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Conodonts from the Lower Ordovician Coolibah Formation, Georgina Basin, central Australia

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The Coolibah Formation outcropping around the Toko Syncline, southeastern Georgina Basin, was sampled for conodonts during a multidisciplinary study of Georgina Basin geology by the Australian Geological Survey Organisation. Twenty-two species of conodonts belonging to 17 genera recovered from acid insoluble residues are described. *Alcoorina* and *Tokoconus* are new genera; *Alcoorina nadala*, *Bergstroemognathus kirki* and *Tokoconus wheelamanensis* are previously undescribed species. Four species remain in open nomenclature awaiting more material. The conodont faunas are grouped into three broad biostratigraphic associations, although few sections record all three. Faunas low in the Coolibah Formation are dominated by *Drepanoistodus costatus* (Abaimova) and *Scolopodus multicostatus* Barnes & Tuke, with *Diaphorodus tortus* (McTavish), *Scandodus* sp. nov. A and hyaline conical elements. The succeeding conodont association records first appearances of *Ansella fengxiangensis* (An & others), *Aurilobodus? leptosomatus* An, *Paroistodus originalis* (Sergeeva), *Protoprioniodus nyinti* Cooper, and *Triangulodus larapintinensis* (Crespin). Specimens of younger species are found in the uppermost Coolibah Formation. Examination of these associations within different sections indicates that both upper and lower contacts of the Coolibah Formation are probably diachronous. Recovered conodonts are closest in affinity to those of North China, and North and South Korea. They range in age from middle to late Arenig.

Introduction

The Coolibah Formation is part of the Cambrian to Ordovician shallow water succession in the Georgina Basin (Fig. 1). It is exposed near the rims of the northwest–southeast trending Toko Syncline which crosses the Northern

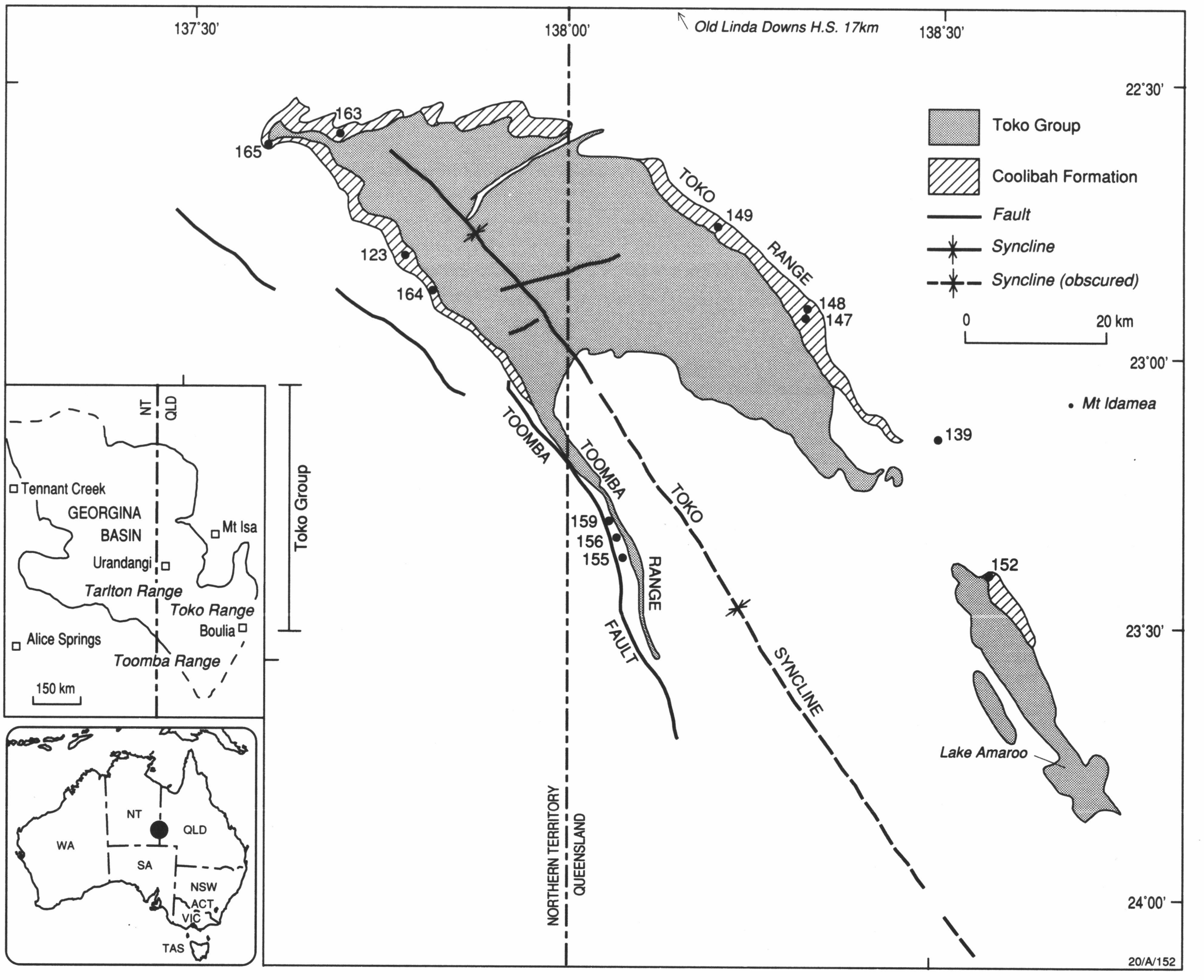

Figure 1. Coolibah Formation in southern Georgina Basin, and location of sampled sections (modified from Draper, 1980).

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Territory–Queensland border just north of the Tropic of Capricorn. This formation is also known in core from the Toko Range.

The Coolibah Formation is underlain by the predominantly dolomitic Kelly Creek Formation, and overlain by the carbonate-rich and clastic sequences of the Nora Formation. It comprises a variable succession of fine-grained, grey to white limestones with minor grey calcareous siltstones (Playford and Wicander, 1988). Lithologies have been more fully described in Shergold & others (1976) and Webby & others (1981).

Relationships of the Coolibah Formation with both underlying and overlying rocks are unclear. Shergold (1985) believed the Kelly Creek–Coolibah contact to be interdigitative. Others have maintained that sequences may be either conformable or disconformable (see Webby & others, 1981). Similarly, contact between the Coolibah and Nora Formations is reported to be conformable (e.g. Draper, 1980; Shergold, 1985) or unconformable, at least in places (Wade *in* Playford & Wicander, 1988).

The Coolibah Formation varies in thickness, from 7.5 m at the type locality (Fig. 2) to 110 m near the southeastern end of the Toko Range (Smith, 1972)

The precise age of the Coolibah Formation is doubtful. Its fauna and flora are largely unknown outside Australasia (e.g. Playford & Wicander, 1988) or may even, in some cases, be endemic to the Georgina Basin. Shergold & others (1976), Shergold & Druce (1980) and Nicoll & others (1992) assign an early Arenig age to this formation. Acritarchs described by Playford & Wicander (1988) range from latest Tremadoc to Llanvirn. Nautiloids from the base of the Nora Formation are late Arenig (Wade *in* Playford & Wicander, 1988). Nora Formation trilobites are largely endemic (Fortey & Shergold, 1984): the only species known with certainty from outside Australia appears to be mid Arenig (Fortey & Shergold, 1984, 350).

The lower boundary of the Coolibah Formation may be diachronous (Smith, 1972), and the implication of nautiloid distribution within the basal Nora Formation is that the Coolibah–Nora formation boundary is not isochronous (M. Wade, Queensland Museum, pers. comm., July 1991).

This study is one part of a systematic evaluation of conodont faunas throughout the Kelly Creek to Nora formations. Detailed taxonomy of these collections, in the light of improved understanding of conodont apparatuses, should clarify much of the biostratigraphic uncertainty relating to these sequences.

The following is a re-evaluation of unpublished material collected by Druce before 1970 as part of the Australian Geological Survey Organisation (then the Bureau of Mineral Resources) multidisciplinary study of Cambrian to Ordovician rocks from the southern margin of the Georgina Basin.

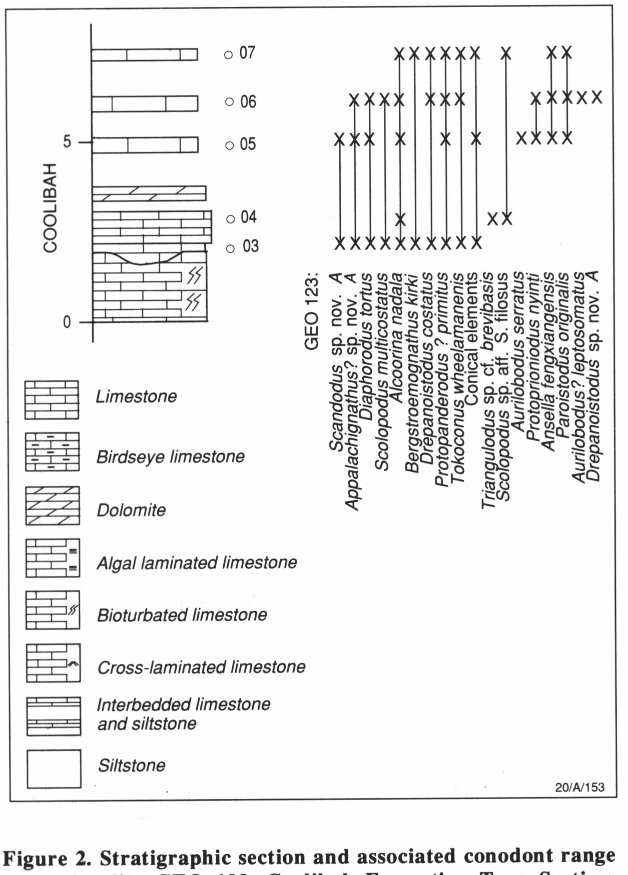


Figure 2. Stratigraphic section and associated conodont range chart, locality GEO 123, Coolibah Formation Type Section, Bloodwood Creek.
Stratigraphic thickness is measured in metres. Symbols defined here are used in Figures 311.

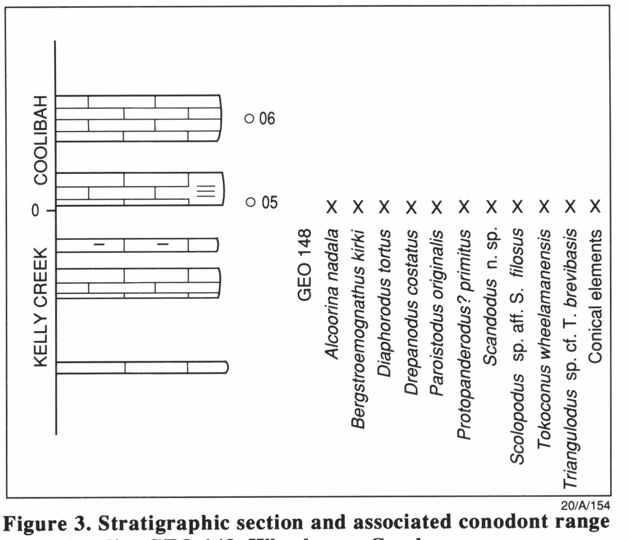


Figure 3. Stratigraphic section and associated conodont range chart, locality GEO 148, Wheelaman Creek.
Stratigraphic thickness is measured in metres. Symbols and scale as in Figure 2.

Samples are accurately located (Fig. 1) where sections were measured and collected. However, during an initial exploratory phase of geological mapping, spot samples were collected and some localities are unclear. Material from these localities was used in taxonomic evaluations, but not biostratigraphically.

Locality information

Samples were collected from sections on both eastern and western limbs of the Toko Syncline, along the Toko and Toomba ranges (Fig. 1). Each section is referred to by number, prefaced by 'GEO'. Sample numbers are composite: each refers to the section from which each sample was collected followed by a sequential number. Precise location

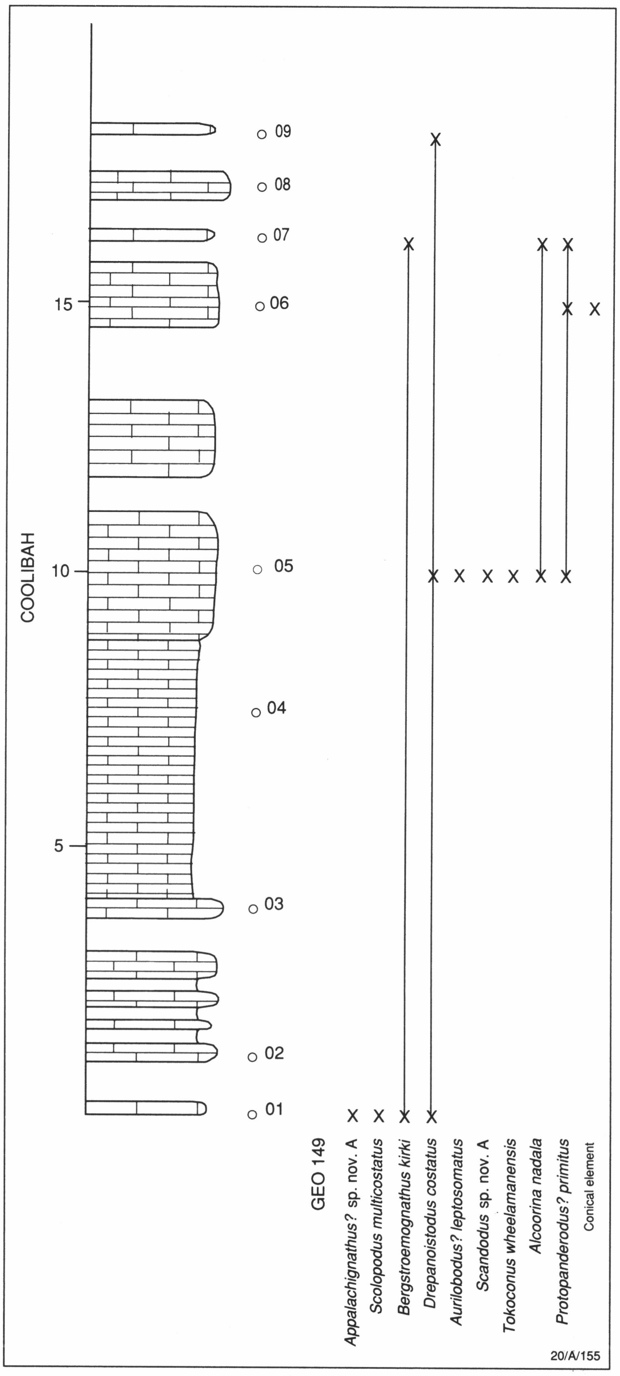


Figure 4. Stratigraphic section and associated conodont range chart, locality GEO 149, south of Linda Creek.
Stratigraphic thickness is measured in metres. Symbols and scale as in Figure 2.

