | | | | | | | | | | | | | | 1 | | | | | | | | | |
| | Sa | | | 1 | | | | | | | | | | | | | | | | | | | | | |
| | S | | | 2 | | 1 | | | | 3 | | | | | | 1 | | | 1 | | | | | | |

TABLE 3| **Continued.**

| species | sample # / element | S.P. 847 | S.P. 848 | S.P. 850 | S.P. 852 | S.P. 853 | S.P. 854 | S.P. 856 | S.P. 857 | S.P. 859 | S.P. 864 | S.P. 865 | S.P. 866 | S.P. 867 | S.P. 868 | S.P. 873 | S.P. 882 | S.P. 884 | S.P. 885 | S.P. 889 | S.P. 890 | S.P. 891 | S.P. 892 | S.P. 893 | S.P. 894 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *?Periodon* n. sp. A | Pa | | | | | | | 1 | | | | | | | | | | | | | | | | | |
| | Pb | | | | | | | 1 | | | | | | | | | | | | | | | | | |
| | M | | | | | | | 1 | | | | | | | | | | | | | | | | | |
| *Phragmodus polystrophos* | Pa | | | | | | | | | | | | | | | | | | | | | | | | |
| | Pb | | | | | | | | | | | | | | | | | | | | | | | | |
| | M | | | | | | | | | | 1 | | | | | | 1 | 1 | | | | | | | |
| | Sa | | | | | | | | | | | | | | | | | | | | | | | | |
| | Sb | | | | | | | | | | 1 | | | | | | 1 | | | | | | | | |
| | Sc | | | 1 | | | | | | 1 | | | | | | | | | 1 | | | | | | |
| *Phragmodus* n. sp. A | Pa | | | | | | | | | | | | | 3 | | | | | | | | | | | |
| | Pb | | | | | | | | | | | | | | | | | | | | | | | | |
| | M | | | | | | | | | | | | | | | | | | | | | | | | |
| | Sa | | | | | | | | | | | | | | | | | | | | | | | | |
| | Sb | | | | | | | | | | | | | | | | | | | | | | 1 | | 1 |
| | Sc | | | | | | | | | | | | | 1 | | | | | | | | | 1 | | |
| *?Serratognathus* sp. | Sa | | | 1 | | | | | | | | | | | | | | | | | | | | | |
| *Stauferella divisa* | Sa | | | | | | | | | | | | | | | | | | | | | | | | |
| *Triangulodus mithakensis* | Pa | | | | | 1 | | 2 | 1 | 1 | | 2 | | 5 | | | | | | | | | | | |
| | Pb | | | | 1 | 1 | | | | 1 | | | | 5 | 1 | | | | | | | | | | |
| | M | 1 | | 1 | | 2 | 1 | 2 | 3 | 5 | | 2 | 1 | 3 | | | | | | | | | | | |
| | Sa | 1 | | | | | 1 | 2 | | 1 | | 1 | 1 | 4 | | | | | | | | | | | |
| | Sb | | | | | 2 | 1 | | | 3 | | 1 | | 2 | | | | | | | | 1 | 1 | 1 | |
| | Sc | 1 | | | 2 | 3 | 1 | 3 | 1 | 5 | | | | 2 | 1 | 1 | | | | | | | | | |
| | Sd | 1 | | | | 1 | 1 | 3 | 1 | 1 | | 1 | 1 | 2 | | | | 1 | | | | | | | |
| *Yaoxianognathus? neonychodonta* | Pa | | | | | | | | | | | | | | | | | | | | | | | | |
| | Pb | | | | 1 | | 3 | | | | | | | | | | | | | | | | | | |
| | M | | | | | | | | | | | | | | | | | | | | | | | | |
| | Sc | | | | | | | | | | | | | | | | | | | | | | | | |
| *Juanognathus* sp. A | S | | | | | | | | | | | | | | | | | | | | | | | | |
| *Taoqupognathus* n. sp. A | P | | | | | | | | | | | | | | | | | | | | | | | | |
| gen et sp indet A | Sb | | | | | 1 | | | | | | | | | | | | | | | | | | | |
| gen et sp indet B | Sc | | | | | | | | | | | | | | | | | | | | | | | | |
| *Total* | | 6 | 1 | 13 | 6 | 24 | 27 | 37 | 23 | 46 | 8 | 10 | 7 | 59 | 3 | 3 | 5 | 3 | 4 | 0 | 0 | 2 | 9 | 3 | 2 |