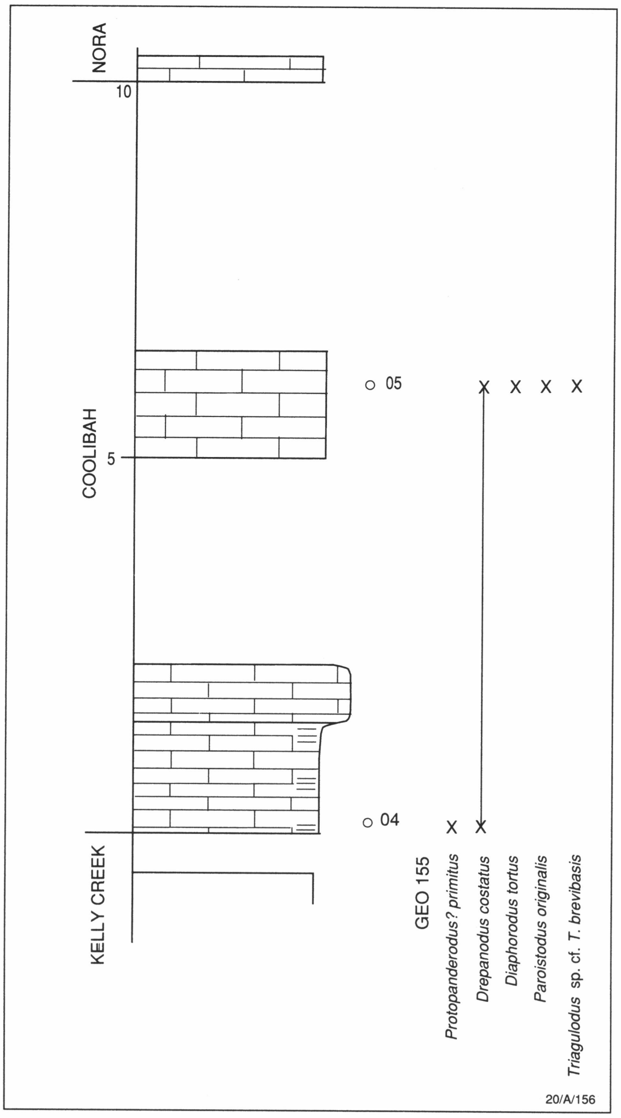


Figure 5. Stratigraphic section and associated conodont range chart, locality GEO 155, southern end of Toomba Range.
Stratigraphic thickness is measured in metres. Symbols and scale as in Figure 2.

of conodont-bearing samples is indicated on accompanying stratigraphic sections (Figs 2–10).

Grid references refer to locality of sections, as follows:

GEO 123: Coolibah Formation type section; Bloodwood Creek, grid reference 596153 on Tobermory 1:250 000 topographic sheet SF 53–12, Edition 2, Series R 502.

GEO 132: spot samples, Coolibah Formation, precise locations unknown.

GEO 139: Coolibah to Nora formations, 2 km south of Ilanama Swamp, grid reference 455??7 on Mt Whelan 1:100 000 geological sheet 6651, Preliminary Edition, September 1979.

GEO 147: Coolibah Formation, Wheelaman Creek near Wheelaman East Hut, grid reference 656144 on Glenormiston 1:250 000 geographic sheet SF 54-9 Edition 1, Series R 502.

GEO 148: Kelly Creek and Coolibah formations, Wheelaman Creek near Wheelaman East Hut, grid reference 656145 on Glenormiston 1:250 000 geographic sheet SF 54–9 Edition 1, Series R 502.

GEO 149: Coolibah Formation, south of Linda Creek, grid reference 637165 on Glenormiston 1:250 000 geographic sheet SF 54–9 Edition 1, Series R 502.

GEO 152: Kelly Creek to Coolibah formations, 10 km west of Jewlerry Waterhole, grid reference 593189 on Mt Whelan 1:100 000 geological sheet 6651, Preliminary Edition, September 1979.

GEO 155: Kelly Creek to Coolibah formations, southern end of Toomba Range, grid reference 055134 on Abudda Lakes 1:100 000 geological sheet 6551, Preliminary Edition, May 1980.

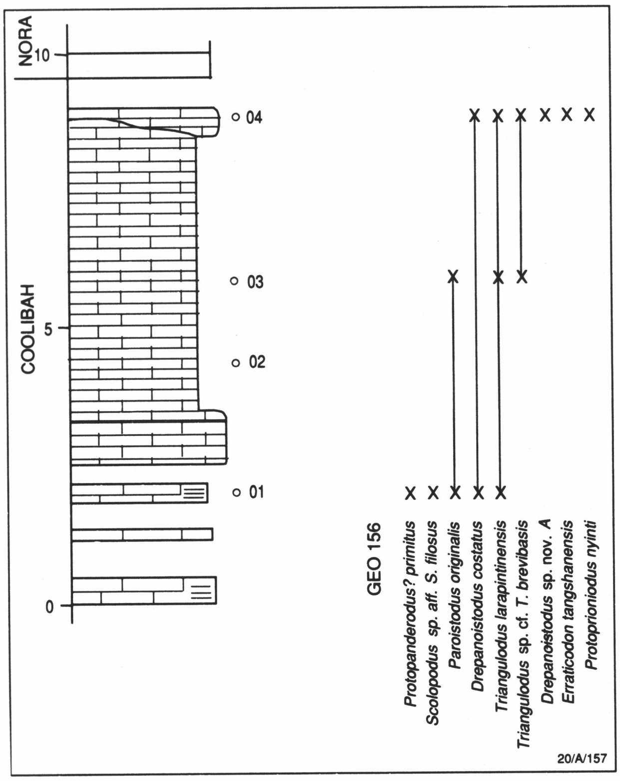


Figure 6. Stratigraphic section and associated conodont range chart, locality GEO 156, Toomba Range, near Craven's Peak. Stratigraphic thickness is measured in metres. Symbols and scale as in Figure 2.

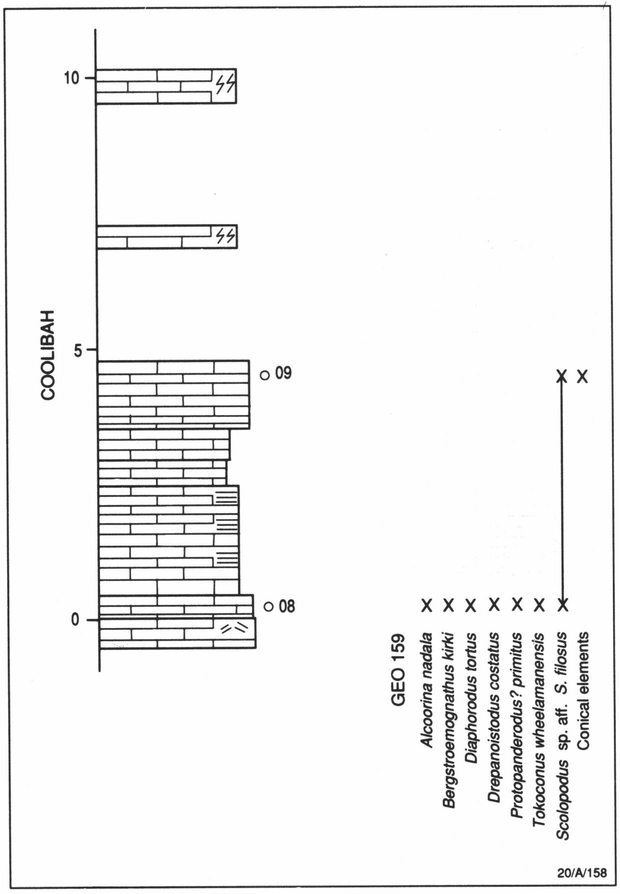


Figure 7. Stratigraphic section and associated conodont range chart, locality GEO 159, Toomba Range, west of Twin Hills. Stratigraphic thickness is measured in metres. Symbols and scale as in Figure 2.

GEO 156: Coolibah to Nora formations, on low hill near Craven's Peak, grid reference 028171 on Abudda Lakes 1:100 000 geological sheet 6551, Preliminary Edition, May 1980.

GEO 159: Kelly Creek to Coolibah Formations, west of Twin Hills, grid reference 030211 on Abudda Lakes 1:100 000 geological sheet 6551, Preliminary Edition, May 1980.

GEO 163: Coolibah Formation, Alcoora Creek, grid reference 615175 on Tobermory 1:250 000 topographic sheet SF 53–12, Edition 2, Series R 502.

GEO 164: Coolibah Formation, Halfway Dam, grid reference 606146 on Tobermory 1:250 000 topographic sheet SF 53–12, Edition 2, Series R 502.

GEO 165: Coolibah Formation, Bloodrock Creek near MarquaTobermory boundary fence, grid reference 589173 on Tobermory 1:250 000 topographic sheet SF 53–12, Edition 2, Series R 502.

TOK samples were collected from the Toko Range during early reconnaissance of the area; localities unknown.

Biostratigraphy

Ranges of Coolibah Formation conodonts are shown in Figs 2–10 plotted against lithostratigraphy of sections in which they occur.

The conodont fauna in basal strata of the Coolibah Formation generally consists of *Diaphorodus tortus* McTavish, *Scolopodus multicostatus* Barnes & Tuke, *Alcoorina nadala* gen. et sp. nov., *Bergstroemognathus kirki* sp. nov., *Drepanoistodus costatus* (Abaimova), *Protopanderodus? primitus* Cooper, *Tokoconus wheelamanensis* gen. et sp. nov., with new species of *Scandodus* Lindström and *Appalachignathus*? Bergström & others. While many of these species continue through much of the studied sections, they are most abundant low in the Coolibah Formation. Neither *Scandodus* sp. nov. A nor *Diaphorodus tortus* occurs in upper Coolibah Formation.

Middle strata frequently record first appearance of *Scolopodus* sp. aff. *S. filosus* Ethington & Clark, *Triangulodus* sp. cf. *T. brevibasis* (Sergeeva), *Ansella fengxiangensis* (An & others), *Protoprioniodus nyinti* Cooper, *Aurilobodus? leptosomatus* An, *Paroistodus originalis* (Sergeeva) and *Triangulodus larapintinensis* (Crespin). These last five species have not been found in basal Coolibah Formation.

Upper Coolibah Formation contains a few specimens of younger species (e.g. *Erraticodon tangshanensis* Yang & Xu). This is also the level of maximum abundance of *Triangulodus larapintinensis*.

Within this general scheme, there are exceptions. *Scolopodus multicostatus* may occur in sequences underlying the base of the Nora Formation (e.g. GEO 165) together with species more common to this stratigraphic level. *Triangulodus* sp. cf. *T. brevibasis*, commonly first found in mid Coolibah Formation, may occur in basal Coolibah Formation rocks. These, and similar perturbations in the

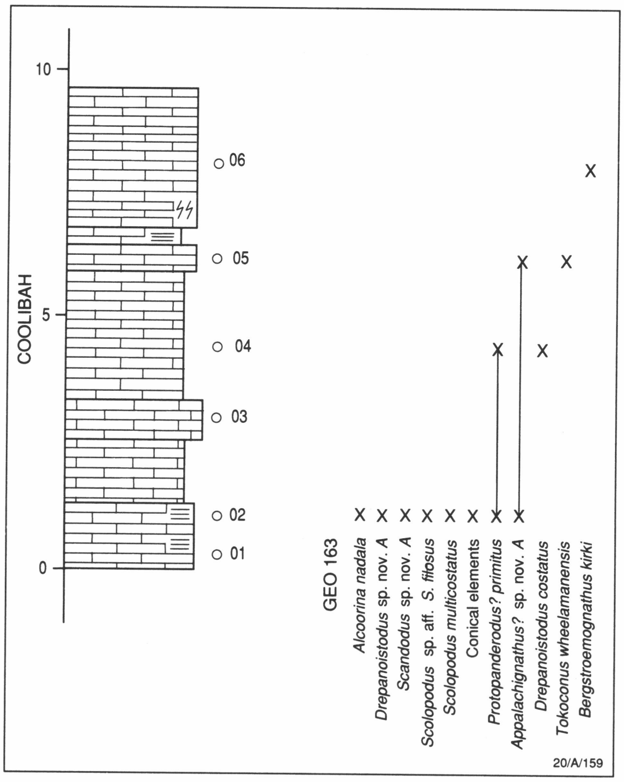


Figure 8. Stratigraphic section and associated conodont range chart, locality GEO 163, Alcoora Creek.
Stratigraphic thickness is measured in metres. Symbols and scale as in Figure 2.

succession of conodont species, suggest environmental control on conodont occurrence.

Possibly as a consequence, bases of both Coolibah and Nora formations appear to be diachronous (Fig. 11). While the upper conodont fauna of the Coolibah Formation is recorded below the base of the Nora Formation in GEO 156, and at localities spot sampled from the Toko Range, basal Nora Formation at GEO 165 contains the middle conodont fauna more typical of the Coolibah Formation. Conodonts from both underlying Kelly Creek Formation and overlying Nora Formation are similar to lower and upper faunas respectively of the Coolibah Formation. Study of these conodonts should reveal the extent of diachroneity of upper and lower boundaries of the Coolibah Formation.

Correlation with Australian successions

Correlation of Australian Ordovician sequences with the Coolibah Formation is shown in Table 1.

Oistodus multicorrugatus Harris, *Protoprioniodus nyinti* Cooper, *Triangulodus larapintinensis* (Crespin) and *Protopanderodus? primitus* Cooper are found in both Coolibah Formation and Horn Valley Siltstone. *Protoprioniodus nyinti* indicates lower Horn Valley Siltstone, while *Oistodus multicorrugatus* and *Triangulodus larapintinensis* are found throughout this formation. *Protopanderodus? primitus,* while restricted to upper Horn Valley Siltstone, may be excluded because of environmental differences. The uppermost Coolibah Formation conodont fauna most likely correlates with that of the lower Horn Valley Siltstone.

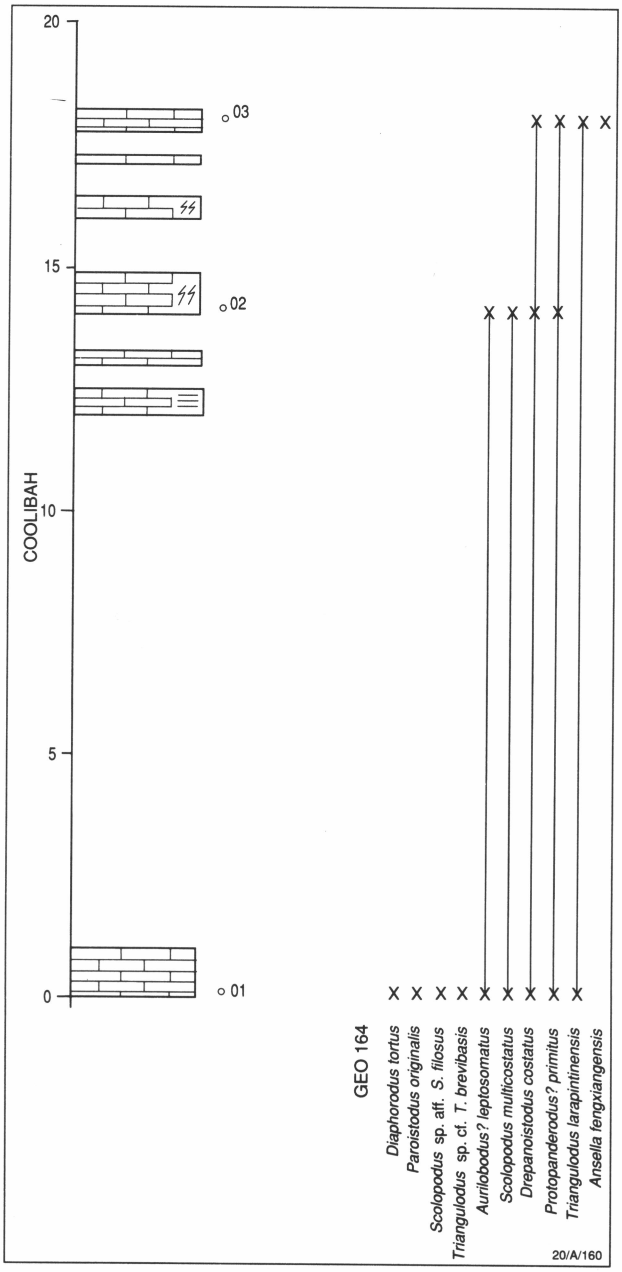


Figure 9. Stratigraphic section and associated conodont range chart, locality GEO 164, Halfway Dam.
Stratigraphic thickness is measured in metres. Symbols and scale as in Figure 2.

Conodont elements figured (Cooper, 1986) from interbeds within the Innamincka Red Beds of the Warburton Basin include one (Cooper, 1986, fig. 3) closely resembling the erectiform element of *Ansella fengxiangensis* (An & others). Some of Cooper's specimens (Cooper, 1986, figs 4, 5) are similar to elements of *Triangulodus* species from the Coolibah Formation. The Innamincka Red Beds and the Coolibah Formation are therefore likely to be approximately the same age.

Within the Canning Basin Ordovician sequence, *Diaphorodus tortus* is found in upper Emanuel Formation. This corresponds to zone OCC of McTavish & Legg (1976), which also contains species previously referred to the Chirognathacea. These are also found in the Coolibah Formation as part of *Bergstroemognathus* and *Appalachig-*

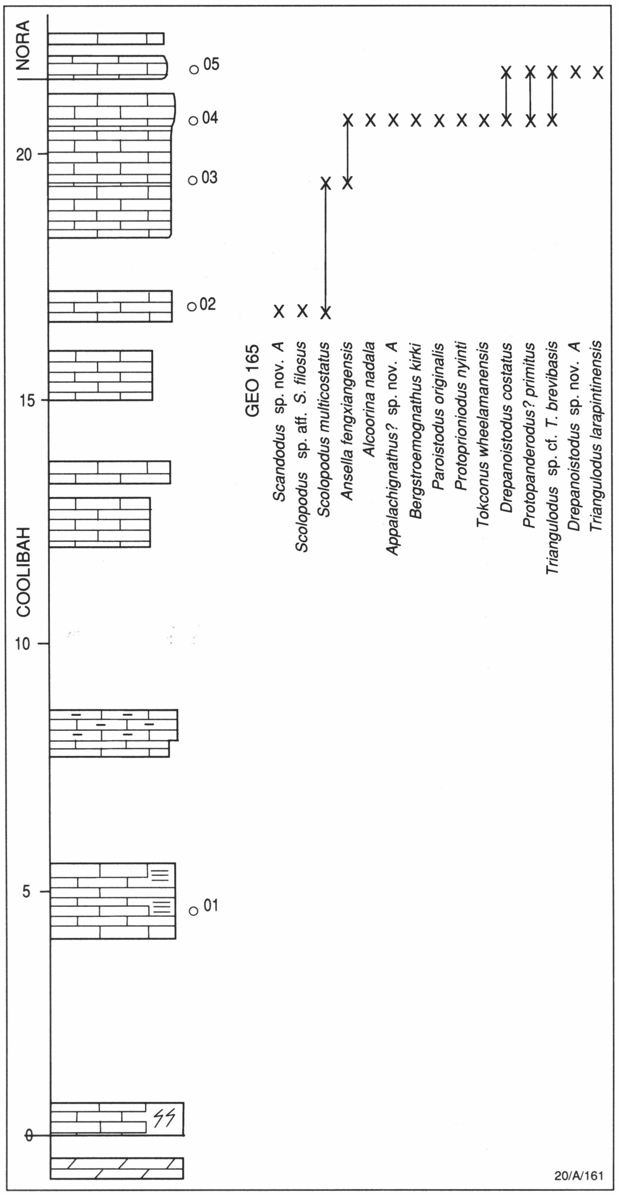


Figure 10. Stratigraphic section and associated conodont range chart, locality GEO 165, Bloodrock Creek near Marqua Tobermory boundary fence.
Stratigraphic thickness is measured in metres. Symbols and scale as in Figure 2.

nathus? apparatuses. *Protoprioniodus* species occur in overlying strata, which contains zone OCD conodonts, including *Paroistodus originalis*. It is concluded that the Coolibah Formation correlates with rocks containing faunas of upper zone OCC and zone OCD. This corresponds to the interval extending from upper Emanuel Formation to low in the Gap Creek Formation.

Conodonts from Mt Arrowsmith contain *Protoprioniodus nyinti*, and tentatively correlate with those from middle or upper Coolibah Formation (Kennedy, 1975).

The Victorian conodont fauna (Stewart, 1988) has no zonal fossils in common, and therefore cannot be directly correlated, with the Coolibah Formation.

International correlation

Coolibah Formation conodonts have strongest links with faunas of North China, and North and South Korea, supporting the prediction of 'close proximity (but not contiguity) of North China with ... Australia' during the early Ordovician (Burrett & Stait, 1987, 70). Appropriate correlations are detailed in Table 1.

The occurrence of *Drepanoistodus costatus, Tokoconus wheelamanensis, Triangulodus* sp. cf. *T. brevibasis, Aurilobodus? leptosomatus* and *'Oepikodus' maggolensis* Lee in lower Majiagou Formation rocks of northern China, and of *Protopanderodus? primitus* and *Oistodus multicorrugatus* within the Majiagou Formation indicates contemporaneity of lower and middle Coolibah Formation with lower Majiagou Formation.

On the basis of co-occurrence of *Ansella fengxiangensis*, Coolibah Formation conodonts probably correlate with those from part of the Dawan Formation of southern China (see An, 1987).

Protopanderodus? primitus is present in the Dumugol Formation of Kangweon-Do in South Korea (Lee, 1975a). The overlying Maggol Formation contains *'Oepikodus' maggolensis* and *Erraticodon tangshanensis* Yang & Xu (Lee, 1976). Coolibah Formation conodonts correlate with those from the Dumugol Formation and into the Maggol Formation.

Drepanoistodus costatus and *Scolopodus multicostatus* dominate faunas of the lower Coolibah Formation. These two species, together with *Oistodus multicorrugatus,* are found in strata of Ugorian to Kimaian age on the Siberian Platform (see Abaimova, 1975 and Moskalenko, 1984).

Presence and succession of *Scolopodus multicostatus, Oistodus multicorrugatus* and *Protoprioniodus nyinti* within both Coolibah Formation and Ordovician strata of the Ibex area indicate deposition of the Coolibah Formation during the time of Zone G2 to zone L conodont faunas (Ethington & Clark, 1981).

This corresponds, according to mutual presence of *Protopanderodus? primitus, Triangulodus* sp. cf. *T. brevibasis* and *Oistodus multicorrugatus,* with upper San Juan Formation of Argentina (Serpagli, 1974).

The presence of *Paroistodus originalis* indicates a tentative correlation of the Coolibah Formation conodonts with those of the Arenig or lower Llanvirn of northern Europe (see Löfgren, 1978).

Systematic palaeontology

Type and figured specimens are housed in the Commonwealth Palaeontological Collection at the Australian Geological Survey Organisation, Canberra, and have numbers prefixed by the letters CPC.

Only one association of elements remains unnamed because of small numbers of specimens. All other taxa described form part of multielement apparatuses.

Conodont apparatuses are described according to the nomenclatural system of Barnes & others (1979), together with the descriptive form terminology commonly used to designate general element shape. Apparatus positions of

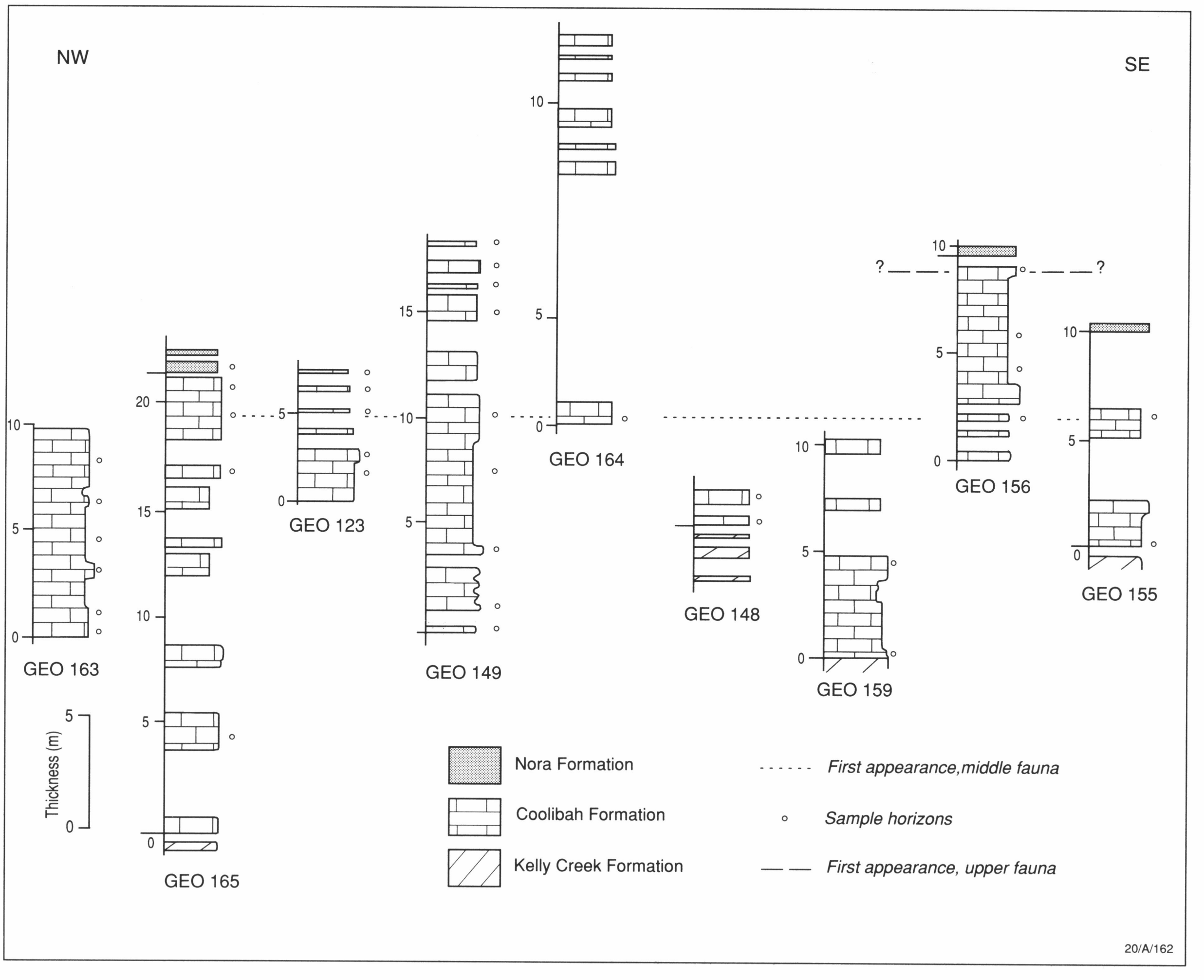


Figure 11. Correlation of Coolibah Formation measured sections.

Sweet (1981) are also indicated, where possible.

As a consequence of rapid evolution of Lower and Middle Ordovician conodonts, with a considerable variety of apparatuses, systematics of this group has not yet stabilised. Taxa considered herein are therefore listed alphabetically.

Conodont occurrence and abundance charts for all GEO localities are included in Table 2. Specimens were processed while in the field. No record of sample weight has been retained, and comparison of faunal abundance per kilogram of sample is not possible.

Genus *Alcoorina* gen. nov

Type species. *Alcoorina nadala* sp. nov.

Etymology. For Alcoora Creek, which passes one section from which specimens of this genus were collected.

Diagnosis. An apparatus of coniform elements with short base; cusp striate on inner or both lateral faces, with sharp edges, densely albid. Striae meet at acute angle at grooves. All elements have base flared to some extent.

Drepanodontiform (a, S_c), asymmetrical acontiodontiform (b, S_b), acontiodontiform (c, S_a), oistodontiform (e, M), scandodontiform (f, P_b) and suberectiform (g, P_a) elements are included within a Type IVB apparatus of Barnes & others (1979).

Remarks. Elements of this apparatus bear some similarity to co-occurring species of *Protopanderodus* Lindström, but are distinguished by their extremely short base and their cusp cross-section: lateral keels are poorly developed on b and c elements of *Alcoorina* when compared with those of *Protopanderodus*.

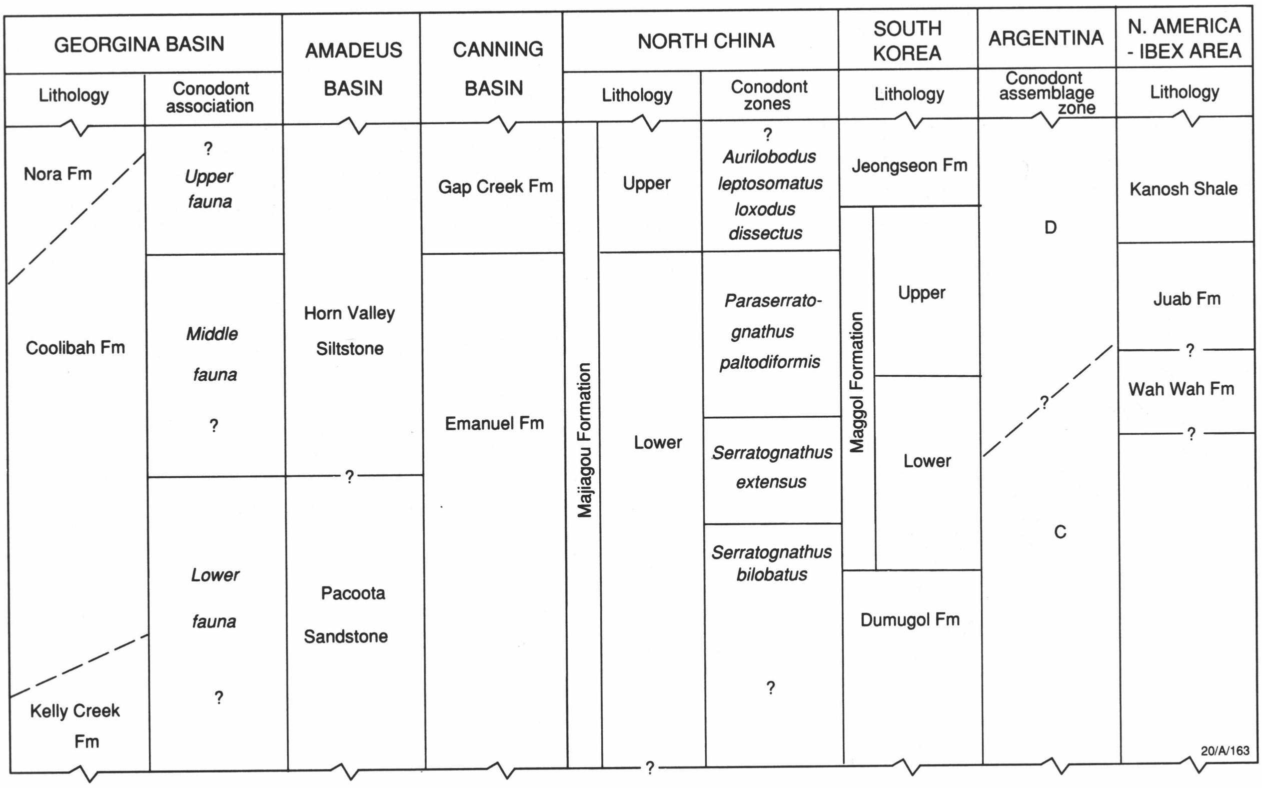
Alcoorina nadala sp. nov.
Figs 12A–D, 15A–J

Etymology. From the Old High German *nadal*, needle, alluding to the form of the diagnostic scandodontiform and suberectiform elements.

Type specimens. Holotype CPC 23312 (GEO 123/OO6), suberectiform element; paratypes CPC 23313 (GEO 123/003), suberectiform element; CPC 23314 (GEO 148/005) drepanodontiform element; CPC 23315 (GEO 149/005), asymmetrical acontiodontiform element; CPC 23316 (GEO 132/016), acontiodontiform element; CPC 23317 (TOK 9/6), oistodontiform element; CPC 23318 (GEO 123/005), scandodontiform element; CPC 23319 (GEO 123/005), scandodontiform element. All are figured specimens.

Table 1. Correlation of the Coolibah Formation with significant localities within Australia and internationally, on the basis of conodont faunas.

Only localities with conodonts showing faunal affinity with those of the Coolibah Formation are considered. Data for the Georgina Basin are from this study. Other sources include Cooper (1981) and Nicoll & others (1992) for the Amadeus Basin, McTavish (1973) and Cooper (1981) for the Canning Basin, An & others (1983) for North China, Lee (1975a, 1976) for South Korea, Serpagli (1974) for Precordilleran Argentina, and Ethington & Clark (1981) for the Ibex Area of Utah-Nevada in North America.