TABLE 3| **Continued.**

| species | element | S.P. 895 | S.P. 898 | S.P. 899 | S.P. 900 | S.P. 901 | S.P. 904 | S.P. 906 | S.P. 909 | S.P. 912 | S.P. 913 | S.P. 914 | S.P. 915 | S.P. 916 | S.P. 917 | S.P. 918 | S.P. 919 | S.P. 920 | S.P. 921 | Total | Species Total | % Species |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Aurilobodus leptosomatus* | Sa | | | | | | | | | | | | | | | | | | | 2 | | |
| | S | | | | | | | | | | | | | | | | | | | 2 | 4 | 0.38 |
| *Baltoniodus? sp. A* | Pa | | | | | | | | | | | | | | | | | | | 2 | | |
| | Pb | | | | | | 1 | | | | | | | | | | | | | 10 | | |
| | Sa | | | | | | | | | | | | | | | | | | | 2 | | |
| | Sb | | | | | | | | | | | | 1 | | | | | | | 1 | 15 | 1.44 |
| *Bergstroemognathus sp. A* | Pa | | | | | | | | | | | | | | | | | | | 2 | | |
| | Sb | | | | | | | | | | | 1 | | | | | | | | 3 | 5 | 0.48 |
| *Bergstroemognathus? n. sp. A* | Sb | | | | | | | | | | | | | | | | | | | 4 | 4 | 0.38 |
| *Drepanoistodus basiovalis* | P | | | | | | | | | | | | | | | | | | | 5 | | |
| | M | | | | | | | | | | | 1 | | | | | | | | 8 | | |
| | Sa | | 3 | | | | | | | | | 1 | | | | | | | | 21 | | |
| | Sb | | | | | | | | | | | | | | | | | | | 6 | | |
| | Sc | | 2 | | | | | | | | | | | | | | | | | 9 | 49 | 4.72 |
| *Drepanoistodus suberectus* | P | | | | | | | | | | | | | | | | | 1 | | 16 | | |
| | M | | | | | | | | | | | | | | | | | | | 8 | | |
| | Sa | | | 1 | | 1 | | 1 | | 1 | | | 2 | | | 2 | | 1 | | 31 | | |
| | Sb | | | | | | | | | | | | | 1 | | | | | | 28 | | |
| | Sc | | | | | | | 1 | | | | | | | | | | | | 4 | 87 | 8.37 |
| *Drucognathus yiranus* | Pa | | | | | 1 | | | | | | | | | | | | | | 8 | | |
| | Pb | 1 | | | | | | | 1 | 1 | | | | | | | | | | 9 | | |
| | M | | | | | | | | | | | | | | | | | | | 2 | | |
| | Sa | | | | | | 1 | | | | | | | 2 | | 2 | | | | 13 | | |
| | Sb | 2 | | | | | | | | | | | | | | | | | | 10 | | |
| | Sc | 1 | | | | | | | | | 1 | | 1 | 1 | | | | | 1 | 34 | 76 | 7.31 |
| *Erismodus nicolli* | Pa | | | | | | | | | | | | | | | | | | | 2 | | |
| | Pb | | | | | | | | | | | | | | | | | | | 3 | | |
| | M | | | | | | | | | | | | | | | | | | | 2 | | |
| | Sa | | | | | | | | | 1 | | | | | 1 | | 1 | | | 7 | | |
| | Sb | | | | | | | | | | | | | | | | | | | 3 | | |
| | Sc | | | | | | | | | | | | | | | 3 | 1 | | | 9 | 26 | 2.50 |
| *Erismodus quadridactylus* | Pa | | | | | | 1 | | | | | 1 | 1 | 3 | | | | | | 27 | | |
| | Pb | | | | | | 1 | | | | | 2 | 1 | 2 | | | | | | 41 | | |
| | M | | 3 | | | | | | | | 1 | 1 | 1 | | | | | | | 34 | | |
| | Sa | | | | | | | | | | 1 | 1 | | | 1 | | | | | 30 | | |
| | Sb | | | | | | 2 | | | 1 | 1 | | | 4 | | | | | | 31 | | |
| | Sc | | 3 | | | | 1 | | | 1 | 1 | | | 3 | 1 | | | | | 61 | | |
| | frags | | | | | | 3 | | | | | | | | | | | | | 18 | 242 | 23.29 |
| *Erraticodon cf. E. patu* | Sd | | | | | | | | | | | | | 1 | | | | | | 12 | | |
| | Pa | | | | | | | | | | | | | | | | | | | 1 | | |
| | Sa | | | | | | | | | | | | 1 | | | | | | | 2 | | |
| | Sb | | | | | | | | | | | | | | 1 | | | | | 3 | 18 | 1.73 |
| *Onyxodus acuoliratus* | S-sym | | | | | | | | | | | | | | | | | | | 4 | | |
| | S-asym | | | | | | | | | | | | | | | | | | | 1 | 5 | 0.48 |
| *?Oulodus sp.* | frag | | | | | | | | | | | | | | | | | | | 19 | 19 | 1.83 |
| *Panderodus nogamii* | M | | | | | | | | | 1 | | | | | | | | | | 6 | | |
| | Sa | | 1 | | | | | | | 1 | | | | | | | | | | 7 | | |
| | S | | 1 | | | | | | | | | | 1 | | | | | | | 17 | 30 | 2.89 |