Type stratum. GEO 123/006, five m above base of Coolibah Formation exposed to side of Bloodwood Creek, (grid co-ordinates 596153, on Tobermory topographic 1:250 000 map SF 53–12, Edn 2, Series R 502).

Material studied. 67 specimens: 9 drepanodontiform, 11 asymmetrical acontiodontiform, 4 acontiodontiform, 8 oistodontiform, 20 scandodontiform and 15 suberectiform elements.

Diagnosis. As for genus.

Description. All elements with sharp edges to cusp, and short base; cusp striate on at least part of lateral faces, densely albid.

Drepanodontiform element with reclined to erect cusp; cusp edge, with or without narrow blocky keels; element has unequally biconvex cross-section. Intersection of posterior and oral margins is obtuse (approximately 130–150°); antero-aboral intersection is approximately perpendicular; aboral and oral margins form an acute to perpendicular intersection (70–90°). Oral margin is short; base occupies less than 1/6 length of element; aboral opening is teardrop to D-shaped, base may flare slightly inwards. Tip of shallow basal cavity is close to anterior margin of cusp; anterior edge of cavity convex towards cavity; posterior margin of cavity almost straight from oral–aboral intersection to tip.

Asymmetrical acontiodontiform element as above except that anterior margin has broad, blocky keel extending along cusp to base, and there is a shallow groove in posterior part of inner lateral face; cusp cross-section is triangular, but asymmetrical; intersection of aboral and oral margins is acute (approximately 60°). Inner lateral face of base flares inwards and up; aboral opening is teardrop-shaped; tip of basal cavity is situated at approximately 1/3 distance between anterior and posterior margins (at edge of anterior keel).

Acontiodontiform element has equidimensional cusp; lateral edges sharp and keeled only in region of greatest cusp curvature. Aboral opening has shape of gothic arch, with no projecting lateral flanges; oral margin short; postero-oral intersection obtuse (approximately 120°); each lateral edge intersects aboral opening approximately perpendicularly.

Oistodontiform element similar to asymmetrical acontiodontiform element except that postero-oral intersection is acute (30–40°); antero-aboral intersection approximates 130–150°; 30–40° is subtended by intersection of oral and aboral margins. Oral margin keeled, straight; a depression is formed on cusp anterior of postero-oral intersection. Base has inner lateral flare medially.

Scandodontiform element is similar to asymmetrical acontiodontiform element, but cusp is twisted, posterior groove may or may not be pronounced, and aboral opening is lenticular.

Suberectiform element as scandodontiform element, but cusp is more noticeably twisted, with more pronounced inner lateral flare to base, generally a pronounced posterior groove to inner lateral face and acontiodontiform cross-

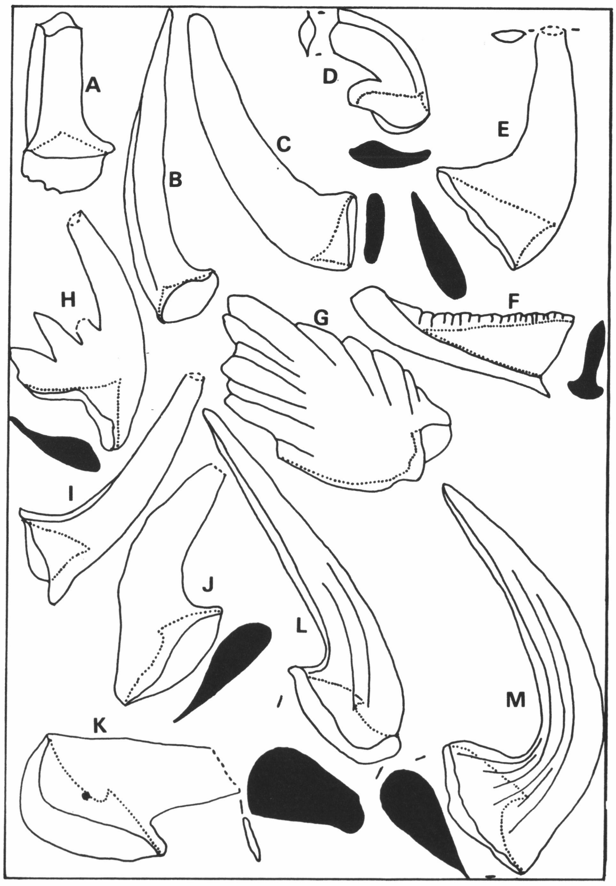


Figure 12. Selected conodont elements.
Basal cavity outline is indicated by dotted lines; cusp cross-section (unshaded) and shape of aboral opening (shaded) are included.
All specimens X80 unless otherwise stated.
A-D, ***Alcoorina nadala*** **gen. et sp. nov. A,** suberectiform element, paratype, CPC 23313, posterior view, GEO 123/003. **B,** scandodontiform element, paratype, CPC 23319, inner lateral view, GEO 123/005. **C,** drepanodontiform element, paratype, CPC 23314, lateral view, GEO 148/005. **D,** oistodontiform element, paratype, CPC 23317, inner lateral view, TOK 9/6. **E, F** ***Ansella fengxiangensis*** (An & others). **E,** erectiform element, CPC 23324, lateral view, GEO 123/005. **F,** asymmetrical belodelliform element, CPC 23321, lateral view, GEO 123/006. **G,** ***Appalachignathus?*** **sp. nov.** Eoliginodinaform element, CPC 23326, inner view, GEO 123/005. **H,** ***Bergstroemognathus kirki*** **sp. nov.** X70, cordylodontiform element, paratype, CPC 23334, inner lateral view, GEO 123/003. **I,** ***Diaphorodus tortus*** (McTavish) gothodontiform (b, sb) element, CPC 23340, inner lateral view, GEO 132/022. **J, K,** ***Drepanoistodus*** **sp. nov. A,** X70, from GEO 156/004. **J,** homocurvatiform element, CPC 23352, inner lateral view. **K,** oistodontiform element, CPC 23354, inner lateral view. **L, M,** ***Drepanoistodus costatus*** (Abaimova), X40. **L,** oistodontiform element, CPC 23350, inner lateral view, GEO 148/005. **M,** scandodontiform element, CPC 23351, lateral view, GEO 132/016.

section to cusp; aboral opening is D-shaped to rectangular.

Remarks. Elements of *Alcoorina nadala* are superficially similar to *Scolopodus warendensis* Druce and Jones, *Scolopodus transitans* Druce and Jones and *Oneotodus erectus* Druce and Jones from the Ninmaroo Formation of the Georgina Basin. These may be congeneric with *A. nadala,* but differ in cusp cross-section and morphology of basal region.

Distribution. Throughout the Coolibah Formation within the study area.

Genus *Ansella* Fåhraeus and Hunter, 1985

Type species. *Belodella jemtlandica* Löfgren, 1978

Remarks. Apparatus of this genus, as reconstructed by Fåhraeus & Hunter (1985) and Watson (1988), include oepikodontiform, belodelliform, oistodontiform, and drepanodontiform elements. Symmetry transitions mentioned by Fåhraeus & Hunter allow for both asymmetrical and symmetrical forms of oepikodontiform, belodontiform and drepanodontiform elements in a Type IVB apparatus, as described by Watson (1988, 104). The following species was also found to follow this plan, with symmetrical oepikodontiform (a, Sc), asymmetrical oepikodontiform (b, Sb), symmetrical and asymmetrical belodelliform (c, Sa), oistodontiform (e, M), drepanodontiform (f, Pa) and erectiform elements (g, Pb). It is possible that asymmetrical belodelliform elements may occupy the d (Sd) position in this apparatus, in which case the apparatus is modified Type IVC.

Ansella fengxiangensis (An & others, 1981)
Figs 12E-F, 15K–N

Synonymy.
Multielement reconstructions
Belodella fengxiangensis An, Du, Gao, Chen & Lee. An & others, 1985, pp. 43–44, pl. 15, figs 16–19 only; An, 1987, pp. 129–130, pl. 21, figs 25–26, pl. 24, fig. 26, pl. 29, fig. 5 (synonymy).

Unfigured specimens. CPC 23322 (GEO 123/005), symmetrical belodelliform element; CPC 23325 (GEO 123/005), drepanodontiform element

Material studied. 36 specimens: 5 symmetrical oepikodontiform, 7 asymmetrical oepikodontiform, 2 symmetrical belodelliform, 3 asymmetrical belodelliform, 3 oistodontiform, 7 drepanodontiform and 9 erectiform elements.

Remarks. Intraspecific variation in denticle size and orientation, and strength of costae preclude use of these variables to distinguish between species of *Ansella* (Watson, 1988). However, depth and shape of basal cavity appear consistent within populations of *Ansella.* The relatively shallow and less convex anterior margin to basal cavity appears consistent throughout geographic occurrence of *A. fengxiangensis.* Additionally, cusp of belodelliform and oepikodontiform elements is consistently twisted. Symmetry of these elements is then determined by position of costae or lateral carinae on the base.

The oistodontiform element figured by An & others (1985, pl. 15, figs 13, 14) has a larger base than Coolibah Formation specimens, but is similarly twisted. Possibly this belongs to a related species.

Distribution. *Ansella fengxiangensis* is known from North and South China, and middle and upper Coolibah Formation of the Georgina Basin.

Genus *Appalachignathus* Bergström, Carnes, Ethington, Votaw & Wigley, 1974

Type species. *Appalachignathus delicatulus* Bergström, Carnes, Ethington, Votaw & Wigley, 1974.

Remarks. The apparatus reconstruction of Bergström & others (1974) is followed here. Eoliginodiniform (a, S_c), zygognathodontiform (b, S_b), trichonodelliform (c, S_a), spathognathodontiform (e, M) and ozarkodiniform (f, P_a) elements are recognised in a Type IVE apparatus.

Bergstroemognathus Serpagli and *Leptochirognathus* Branson & Mehl have similar apparatuses to that of *Appalachignathus*. All these genera have palmate elements and it is possible they are closely related. *Bergstroemognathus* is distinguished from *Appalachignathus* in having a cordylodontiform element in the a position and a prioniodontiform f element; *Leptochirognathus* also has a cordylodontiform a element, with similar f element to that of *Appalachignathus*.

Appalachignathus? sp. nov. A
Fig. 12G, 16A–C,E

Synonymy.
Ozarkodiniform? element
cf. *Loxodus dissectus* An. An & others, 1983, pp. 106–107, pl. 21, figs 12,13; An, 1990, pl. 8, figs 2-5.
cf. *Loxodus* aff. *dissectus* An. An, 1990, pl. 8, fig. 1.

Material studied. 15 specimens: 7 eoligonodiniform, 7 zygognathodontiform and 1 ozarkodiniform? elements. In addition, 7 blade-like fragments were located.

Description. All elements palmate, or curved blades, with cusp only slightly longer than denticles, but twice as broad; denticles thin, commonly eight times as high as broad, fused for most of length; basal region almost 1/3 height of element; basal cavity very shallow, consisting of narrow slit beneath processes, conical beneath cusp and flaring to posterior or posterolaterally. All elements may be completely hyaline, or with cone-in-cone growth axis in cusp and denticles, or with milky albid cusp and denticles.

Eoligonodiniform element with anterolaterally directed conical basal cavity which continues as a slit beneath one process; posterolateral region has up to six poorly developed denticles.

Zygognathodontiform element similar to eoliginodiniform element except that basal cavity is directed towards anterior margin; posterolateral process shorter than lateral process.

Ozarkodiniform? element blade-like, with proximal denticles isolate for half to quarter length, erect; distal denticles become progressively more reclined, fused for most of length; basal cavity conical and not flared, tip situated near anterior margin; first or second denticle on inner lateral face rather than within plane of blade.

Remarks. Only the three elements described above have been found in the Coolibah Formation. First symmetry transition (S) elements show the range of basal cavity morphology typical of *Appalachignathus delicatulus*, and are accompanied by a considerable number of fragmented blades. It is most likely that the apparatus is that of *Appalachignathus*, but ozarkodiniform? elements may be sufficiently distinct to separate these specimens into a previously undescribed genus.

Loxodus dissectus An has similar denticulation to specimens of P elements described above, and may belong to this apparatus, but no flexing, or misaligned denticles are reported within An's specimens.

Distribution. *Appalachignathus?* sp. nov. A is found through the Coolibah Formation, but is more common in lower parts of this formation.

Genus *Aurilobodus* Xaing & Zhang, 1983

Type species. *Tricladiodus? aurilobus* Lee, 1975.

Remarks. Apparatus of *A. aurilobodus* (Lee) consists of cordylodontiform (s), zygognathodontiform (t) and trichonodelliform, or acontiodontiform, where elements are not denticulate, (u) elements (Lee, 1975; An & others, 1983), which forms a Type IA apparatus.

Aurilobodus? leptosomatus An, 1983
Fig. 17A–C

Synonymy.
Aurilobodus leptosomatus An. An & others, 1983, pp. 72–73, pl. 21, figs 14–17, pl. 22, fig. 1.
Juanognathus leptosomatus (An). Watson, 1988, p. 116, pl. 1, figs 1–3, 6 (synonymy).

Material studied. 6 specimens: 2 zygognathodontiform, 3 acontiodontiform and 1 alate acontiodontiform elements.

Remarks. *Aurilobodus* is distinguished from *Juanognathus* by the shape of aboral opening, and alae on lateral flanges; the former genus generally has a basal ledge parallel to aboral opening, which is not present on most species of *Juanognathus*. *Aurilobodus leptosomatus* has a poorly developed basal ridge, and aboral opening with rounded rather than angulate posterior region, similar to Juanognathus. This species is clearly transitional between *Juanognathus* and *Aurilobodus*, and is tentatively assigned to *Aurilobodus* following An (*in* An & others, 1983).

Elements figured by Harris & others (1979, pl. 1, figs 3–5) and *Juanognathus serpaglii* Stouge may be congeneric with *A?. leptosomatus*, but the different angle in lateral outline on elements with alae and the more pronounced development of basal ledge preclude conspecificity.

Different lateral outlines distinguish Gen. nov. B of Cooper and Druce (1975) and *Aurilobodus simplex* Xiang & Zhang from *A?. leptosomatus*. In addition, Gen. nov. B has twisted cusp.

Distribution. *Aurilobodus? leptosomatus* is found in the lower Majiagou Formation of North China (An & others, 1983), lower and middle Goldweyer Formation of the Canning Basin in Western Australia (Watson, 1988) and lower to middle Coolibah Formation of the Georgina Basin.

Genus *Bergstroemognathus* Serpagli, 1974

Type species. *Oistodus extensus* Graves and Ellison, 1941.

Remarks. The apparatus of *Bergstroemognathus* has first symmetry transition of cordylodontiform, (a, S_c), zygognathodontiform (b, S_b) and trichonodelliform (c, S_a) elements accompanied by falodontiform (e, M) and prioniodontiform (f, P) elements in a Type IVE apparatus.

Serpagli's (1974, pp. 41–2) symmetry transition of prioniodontiform elements includes zygognathodontiforms, but no cordylodontiforms are reported from his material. These, however, occur together in material from the Appalachians of North America (Stait & Barnes, in press).

Bergstroemognathus kirki sp. nov.
Fig. 12H, 16D,F–H,J

Etymology. After R. and V. Kirk of Glenormiston Station, Queensland, on which the type locality is situated.

Type specimens. Holotype CPC 23338 (GEO 123/ 003), prioniodontiform element; paratypes CPC 23334 (GEO 123/003), cordylodontiform element; CPC 23335 (GEO 132/016), zygognathodontiform element; CPC 23336 (GEO 149/007), trichonodelliform element; and CPC 23337 (GEO 149/001), falodontiform element.

Type stratum. GEO 123/003, 1.6 m above the base of outcropping Coolibah Formation to side of Bloodwood Creek. (Grid reference 596153 on Tobermory 1:250 000 topographic sheet SF 53–12, Edn 2, Series R 502.)

Material. 36 specimens: 2 cordylodontiform, 11 zygognathodontiform, 4 trichonodelliform, 11 falodontiform and 8 prioniodontiform elements.

Diagnosis. A species of *Bergstroemagnathus* with denticulate posterior processes on prioniodontiforms, minimal posterior process and cusp on falodontiforms, and first symmetr transition elements with pronounced aboral extension of anterior.

Description. All elements moderately robust to blocky; hyaline with cone-in-cone growth axis to cusp and denticles; cusp erect to reclined, with broad blocky keels; denticles free distally, fused proximally, laterally compressed with edges or narrow keels on anterior and posterior margins; antero-aboral extension marked in all elements; base has inner ridge parallel to aboral margin; basal cavity shallow, reduced to slit beneath processes, anteriorly directed, but does not reach anterior margin.

Cordylodontiform element has asymmetrically biconvex cusp; inner lateral carina extends onto base as flare of aboral margin. Zygognathodontiform element similar with anterior and posterior processes unequally developed. Trichonodelliform element without lateral flare to base. Falodontiform element with posterior process a round knob, denticles fused for half to two-thirds height, cusp reduced to size of denticles. Prioniodontiform element as zygognathodontiform, but element is not planar and processes may be considered posteriorly and anteriorly directed.

Remarks. Variation within elements includes degree of fusion of denticles, and development of aboral ridge on inner surface. From half to two thirds the length of adjacent denticles may be fused.

Bergstroemognathus kirki differs from previously described species in the poor development of posterior process on falodontiform element. It is distinguished from *B. extensus* (Graves and Ellison) by its aboral extension instead of sinuous aboral margin on other elements. It is similar to *B. pectiniformis* Yang and Zhang, which has adenticulate posterior process on prioniodontiform element (An & others, 1983, pl. 17, figs 14, 15).

Distribution. This species is found throughout the Coolibah Formation of the Georgina Basin.

Genus *Diaphorodus* Kennedy, 1980

Type species. *Acodus delicatus* Branson & Mehl, 1933.

Diaphorodus tortus (McTavish, 1973)
Fig. 12I, 17C–E,G-I

Synonymy.
Multielement reconstructions
Acodus deltatus tortus subsp. nov. McTavish, 1973, p. 40, pl. 1, fig. 18, text-figs 3a–d.

Figured specimens. CPC 23339, a, S_c element; CPC 23340, b, S_b element; CPC 23341, c, S_a element; CPC 23342, d, S_d element; CPC 23343, e, M element; CPC 23344, f, P element.

Remarks. Torsion of the cusp, shallower basal cavity and divergent cusp outlines distinguish *Diaphorodus tortus* from other species of *Diaphorodus,* including *D. deltatus* Lindström. We consider these differences significant at the species, rather than subspecies, level as was suggested by McTavish (1973).

Co-occurring specimens of *Triangulodus* sp. cf. *T. brevibasis* (Sergeeva) within the Coolibah Formation are superficially similar to those of *D. tortus*. First symmetry transition elements differ in depth of basal cavity, outline of element when viewed laterally, and cross-sectional symmetry of c and d elements. *Diaphorodus tortus* has shallower basal cavity, with tip further from anterior margin, generally more expanded basal region and more symmetrical arrangement of costae than *T.* sp. cf. *T. brevibasis*. Second symmetry transition elements are more easily distinguished, with oistodontiform (e) elements separated according to lesser development of oral region and broad cusp relative to base of *T.* sp. cf. *T. brevibasis,* and prioniodontiform f elements of *Diaphorodus* where *Triangulodus* has erect scandodontiform elements in the f position. These last are distinguished from gothodontiform (b) elements of *D. tortus* by biconvex cusp and aboral opening

Distribution. *Diaphorodus tortus* occurs in lower to middle Coolibah Formation of the Georgina Basin and uppermost Emanuel Formation of the Canning Basin, Western Australia.

Genus *Drepanoistodus* Lindström, 1971

Type species. *Oistodus forceps* Lindström, 1955

Remarks. *Drepanoistodus* differs from *Drepanodus* in the lack of pipaform and sculponeaform elements. Geniculate element of *Drepanoistodus* has postero-oral intersection which is commonly more acute than any (i.e. graciliform of Kennedy, 1980) which may be assigned to *Drepanodus*.

Elemental nomenclature of Barnes & others (1979) only is applied herein, since this apparatus as described does not yet comfortably fit the terminology of Sweet (1981). Arcuatiform elements (q') are herein considered to be modified homocurvatiform elements; scandodontiform elements are also regarded as modified drepanodontiform (q") elements.

Drepanoistodus costatus (Abaimova, 1971)
Fig. 12L–M, 17J–N

Synonymy.
Homocurvatiform (q) element
Drepanodus costatus. Abaimova, 1971, p. 490, pl. X, fig. 6, text-fig. 3; Abaimova, 1975, pp. 59–60, pl. III, figs 6–8,14, text-figs 6:25,28,29; Moskalenko, 1982, p. 109, pl. 27, figs1–3; Moskalenko, 1984, p. 123, pl. 13, figs 19,20.

Table 2. Occurrence and abundance of conodonts in conodont-bearing samples from sections 123, 132, 139, 147, 149, 152, 155, 156, 159, 163, 164 and 165. GEO 132 consists of spot samples of Coolibah Formation lithology collected from the Toko Range. Location of other sections is shown in Figure 1. Precise sample locations within each section are shown in Figures 2–10.

	GEO 123:					GEO 132:												139:
	3	4	5	6	7	2	5	7	11	12	13	14	15	16	22	23	26	1
ALCOORINA NADALA																		
drepanodontiform			1											2				
asym. acontiodontiform		1	2											1				
acontiodontiform														1				
oistodontiform	1				1									1				
scandodontiform	1	1	2		2						1			3				
suberectiform	4		1	1	1									2				
ANSELLA FENGXIANGENSIS																		
sym. oepikodontiform				1			1											
asym. oepikodontiform				2			1											
sym. belodelliform			1	1														
asym. belodelliform				1	1										1			
oistodontiform				1	1													
drepanodontiform			1	1										3				
erectiform			1	1										3				
APPALACHIGNATHUS?* sp. nov. *A																		
eoliginodiniform	2		1	1										1				
zygognathodontiform	2			1										3				
?ozarkodiniform			1															
bladelike fragments	1		1												2			
AURILOBODUS? LEPTOSOMATUS																		
zygognathodontiform																		
acontiodontiform				1														
AURILOBODUS SERRATUS																		
trichonodelliform			1															
BERGSTROEMOGNATHUS KIRKI																		
cordylodontiform	2																	
zygognathodontiform	7										1			1				
trichonodelliform	1				1													
falodontiform	2				2									1				
prioniodontiform	5				1													
DIAPHORODUS TORTUS																		
drepanodontiform	1			1		1								4				2
gothodontiform	1		1			1								3	1			1
acontiodontiform	2		2	2										2	1	1		
distacodontiform	2													3				
oistodontiform	4		1	3		1								18	1			1
prioniodontiform	4					1								4				2
DREPANOISTODUS COSTATUS																		
suberectiform	3				1									1				2
arcuatiform	21			2										7			1	1
homocurvatiform	14			1		1		1		1			1	17				4
oistodontiform														1				
scandodontiform	8												2	2				
DREPANOISTODUS* sp. nov. *A																		
suberectiform												1						
homocurvatiform				1			3					2	1		3			
oistodontiform				1								1			1			
scandodontiform																		
ERRATICODON TANGSHANENSIS																		
b element																		1
neoprioniodontiform															1			1
'OEPIKODUS' MAGGOLENSIS																		
symmetrical element							2											
alate element							1											
OISTODUS MULTICORRUGATUS																		
cordylodontiform																		
trichonodelliform											1	1						
d element												1						
oulodontiform												1						
PAROISTODUS ORIGINALIS																		
drepanodontiform			1	1	1		1					2						1
oistodontiform					2							1						
scandodontiform			1		2													2
PROTOPANDERODUS? PRIMITUS																		
unigrooved	3			2	3		1		1	1								
asym. acontiodontiform	4		4	3	3	1	3			1	1			2	1			2
acontiodontiform	2		2	3	4		3				1			3	5			
paltodontiform																		
scandodontiform	1		8	2	2		2		1					2	2			1
keeled scandodontiform	4		1	1	1							1		1	1			
PROTOPRIONIODUS NYINTI																		
cordylodontiform			1															
gothodontiform			1															
acontiodontiform																		
oistodontiform				1														
blade element			1															
SCANDODUS* sp. nov. *A																		
drepanodontiform											1			1				
planoconvex								1			1			1				
acontiodontiform	1													1				
distacodontiform														1				
oistodontiform			1								1			1				
scandodontiform	1								1					1				
SCOLOPODUS* sp. aff. *S. FILOSUS																		
later. compr. paltodontiform																		
planoconvex		1										1					3	
acontiodontiform		1						1										
equidim. paltodontiform																		
scandodontiform		2			1			1							1		1	
keeled scandodontiform		1						1				1			1			
SCOLOPODUS MULTICOSTATUS																		
later. compr. paltodontiform	8													3			1	
planoconvex	22										1			10	1		2	
acontiodontiform	5					1								6				
equidim. paltodontiform	1			1										1				
scandodontiform	8													6			1	
keeled scandodontiform	11													3				
TOKOCONUS WHEELAMANENSIS																		
drepanodontiform	1				3									5				
gothodontiform	5			1	1									2				1
acontiodontiform	6													1				
distacodontiform	1				1									3				
acodontiform	4				1									3				
scandodontiform	4			1	1									4				
TRIANGULODUS* sp. cf. *T. BREVIBASIS																		
drepanodontiform												1			2			1
acodontiform												2						1
roundyaform												1			1			1
paltodontiform												3			2			1
oistodontiform												7	1		1			5
erect scandodontiform		1										5			2			3
TRIANGULODUS LARAPINTINENSIS																		
drepanodontiform										1								2
acodontiform							2											3
acontiodontiform							1				1	1						4
paltodontiform							1											1
oistodontiform							3											3
erect scandodontiform							2											2
Conical elements																		
element I																		
element II																	1	
element III																	1	
element IV	1																	
element V					1													
element VI			1														2	
TOTAL:	181	8	39	39	38	7	27	5	3	4	10	33	5	145	31	1	13	49

GEO 147:					148:	GEO 149:					GEO 152:		GEO 155:		GEO 156:			GEO 159:		GEO 163:				GEO 164:			GEO 165:				TOTAL
2	3	4	5	6	5	1	5	6	7	9	4	6	4	5	1	3	4	8	9	2	4	5	6	1	2	3	2	3	4	5	
	1				3		1																						1		9
	1				4		1																						1		11
											1							1		1											4
					4		1																								8
	1			1	3		1													2									2		20
				1	3				1		1																				15
																												1	2		5
												1														1			2		7
																															2
																															3
																													1		3
												1																	1		7
											2	1																	1		9
						1																1									7
																				1											7
																															1
				1																1									1		7
							1																	1							2
							1																		1						3
																															1
																															2
											1							1													11
									1														1								4
					3	1			1																				1		11
									1									1													8
1					2													1													13
											1							1													10
1				1	5						2			1				1													21
					4						1																				10
1					7						1			1										1							40
					1						4																				16
						3							1											1						1	13
	1			2	5					1	2	1		1	2		1								1					2	51
	2		1		11		1				2	2	2		2			1			1				1	1			1	3	71
					3		1				1																				6
					7										1			1												2	23
																	2													1	4
																	1													2	13
																	1			1											5
																														1	1
																															1
																	1														3
																															2
																															1
				1																											1
																															2
																															1
																															1
				1											1	1								1					1		12
					2							1		1										1							8
					1																										6
			1		4																								2		18
		1	1	3	4		3		3						1			1		1	1			6	2				25		77
1	1			5	1		4		1		1				2			1		1					1	1			18	1	62
					1			1							1														1		4
1	1	1		2	2		2						1		1			1							1				17		51
				5			1				1													3	1				27		48
																	1														2
																															1
																													1		1
																													2		3
																															1
																				1							1				4
					1		1													1							1				7
																				1							1				4
																															3
1			1		1															4							1				11
1					1						1									4											7
					4						2	1			1			3	1	8				1			1				27
																				4							1				7
																		1		2							1				4
					7						1							2		2							1				19
					8															2							1				15
											1	1								2				1							17
				2		1					1	1								5				1	1		1				49
											1									3				1							17
						1					1													1							6
						1					1									7							2	1			27
																				9							1				24
		1			1		1																								12
1					3		2																						2		18
		1			2													1											1		12
					2																										7
					1		1																								10
1							2				1											1									15
					7						1	1					2													1	16
					3												1														7
			1		4						1					1													1		11
					5									1			3														15
			1		18						1			1		2	1												1	3	42
			1	1	5						2	2		1		2	1							1					1		28
															2	1	2							2						2	12
															2	2	2							1						2	14
																3	1							1		1				1	14
																2	1													1	6
															1	1	1							1						2	12
															1	2	2							1						4	14
																				1											1
																															1
					1																										2
					1														1	1											4
																															1
								1																							4
9	8	4	7	26	155	8	25	2	8	1	36	13	4	7	18	17	24	18	2	65	2	2	1	26	9	4	13	2	114	29	1296

20/A/164

Arcuatiform (q') element

Drepanodus sibiricus. Abaimova, 1975, p. 69, pl. VI, figs 4, 5, text–figs 7:3,9.

Multielement reconstructions

Scolopodus flexilis. An, 1981, p. 222 (incomplete), pl. 3, figs 1–2; An & others, 1983, pp. 142–3, pl. XIV, figs 13–18; An, 1990, pl. 5, figs 1–6.

Material. 163 specimens: 13 suberectiform, 71 homocurvatiform, 51 arcuatiform, 6 oistodontiform and 23 scandodontiform elements.

Description. Homocurvatiform, suberectiform and arcuatiform elements are well known (e.g. Abaimova, 1975; An, *in* An & others, 1981; Moskalenko, 1984). These are similar to oistodontiform and scandodontiform elements in their posteriorly costate cusp, commonly with one persistent costa extending entire length of cusp (An, *in* An & others, 1981). All are robust, with shallow basal cavity.

Oistodontiform and scandodontiform elements have sharp posterior and anterior edges on a laterally compressed cusp, are asymmetrically costate. Oistodontiform element has antero-aboral depression on inner lateral face; base short; aboral margin arcuate with antero-aboral intersection at approximately 80° and acute angle (30–45°) between oral and aboral margins; apex of basal cavity situated anterior of cusp midline. Scandodontiform element distinguished from other elements by slightly acute, instead of obtuse, postero-aboral intersection, posteriorly expanded base, and twisted cusp.

Remarks. No elements have the typically equidimensional cusp cross-section of *Scolopodus* Pander. Biconvex cusps, and elemental composition, are more characteristic of the genus *Drepanoistodus* (Lindström, 1971). *Drepanoistodus costatus* is distinguished from *D. pitjanti* Cooper by a more strongly costate cusp, shallower basal cavity and more slender cusp on most elements.

Distribution. *Drepanoistodus costatus* is known from upper Ugorian and Kimaian stages of the Siberian Platform (Abaimova 1971, 1975; Moskalenko 1982, 1984), and lower Majiagou Formation in the Tangshan area of North China (An, 1981). It occurs throughout the middle Coolibah Formation, Georgina Basin

Drepanoistodus sp. nov. A
Fig. 18A–C

Material studied. 23 specimens: 4 suberectiform, 13 homocurvatiform, 1 scandodontiform and 5 oistodontiform elements.

Description. All elements dominated by broad cusp, which tapers evenly, commonly without visible microstructure; basal cavity a shallow to moderately shallow 'phrygian cap' (Lindström, 1964), tip situated in posterior half of element, or close to midline; all elements are hyaline with central, dense, growth axis. Suberectiform elements with erect, asymmetrically biconvex, stout, evenly tapering cusp with sharp anterior and posterior margins, conical outline when viewed laterally, large specimens may have few fine costae close to posterior margin of inner lateral face; intersection of anterior and aboral margins approximately 70°, anterobasal area drawn out, postero-oral intersection obtuse (about 120°); base short, flares posteriorly and has teardrop shaped aboral opening, oral margin sharp.