TABLE 3 **Continued.**

| species | sample # / element | S.P. 895 | S.P. 898 | S.P. 899 | S.P. 900 | S.P. 901 | S.P. 904 | S.P. 906 | S.P. 909 | S.P. 912 | S.P. 913 | S.P. 914 | S.P. 915 | S.P. 916 | S.P. 917 | S.P. 918 | S.P. 919 | S.P. 920 | S.P. 921 | Total | Species Total | % Species |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *?Periodon* n. sp. A | Pa | | | | | | | | | | 1 | | | | | | | | | 8 | | |
| | Pb | | | | | | | | | | | | | | | | | | | 5 | | |
| | M | | | | | | | | | | 2 | 1 | 1 | 1 | | | | | | 18 | 31 | 2.98 |
| *Phragmodus polystrophos* | Pa | | | | | | | | | | 1 | | | | | | | | | 4 | | |
| | Pb | | | | | | | | | | | | | | | | | | | 1 | | |
| | M | | | | | | | | | | | | | | | 1 | | | | 7 | | |
| | Sa | | | | | | | | | | | | | | | | | | | 2 | | |
| | Sb | | | | | | | | | | | | | | | | | | | 7 | | |
| | Sc | | | | | | | | | | | | | | | | 1 | | | 13 | 34 | 3.27 |
| *Phragmodus* n. sp. A | Pa | | | | | | | | | | 1 | | | | | | | | | 5 | | |
| | Pb | | | | | | | | | | | | | | | | | | | 2 | | |
| | M | | | | | | | | | | | | 1 | | | | | | | 2 | | |
| | Sa | | | | | | | | | | | | | | | | | | | 1 | | |
| | Sb | | | | | | | | | 1 | | | | | | | | | | 7 | | |
| | Sc | | | | | | | | | 1 | | | | | | | | | | 5 | 22 | 2.12 |
| *?Serratognathus* sp. | Sa | | | | | | | | | | | | | | | | | | | 2 | 2 | 0.19 |
| *Stauferella divisa* | Sa | | | | | | | | | | | | | | | | | | | 1 | 1 | 0.10 |
| *Triangulodus mithakensis* | Pa | | | | | | 1 | | | 1 | 2 | 3 | 1 | 1 | | 1 | | | | 39 | | |
| | Pb | | 1 | | | | | 1 | | | 2 | 1 | 1 | 1 | 1 | 2 | | | 1 | 42 | | |
| | M | | 3 | | | 1 | 1 | | | | 2 | 2 | 2 | 3 | | 2 | | | | 62 | | |
| | Sa | | 1 | 1 | 1 | | 1 | 1 | | | | 1 | 2 | | | 1 | | | | 49 | | |
| | Sb | 1 | 1 | | | | | | | | 1 | 2 | 1 | 1 | | 1 | 1 | | | 43 | | |
| | Sc | | 1 | 1 | | | 1 | 1 | | 2 | | 1 | 1 | 1 | 1 | | | | | 71 | | |
| | Sd | | 1 | | | | 1 | | | | 1 | 1 | | 1 | | | | | | 36 | 342 | 32.92 |
| *Yaoxianognathus? neonychodonta* | Pa | | | | | | | | | | | | | | | | | | | 2 | | |
| | Pb | | | | | | | | | | | | | | 2 | | | | | 7 | | |
| | M | | | | | | | | | | | | | | | | | | | 1 | | |
| | Sc | | | | | | | | | | | | | | | | | | | 4 | 14 | 1.35 |
| *Juanognathus* sp. A | S | | | | | | | | | | 1 | | | | | | | | | 8 | 8 | 0.77 |
| *Taoqupognathus* n. sp. A | P | | | | | | | | | | | | | | | | | | | 1 | 1 | 0.10 |
| gen et sp indet A | Sb | | | | | | | | | | | | | | | | | | | 1 | 1 | 0.10 |
| gen et sp indet B | Sc | | | | | | | | | | 1 | 1 | 1 | | | | | | | 3 | 3 | 0.29 |
| *Total* | | 5 | 21 | 3 | 1 | 3 | 15 | 5 | 1 | 12 | 20 | 21 | 20 | 26 | 8 | 15 | 4 | 2 | 2 | 1039 | 1039 | 100.00 |