Homocurvatiform element as above except aboral extension is more pronounced, with anterior and aboral margins intersecting at a more acute angle (60°); cusp plano-convex in cross-section, and reclined to recurved; inner lateral face has deep depression anterior of tip to basal cavity; base has plano-convex aboral opening.

Oistodontiform element differs from suberectiform element in angle of postero-oral intersection (around 60°) and subrectangular base, in which inner and outer lateral faces are unequally developed.

Remarks. This species is distinguished from previously described species of *Drepanoistodus* by subrectangular base of oistodontiform element, deeper basal cavity and unequal development of inner and outer lateral faces of oistodontiform elements.

Distribution. *Drepanoistodus* sp. nov. A occurs in middle and upper Coolibah Formation and is known from low in the overlying Nora Formation of the Georgina Basin.

Genus *Paroistodus* Lindström, 1971

Type species. *Oistodus parallelus* Pander, 1856.

Paroistodus originalis (Sergeeva, 1963)
Fig. 18F

Synonymy.

Paroistodus originalis Lindström. Löfgren, 1978, pp. 69–71, pl. 1, figs 22–25, text-fig. 28 (synonymy to 1976).

Material studied. 26 specimens: 12 drepanodontiform, 8 oistodontiform and 6 scandodontiform elements.

Remarks. While drepanodontiform, oistodontiform and scandodontiform elements are included, there are insufficient specimens to clarify the apparatus of this species.

Distribution. Löfgren lists occurrence of this species from middle Arenig to early Llanvirn: it is known from North America, Sweden, Norway, Estonia, the Leningrad area, Poland, and the Canning Basin of Western Australia. In the Georgina Basin, it occurs throughout the Coolibah Formation, usually in very low abundance.

Genus *Protopanderodus* Lindström, 1971

Type species. *Acontiodus rectus* Lindström, 1955.

Remarks. Specimens tentatively assigned to *Protopanderodus* from the Coolibah Formation, in common with those figured by recent authors (e.g. Serpagli, 1974; Löfgren, 1978; Olgun, 1987), vary not only with respect to cusp symmetry and twisting (McCracken, 1989), but also in degree of posterior extension of base. It is possible that elements without posteriorly extended base occupy different positions in the apparatus to those elements with similar cusp symmetry.

Reconstructions of the type species of *Protopanderodus* include asymmetrical and symmetrical acontiodontiform, and scandodontiform elements (Löfgren, 1978; Olgun, 1987; McCracken, 1989). Species described from North (e.g. Barnes & Poplawski, 1973; Ethington & Clark, 1981; McCracken, 1989; Stait & Barnes, in press) and South America (Serpagli, 1974) also have paltodontiform elements, with three grooves. Previously, these were considered to be modified asymmetrical acontiodontiform elements. They occur in such low abundance that this may be the case. However, the sequence of drepanodontiform–asymmetrical acontiodontiform–acontiodontiform–paltodontiform elements suggests a first symmetry transition (a, b, c and d elements respectively; i.e. S elements).

Protopanderodus? primitus Cooper, 1981
Fig. 13A–C,18D,E,G–K

Synonymy.
First symmetry transition (S) elements
Scolopodus sp. nov. A. Hill, Playford & Woods, 1969, p. O14, pl. O VII, fig. 13.
'Panderodus' sp. Serpagli, 1974, p. 43, pl. 24, figs 12, 13; pl. 30, figs 12, 13.
Panderodus striatus Lee. Lee, 1975a, p. 89, pl. 2, figs 11, 13; not Lee, 1975, p. 178, pl. 1, fig. 14; not Lee, 1977, p. 138, pl. 1, figs 11, 13; not Lee, 1979, p. 48, pl. 1, fig. 11.
Scolopodus euspinus Jiang & Zhang sp. nov. An & others, 1983, pp. 140–141, pl. 13, fig. 27, pl. 14, figs 1–8, text–fig. 12:3–4; An, 1990, pl. 11, figs 7–11, 13, 14, 16.
Second symmetry transition (P) elements
Scolopodus sp. nov. C. Hill, Playford & Woods, 1969, p. O14, pl. O VII, fig. 15.
Scolopodus nogamii Lee. Lee, 1975a, p. 89, pl. 2, figs 11, 14, text–fig. 4K; not Lee, 1975, p. 179, pl. 2, fig. 13, text–fig. 3L; not Lee, 1977, p. 141, pl. 2, fig. 12; not An & others, 1983, p. 144, pl. 13, figs 20–25; An, 1990, pl. 11, figs 15, 17, 20.
Multielement reconstructions
cf. *Scolopodus* cfr. *bassleri* (Furnish). Igo & Koike, 1967, p. 23, pl. III, figs 7,8, text-fig. 6-B.
Protopanderodus primitus Druce. Cooper, 1981, p. 174, pl. 27, figs 3,4.

Material studied. 260 specimens: 18 unigrooved, 77 asymmetrical acontiodontiform, 62 acontiodontiform, 4 paltodontiform, 51 scandodontiform, 48 laterally compressed acontiodontiform elements.

Description. Only a brief diagnosis of this species has previously been published (Cooper, 1981). Conical unigrooved, asymmmetrical and symmetrical acontiodontiform, and rare three-grooved paltodontiform elements, all expanding evenly from tip of cusp to aboral margin, are accompanied by laterally compressed, symmetrical acontiodontiform elements and scandodontiform elements, both with base rapidly expanding in lateral view. These last two have compressed morphology typical of second symmetry transition (P) elements, and are herein designated f (P_a) and g (P_b) respectively.

All elements are striate; striae parallel to posterior and lateral carinae and meeting at acute angle in lateral grooves, extending close to posterior margin, but anterior and lateral regions of rim of base are smooth; cusp is slender, smoothly tapering, arcuate, with region of greatest curvature at approximately one-third cusp length; antero-aboral intersection approximately perpendicular, acute intersection of posterior and aboral margins (70°–80°); aboral margin straight; basal cavity is shallow to moderate depth, triangular, with anterior margin close to anterior of cusp.

Remarks. Cooper (1981) illustrated and briefly described

Figure 13. Selected conodont elements.
Symbols as for Figure 12. Magnification approximately ×80.
A–C, *Protopanderodus? primitus* Cooper, GEO 123/006 **A,** element with symmetrical, laterally compressed cusp and expanded base, CPC 23364, lateral view. **B,** scandodontiform element, CPC 23363, inner lateral view. **C,** element with symmetrical cusp and unexpanded base, CPC 23360, lateral view. **D–F, *Scandodus* sp. nov. A,** GEO 132/016. **D,** oistodontiform element, CPC 23369, inner lateral view. **E,** drepanodontiform element, CPC 23366, lateral view. **F,** acontiodontiform element, CPC 23367, lateral view. **G, *Scolopodus* sp. aff. *S. filosus*** Ethington & Clark, keeled scandodontiform element, CPC 23377, posterolateral view, GEO 163/002. **H, I, *Scolopodus multicostatus*** Barnes & Tuke **H,** planoconvex element, CPC 23379, lateral view, GEO 123/003. **I,** keeled scandodontiform element, CPC 23384, posterolateral view, GEO 163/002. **J–L, *Tokoconus wheelamanensis* gen. et sp. nov. J,** acontiodontiform element, CPC 23391, posterolateral view, GEO 123/003. **K,** acodontiform element, CPC 23396, lateral view, GEO 132/016. **L,** distacodontiform element, CPC 23394, lateral view, GEO 123/003.

these forms as *Protopanderodus primitus* Druce. The name is therefore not a *nomen nudem,* but the species should be attributed to Cooper. No holotype was then designated. Examination of Cooper's types reveals that GSSA Co 71 & 72 (Cooper, 1981, 162) are both b elements: a further (unnumbered) specimen included in this collection is a c element of *Protopanderodus? primitus*.

As first revisers, we designate specimen number GSSA Co 72 as lectotype of *Protopanderodus primitus* sensu Cooper, and both GSSA Co 71 and the unnumbered specimen as paralectotypes. Type locality for this species is then Cooper's locality MC–13, within upper Horn Valley Siltstone (31 m above base of formation) of the Maloney Creek section, adjacent to the Stuart Highway Bridge, south of Alice Springs, Northern Territory, Australia.

Only the elements with unexpanded base were figured by

Cooper (1981). Consistency of microstructure, basal cavity morphology, preservational features and co-occurrence support the inclusion of forms with expanded base into the same apparatus as those figured by Cooper (1981, pl. 27, figs 3, 4; see also Watson, 1988, 124). This may be either in different position within the apparatus, or substituting within the position of elements with unexpanded base. Since these elements are found together throughout the Coolibah Formation, and since the morphology of one (unexpanded base with approximately equidimensional cusp cross-section) suggests first symmetry transition elements while elements with expanded base are laterally compressed in the style of second symmetry transition elements, it is likely that both types were incorporated within the one animal.

It is doubtful whether this species should then be assigned to *Protopanderodus*. *Protopanderodus primitus* Cooper has elements which are characteristic of *Protopanderodus* Lindström, but it is doubtful whether *P. rectus* has the same elemental composition.

Protopanderodus? primitus is similar to *Scolopodus gryphus* An and *Protopanderodus nogamii* (Lee). *Scolopodus gryphus* has a much longer base and reduced cusp when compared with Coolibah Formation specimens; *Protopanderodus nogamii* is considerably more anteroposteriorly compressed, and tip of basal cavity is posterior of anterior margin of base. Most likely, the apparatus of *P. nogamii* is the same as that of *P? primitus* (see Watson, 1988, 124–125), and the former is descended from the latter species.

Scolopodus cfr. *bassleri* of Igo & Koike (1967) is distinguished from *P? primitus* by the possession of basal alae.

Distribution. Within Australia, *P? primitus* is known from the Coolibah (this study) and Nora formations of the Georgina Basin (Hill & others, 1969), Horn Valley Formation of the Amadeus Basin (Cooper, 1981), and possibly from subsurface of the Warburton Basin in South Australia (Cooper, 1986). It is also found in the Majiagou Formation of North China (An & others, 1983), Dumugol Formation of Kangweon-Do in South Korea (Lee, 1975a), and uppermost San Juan Formation of Argentina (Serpagli, 1974).

Genus *Scandodus* Lindström, 1955

Type species. *Scandodus furnishi* Lindström, 1955.

Remarks. Lindström (1971, 39–40) redefined *Scandodus* with oistodontiform, drepanodontiform, acodontiform and distacodontiform elements with symmetry transition. Drepanodontiform elements include planoconvex and biconvex cusp cross-section. An acontiodontiform element present in the apparatus may have previously been considered part of symmetry transition between acodontiform and distacodontiform elements. The complete apparatus is Type IVD.

Scandodus sp. nov. A
Fig. 13D-F, 18L-Q

Unfigured specimen. CPC 23371 (GEO 132/016), planoconvex element.

Material studied. 30 specimens: 4 drepanodontiform (a̲, S_c), 7 planoconvex (b̲, S_b), 4 acontiodontiform (c̲, S_a), 1 distacodontiform (d̲, S_d), 3 oistodontiform (e̲, M) and 11 acodontiform (f̲, P) elements.

Description. All elements proclined to erect, striate with striae extending almost to aboral margin, slender, with moderately deep basal cavity. Striae parallel grooves on cusp, and meet in an acute angle at sharp edges.

Drepanodontiform element has unequally biconvex cusp, sharp anterior and posterior edges often with blocky keel on posterior margin of cusp, basal keel on anterior margin, narrow oral keel with arcuate outline in lateral view; base expanded to almost twice maximum cusp width; basal cavity extends to level of maximum cusp curvature, posterior margin almost straight, anterior margin sinuous, tip situated close to anterior margin; cone-in-cone growth axis.

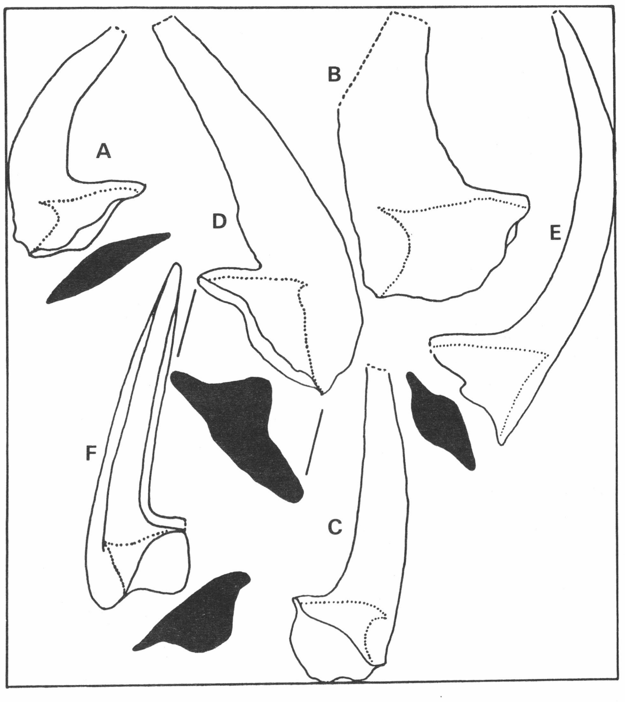
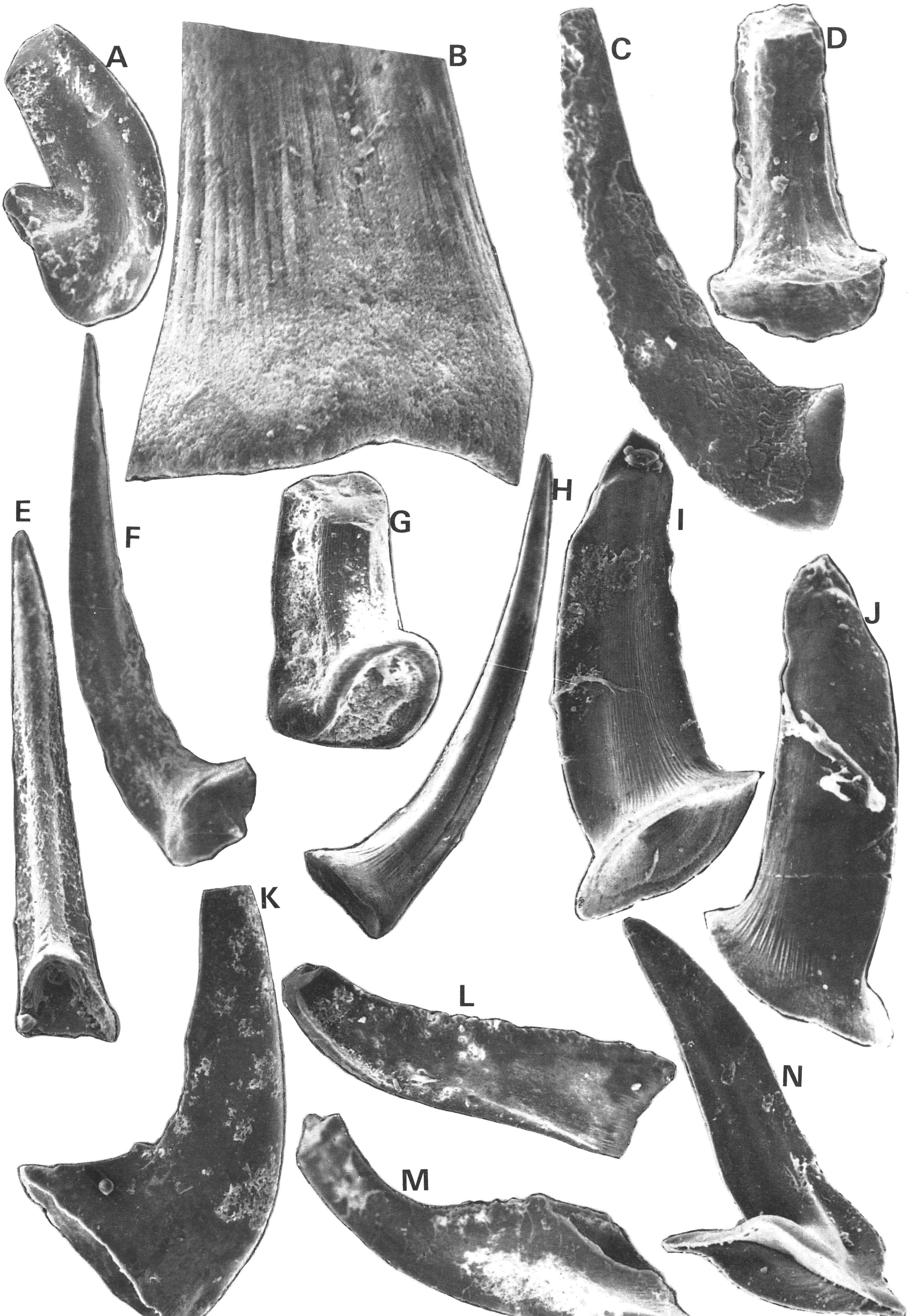


Figure 14. Elements of *Triangulodus* species.
Symbols as for Figure 12.
A–C, *Triangulodus larapintinensis* (Crespin), ×60 **A,** oistodontiform? element, CPC 23410, lateral view, GEO 165/005. **B,** drepanodontiform element, CPC 23406, lateral view, GEO 165/005. **C,** erect scandodontiform element, CPC 23411, posterolateral view, GEO 139/001. **D–F, *Triangulodus* sp. cf. *T. brevibasis*** (Sergeeva), ×80, from GEO 132/014. **D,** oistodontiform element, CPC 23403, inner lateral view.
E, drepanodontiform element, CPC 23399, lateral view. **F,** erect scandodontiform element, CPC 23405, posterolateral view.

Figure 15. Magnification ×120 unless otherwise stated.
A-J, *Alcoorina nadala* gen. et sp. nov. A, oistodontiform element, paratype, CPC 23317, inner lateral view, TOK 9/6. **B,** scandodontiform element, paratype, CPC 23319, detail of surface microstructure, ×600, GEO 132/016. **C,** drepanodontiform element, paratype, CPC 23314, lateral view, GEO 148/005. **D,** suberectiform element, paratype, CPC 23313, posterior view, GEO 123/003. **E,** acontiodontiform element, paratype, CPC 23316, posterior view, GEO 132/016. **F,** scandodontiform element, paratype, CPC 23318, inner lateral view, GEO 123/005. **G,** asymmetrical acontiodontiform element, paratype, CPC 23315, posterior view, GEO 149/005. **H,** same specimen as B, posterolateral view. **I,** suberectiform element, holotype, CPC 23312, posterolateral view, from GEO 123/006. **J,** same specimen, anterolateral view. **K-N, *Ansella fengxiangensis*** (An & others). **K,** erectiform element, CPC 23324, lateral view, GEO 123/005. **L,** asymmetrical belodelliform element, CPC 23321, lateral view, GEO 123/006. **M,** asymmetrical oepikodontiform element, CPC 23320, posterolateral view, ¥140, GEO 164/003. **N,** oistodontiform element, CPC 23323, inner lateral view, GEO 123/007.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Planoconvex element differs in possession of anterolateral costa; expansion of base is less pronounced. Acontiodontiform and distacodontiform elements similarly, with narrow lateral and posterobasal keels.

Oistodontiform element twisted, cusp has carinate inner face, and posterior and anterior keels; base with inner lateral flare; cusp intersects base at approximately 80°; medium to wide keel on oral margin; intersection of posterior and oral keels notched; tip of basal cavity lies approximately one third distance from anterior to posterior of base and below level of intersection of cusp and base.

Acodontiform element differs from first symmetry transition elements in location of keels at anterolateral and posterolateral positions for distal two thirds of cusp; with posterolateral carina on inner cusp.

Remarks. Striate cusp distinguishes *Scandodus* sp. nov. A from previously known species of this genus. Development of costae and differentiation of base from cusp is reduced in *S. sinuosus* Mound. Elements of the latter are generally more robust than those of *Scandodus* sp. nov. A, which has slender elements. Some elements of *Scolopodus* sp. aff. *S. filosus* Ethington & Clark from the Coolibah Formation are similar to those of *Scandodus* sp. nov. A, but *Scolopodus* sp. aff. *S. filosus* has deeper basal cavity, and is more coarsely striate than *Scandodus* sp. nov. A.

Distribution. *Scandodus* sp. nov. A is found in low abundance throughout the Coolibah Formation of the Georgina Basin, although it is most common near the base of this formation.

Genus *Scolopodus* Pander, 1856

Type species. *Scolopodus sublaevis* Pander, 1856.

Remarks. Specimens to hand are congeneric with *Scolopodus rex* Lindström as reconstructed by Dzik (1976, 430). Accepting the current generic concept of *Scolopodus* Pander based on *S. rex* (Löfgren, 1978; Bergström, 1981; Ethington and Clark, 1981), the forms described below are referred to *Scolopodus* Pander, emended Dzik, 1976.

The current separation of hyaline elements of *Scolopodus* into asymmetrical and symmetrical forms (Löfgren, 1978; Bergström, 1981) is extended to the recognition of laterally compressed paltodontiform (a, S_c), planoconvex (b, S_b), acontiodontiform (c, S_a), equidimensional paltodontiform (d, S_d), scandodontiform (f, P_a) and posteriorly keeled scandodontiform (g, P_b) elements. The first four elements may be considered S elements (of Sweet, 1981), and the last two P elements.

Scolopodus sp. aff. *S. filosus* Ethington & Clark, 1964
Fig. 13G,19A–E,K

Synonymy.
?*'Scolopodus' filosus* Ethington & Clark. Ethington & Clark, 1981, p. 100, pl. 11, fig. 22 (synonymy to 1978).

Unfigured specimen. CPC 23372 (GEO 147/002), laterally compressed paltodontiform.

Material studied. 79 specimens: 7 laterally compressed paltodontiform, 27 planoconvex, 7 acontiodontiform, 4 equidimensional paltodontiform, 19 scandodontiform and 15 keeled scandodontiform elements.

Remarks. Specimens from the Coolibah Formation differ from *'Scolopodus' filosus* only in the presence of a fine lateral costa on all elements. General morphology, cusp cross-section, basal cavity and striae of drepanodontiform and equidimensional paltodontiform elements are those described by Ethington & Clark (1964). Additional specimens are required to determine whether this difference is significant at the specific level.

In all elements a fine anterolateral costa runs most of the length of the base and the entire length of the cusp on inner lateral face. This is almost in anterior position on laterally compressed paltodontiform, more lateral on planoconvex elements. The face bearing the costa is planar on this element. On acontiodontiform elements, two slightly asymmetrically disposed costae are modified into narrow keels: cusp compression is marked. Equidimensional paltodontiform elements still bear a reduced costa, but cusp cross-section and aboral opening are subcircular. On scandodontiform elements, the cusp is twisted so that anterior costa moves onto lateral face. This costa is keeled on keeled scandodontiform elements.

The markedly deeper basal cavity and finer striation of *Scolopodus* sp. aff. *S. filosus* distinguish this species from coeval *Scolopodus multicostatus* Barnes & Tuke.

Distribution. *Scolopodus* sp. aff. *S. filosus* is found throughout the Coolibah Formation, but is more abundant in upper parts of these strata.

Scolopodus multicostatus Barnes and Tuke, 1970
Fig. 13H-I, 19F–J,L

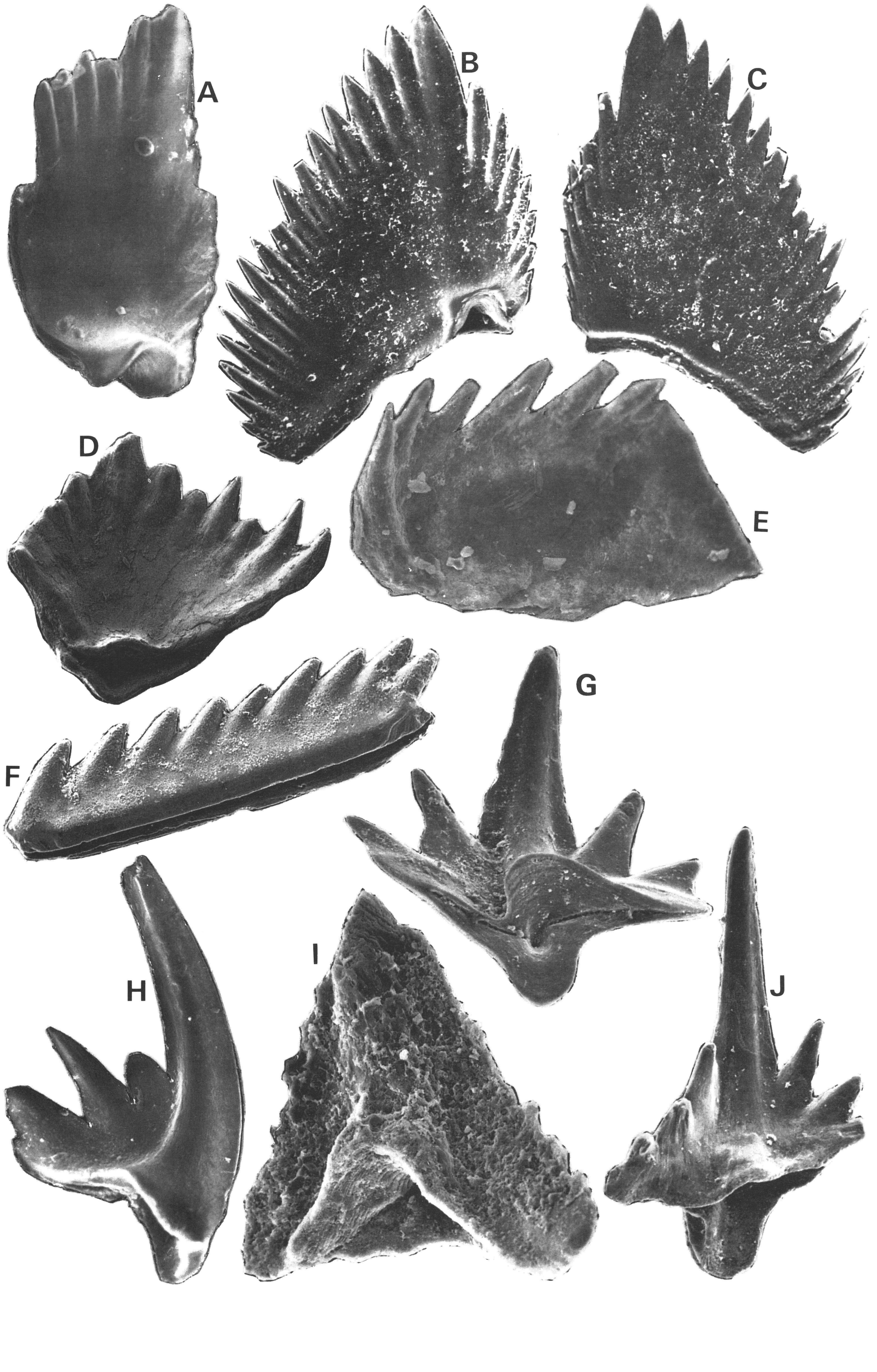
Synonymy.
?*Scolopodus* sp. Abaimova, 1975, pp. 106–107, pl. 9, figs 13, 18, text-fig. 8:32, 33.
Scolopodus multicostatus Barnes & Tuke. Ethington & Clark, 1981, pp. 101–102, pl. 11, figs 19–20 (synonymy).

Unfigured specimen. CPC 23385 (GEO 123/003), acontiodontiform element.

Material studied. 140 specimens: 17 laterally compressed paltodontiform, 49 planoconvex, 17 acontiodontiform, 6 equidimensional paltodontiform, 27 scandodontiform and 24 posteriorly keeled scandodontiform elements.

Description. All elements long, slender, finely costate to coarsely striate, proclined to erect drepanodontiforms. Base is only moderately expanded. Costae do not extend to aboral margin, and may not continue proximally beyond cusp mid-length. Basal cavity is deep, with tip reaching almost to level of maximum cusp curvature; anterior margin of basal cavity is slightly convex towards cavity, and lies close to cusp anterior margin. The laterally

Figure 16. Magnification ×100 unless otherwise stated.
A–C, E, ***Appalachignathus?* sp. nov. A. A,** eoliginodinaform element, CPC 23326, inner view, GEO 123/005. **B,** zygognathodontiform element, CPC 23327, inner view, GEO 132/016. **C,** same specimen as B, outer view. **E,** ozarkodinaform? element, CPC 23328, inner view, ×150, GEO 123/005. **D, F-H, J, *Bergstroemagnathus kirki* sp. nov. D,** trichonodelliform element, paratype, CPC 23336, posterior view, ×50, GEO 123/003. **F,** falodontiform element, paratype, CPC 23337, lateral view, ×60, GEO 149/001. **G,** zygognathodontiform element, paratype, CPC 23335, aboral view, ×80, GEO 132/016. **H,** cordylodontiform element, paratype, CPC 23334, inner lateral view, GEO 123/003. **J,** prioniodontiform element, holotype, CPC 23338, posterolateral view, ×75, GEO 123/003. **I, *Aurilobodus serratus*** Xiang & Zhang, ×200, trichonodelliform element, CPC 23333, posterior view, GEO 123/005.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compressed paltodontiform element was described by Barnes & Tuke (1970, 92–3): it has asymmetrically biconvex cusp cross-section.

Planoconvex element has planoconvex cusp cross-section, and generally has fewer, less distinct costae on the convex (inner) face.

Acontiodontiform element has narrow anterolateral keels, highly convex posterior face, and rounded coarsely costate to acostate anterior face. Equidimensional paltodontiform element as acontiodontiform element except for absence of anterolateral keels on the former.

Scandodontiform element has a broad anterior edge, deep posterolateral groove on inner face becoming more lateral distally, and unequally biconvex cusp. The g element is similar to scandodontiform, but the anterior edge of the latter is replaced by a broad keel and the posterolateral groove is reduced; the g element is more highly laterally compressed than the f element.

Remarks. *S. multicostatus* is distinguished from most species of *Scolopodus* by a large number of fine costae on the cusp. It differs from *S. rex* in bearing costae close to the anterior margin of most elements, and lesser development of costae distally.*Scolopodus* sp. of Abaimova (1975) appears to be of similar morphology to Coolibah Formation specimens. *Scolopodus* rex illustrated from the Baltic region has costae extending further proximally up the cusp than is normal on specimens from the Coolibah Formation.

Distribution. *Scolopodus multicostatus* is found in the St George Group (upper Canadian) of western Newfoundland (Barnes & Tuke, 1970), Jefferson City Formation of central Missouri and middle Filmore Formation of the Ibex area (Ethington & Clark, 1981), and may occur in Kimaian strata near the River Lena, Siberian Platform (Abaimova, 1975). The range of this species covers the entire Coolibah Formation of the Georgina Basin, although lower strata contain more abundant faunas.

Genus *Tokoconus* gen. nov.

Type species. *Tokoconus wheelamanensis* sp. nov.

Etymology. For Toko Range, in which specimens of this genus are found.

Diagnosis. An assemblage of coniform elements consisting of drepanodontiform (a, S_c), gothodontiform (b, S_b), acontiodontiform (c, S_a), distacodontiform (d, S_d), acodontiform (f, P_b) and scandodontiform (g, P_a) elements in a Type IV apparatus. Cusp and base meet in continuous curve on all elements; posterior and anterior margins of cusp have sharp edges, which are not continued to the aboral margin.