TABLE 4 **Occurrence and abundance of conodont specimens from the Bedourie Scout Hole nop. 1, core 3.**

| species | sample # / element | 959' - 961' | 989' | 992' | 993' | 995' | 998' | Total | Species Total | % Species |
|---|---|---|---|---|---|---|---|---|---|---|
| *Drepanoistodus suberectus* | P | | | | | 1 | | 1 | | |
| | M | | | | | 7 | 3 | 10 | | |
| | Sa | | | | | 5 | 1 | 6 | | |
| | Sb | | | | | 6 | 2 | 8 | | |
| | Sc | | | | | 13 | | 13 | 38 | 27.74 |
| *Drucognathus yiranus* | Pa | | | | | 4 | 1 | 5 | | |
| | Pb | | | | | 2 | | 2 | | |
| | Sa | | | | | | 3 | 3 | | |
| | Sb | | | | | 2 | 1 | 3 | | |
| | Sc | | | | | 15 | 3 | 18 | 31 | 22.63 |
| *Erismodus nicolli* | Sa | 1 | | | | | | 1 | 1 | 0.73 |
| *Erismodus quadridactylus* | Sa | | | | | 2 | | 2 | 2 | 1.46 |
| *Onyxodus acuoliratus* | S-sym | | | | | 1 | 1 | 2 | | |
| | S-asym | | | | | 2 | | 2 | 4 | 2.92 |
| *?Oulodus sp.* | frag | | | | | 4 | | 4 | 4 | 2.92 |
| *Phragmodus polystrophos* | Pa | 1 | 3 | | | | | 4 | | |
| | M | | 2 | | | | 1 | 3 | | |
| | Sb | | 1 | | 1 | | | 2 | | |
| | Sc | | 1 | | 2 | 2 | | 5 | 14 | 10.22 |
| *Phragmodus* n. sp. A | M | | | | | | 1 | 1 | | |
| | Sa | | 1 | | | | | 1 | | |
| | Sb | | | | | 1 | 3 | 4 | | |
| | Sc | | | | | 1 | 3 | 4 | 10 | 7.30 |
| *Triangulodus mithakensis* | Pa | | 2 | | | 1 | 1 | 4 | | |
| | Pb | | | | | 3 | | 3 | | |
| | M | | | | | | 4 | 4 | | |
| | Sa | | 1 | | | | | 1 | | |
| | Sb | | 1 | | | 5 | 1 | 7 | | |
| | Sc | | 1 | | | 4 | | 5 | | |
| | Sd | | 1 | | | | | 1 | 25 | 18.25 |
| *Yaoxianognathus? neonychodonta* | Sc | | | | 1 | 3 | | 4 | | |
| | frag | | | | | 4 | | 4 | 8 | 5.84 |
| *Total* | | 2 | 14 | 0 | 4 | 88 | 29 | 137 | 137 | 100.00 |