Remarks. Elements of *Cornuodus* Fåhraeus, *Parapanderodus* Stouge and *Scalpellodus* Dzik are similar in general morphology to those of *Tokoconus*. All have a bi- or tri-membrate apparatus (Löfgren, 1978; Stouge, 1984; Watson, 1988; Stait & Barnes, in press). *Cornuodus* is not striate and has rounded anterior and posterior margins basally; *Scalpellodus* and *Parapanderodus* are striate, with sharp edges, but have short-based drepanodontiform elements which are not present in *Tokoconus*. Elements of *Tokoconus* are essentially graciliform (in the sense of *Scolopodus gracilis* Ethington & Clark s.f.) with apparatus position depending upon number and position of carinae and degree of torsion and compression of cusp.

Tokoconus wheelamanensis sp. nov.
Fig. 13J–L, 20A–I

Synonymy.
Cornuodus longibasis (Lindström). An & others, 1983, pp. 89–90, pl. 13, figs 1–7.

Etymology. From Wheelaman Creek, which transects outcrop of the Coolibah Formation.

Type stratum. GEO 123/007: 6 m above base of Coolibah Formation outcropping to side of Bloodwood Creek (grid reference 596153 on Tobermory 1:250 000 topographic map, sheet SF 53–12, Edn 2, Series R 502).

Material studied. 74 specimens: 12 drepanodontiform, 18 gothodontiform, 12 acontiodontiform, 7 distacodontiform, 10 acodontiform and 15 scandodontiform elements.

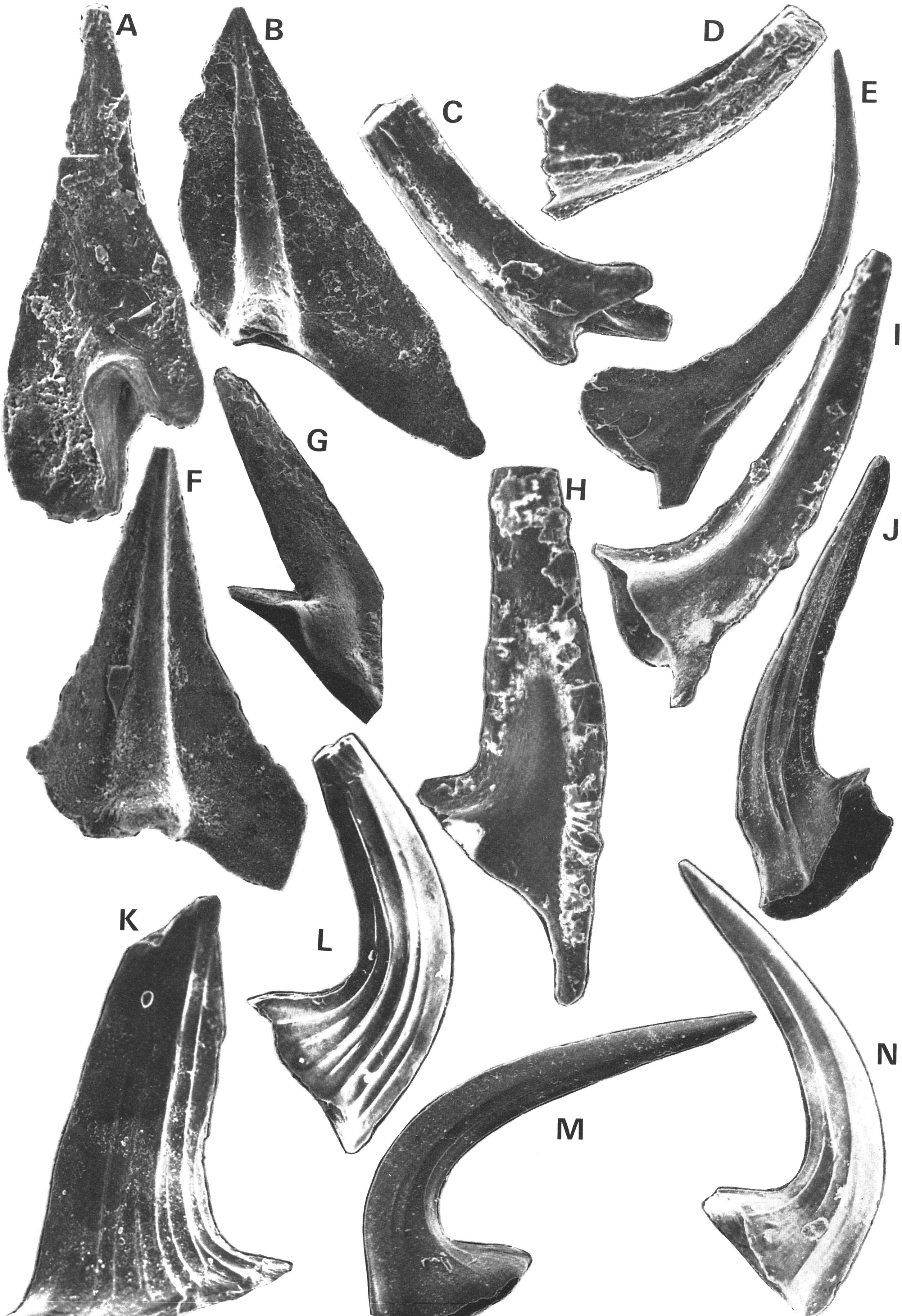
Diagnosis. A slender species of *Tokoconus* in which the base is relatively unexpanded, and anterior margin of the basal cavity lies close to cusp margin; cusp with broad shallow groove posterior of a posterior facing carina on all elements.

Description. Six elements of this apparatus have been identified. All are slender, with outline of posterior and anterior margins a continuous curve; tip of basal cavity at point of maximum curvature of cusp; striate with striae extending to aboral margin, striae strongest posteriorly and on base; dense white matter fills cusp from basal cavity to tip of element.

Drepanodontiform element has biconvex cusp with sharp anterior and posterior edges and broad, shallow, posterolateral depression; brief anterior keel at level of distal half of basal cavity. Gothodontiform element differs only in lateral position of shallow depression, with carina anterior to groove. Both lateral faces of acontiodontiform element have groove; cusp cross-section is triangular; anterior face round; distacodontiform element with asymmetrically positioned depressions, one to each lateral face.

Second symmetry transition elements differ from the above in possession of brief anterior keel for entire length of element, and oral keel; cusp cross-section is approximately plano-convex. Both elements have keel in anterolateral position basally, but anteriorly at distal end of cusp. Acodontiform and scandodontiform elements may be distinguished by degree of twisting of the cusp.

Figure 17. Magnification ×110 unless otherwise stated.
A, B, F, *Aurilobodus? leptosomatus* An. A, zygognathodontiform element, CPC 23329, posterior view, ×150, GEO 164/001. **B,** acontiodontiform element, CPC 23331, posterior view, ×100, GEO 123/006. **F,** ×150, alate acontiodontiform element, CPC 23332, posterior view, TOK 25/4. **C–E, G–I, *Diaphorodus tortus*** (McTavish). **C,** acontiodontiform element, CPC 23341, posterolateral view, GEO 159/008. **D,** distacodontiform element, CPC 23342, lateral view, GEO 148/005. **E,** drepanodontiform element, CPC 23339, lateral view, ×80, GEO 139/001. **G,** oistodontiform element, CPC 23343, inner lateral view, ×100, GEO 148/005. **H,** prioniodontiform element, CPC 23344, inner lateral view, GEO 148/005. **I,** gothodontiform element, CPC 23340, lateral view, GEO 132/022. **J–N, *Drepanoistodus costatus*** (Abaimova), GEO 132/016. **J,** oistodontiform element, CPC 23345, outer lateral view, ×60. **K,** suberectiform element, CPC 23349, lateral view, ×60. **L,** arcuatiform element, CPC 23348, lateral view, ×60. **M,** scandodontiform element, CPC 23346, lateral view, ×560. **N,** homocurvatiform element, CPC 23347, inner lateral view, ×60.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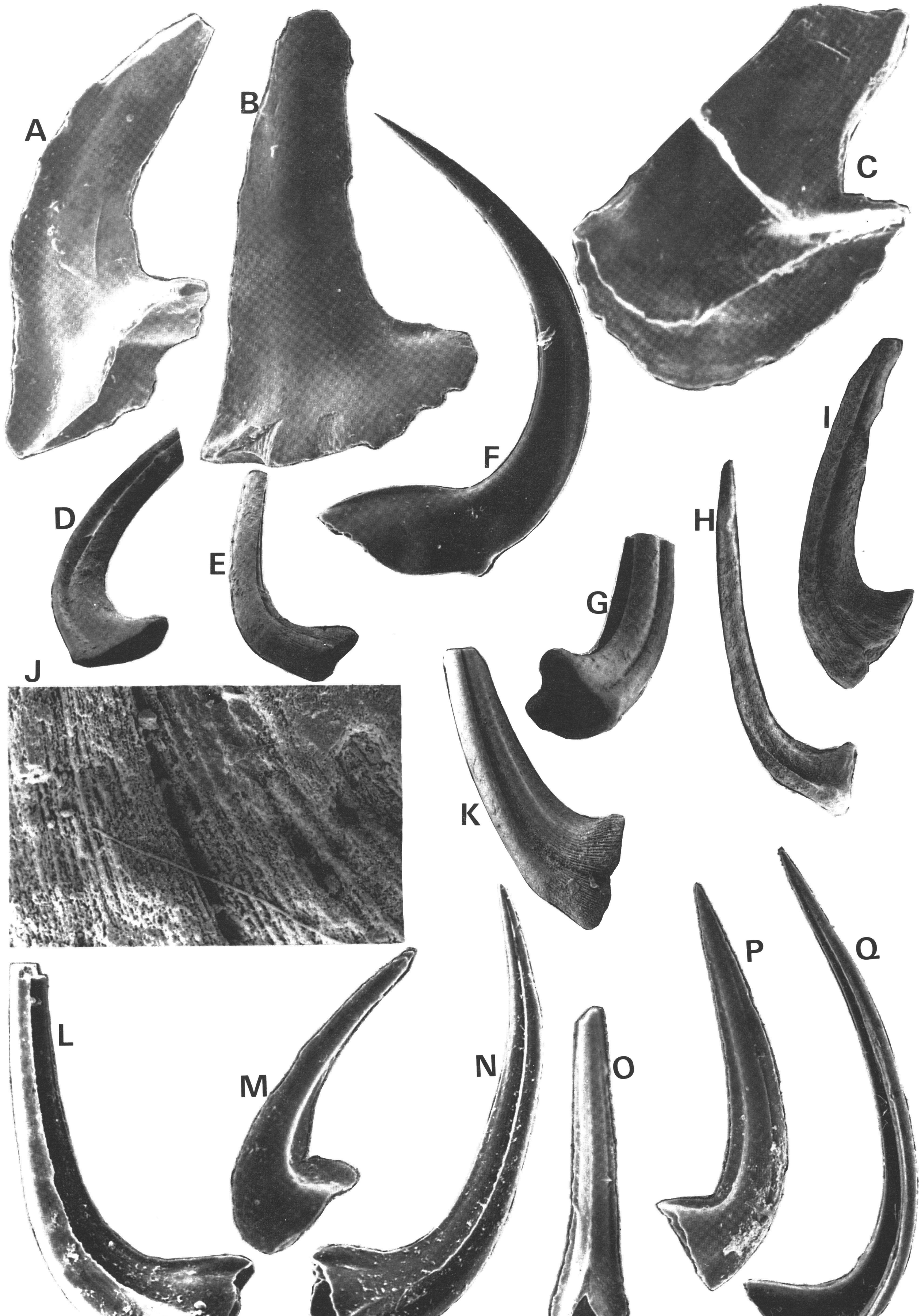
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Remarks. It is uncertain whether acodontiform and scandodontiform elements occupy (e̱) and (f̱) positions, or the apparatus lacks an (e̱) element and the second symmetry transition contains only (f̱) and (g̱). Similarity of these elements supports the second hypothesis.

Distribution. *Tokoconus wheelamanensis* occurs in the lower Majiagou Formation of North China and throughout the Coolibah Formation, Georgina Basin. It is most common in lower to middle strata of this formation.

Genus *Triangulodus* van Wamel, 1974

Type species. *Paltodus volchovensis* Sergeeva, 1963.

Remarks. All elements of this apparatus were described and figured by van Wamel (1974). His reconstruction of *T. brevibasis* (Sergeeva) is appropriate to specimens from the Coolibah Formation, whereas the *Scandodus brevibasis* apparatus of Lindström (1971) and Löfgren (1978) differ in the lack of erect scandodontiform elements. These latter are considered distinct from acodontiform elements.

Triangulodus consists of drepanodontiform (a̱, S_c), acodontiform (ḇ, S_b), roundyaform (or acontiodontiform, c̱, S_a), paltodontiform (or distacodontiform, ḏ, S_d), oistodontiform (e̱, M) and erect scandodontiform elements (f̱, P) in a Type IVC apparatus. The absence of dichognathodontiform elements within the apparatus, and of lobate processes on ramiform elements of *Triangulodus,* distinguish this genus from *Eoneoprioniodus* Mound.

Elements of *Triangulodus* have only rudimentary processes, consisting merely of costae continuing a short distance beyond the aboral margin, without widening or modification of free end of costae. In this regard, *Triangulodus* is similar to *Diaphorodus* Kennedy. The two latter genera differ in outline of ramiform elements: *Triangulodus* has essentially constant curvature from tip to aboral margin whereas the base of *Diaphorodus* elements is marked by a distinct flaring of the basal outline due to flaring of keels proximal to intersection of cusp and base. Additionally, first symmetry elements of *Triangulodus* have a twisted cusp, which is rare in *Diaphorodus.*

Cooper (1981) considered the apparatus of *'Trigonodus' larapintinensis* Crespin to be similar to that of *Triangulodus*, and suggested that these two taxa may be congeneric. Apparatus composition of both are identical in Coolibah Formation material, thereby supporting Cooper's contention. Since *Trigonodus* was pre-occupied when Crespin proposed the name (R.S. Nicoll, AGSO, pers. comm. to KS, 1989), the oldest available name for this conodont genus is *Triangulodus.*

Triangulodus* sp. cf. *T. brevibasis (Sergeeva, 1963)
Fig. 14D–F, 20J–L,N,O, 21K

Synonymy.
Multielement reconstructions

?Scandodus brevibasis (Sergeeva). Serpagli, 1974, pp. 82–83, pl. 18, figs 5a–7c, pl. 27, figs 10,11, pl. 30, figs 2a–3, text-fig. 21.

cf. *Triangulodus brevibasis* (Sergeeva). Van Wamel, 1974, pp. 96–97, pl. 5, figs 1–7.

Triangulodus cf. *brevibasis* (Sergeeva). Zhang *in* An & others, 1983, pp. 158–159, pl. 15, figs 15–20, text-fig. 11:12–15 (with synonymy to 1978).

Material studied. 119 specimens: 16 drepanodontiform, 7 acodontiform, 11 roundyaform, 15 paltodontiform, 42 oistodontiform and 28 erect scandodontiform elements.

Remarks. Specimens from the Coolibah Formation differ from those figured and described by van Wamel in slightly shallower basal cavity of all elements, more reclined cusp of ramiform elements, lessened asymmetry of cusp cross-section in drepanodontiform element, and fine, anticusp-like anterior extension to base of oistodontiform element.

In most respects Coolibah Formation specimens match *T.* cf. *brevibasis* described and figured in An & others (1983), but they differ from other rep[orted occurrences of *T. brevibasis* in the abbreviated oral zone of most oistodontiform elements, and diffuse white matter along keels and central growth axis of the former. Serpagli's (1974) specimens from the San Juan Formation are entirely hyaline. Determination of their relationship with T*riangulodus brevibasis* awaits study of more abundant material.

Distribution. This species occurs in the lower Majiagou Formation of North China (An others, 1983), possibly upper San Juan Formation of Precordilleran Argentina (Serpagli, 1974), and middle and upper Coolibah Formation of the Georgina Basin.

Triangulodus larapintinensis (Crespin, 1943 sensu Cooper, 1986)
Fig. 14A–C, 21D–F,H–J

Synonymy.
Multielement reconstructions

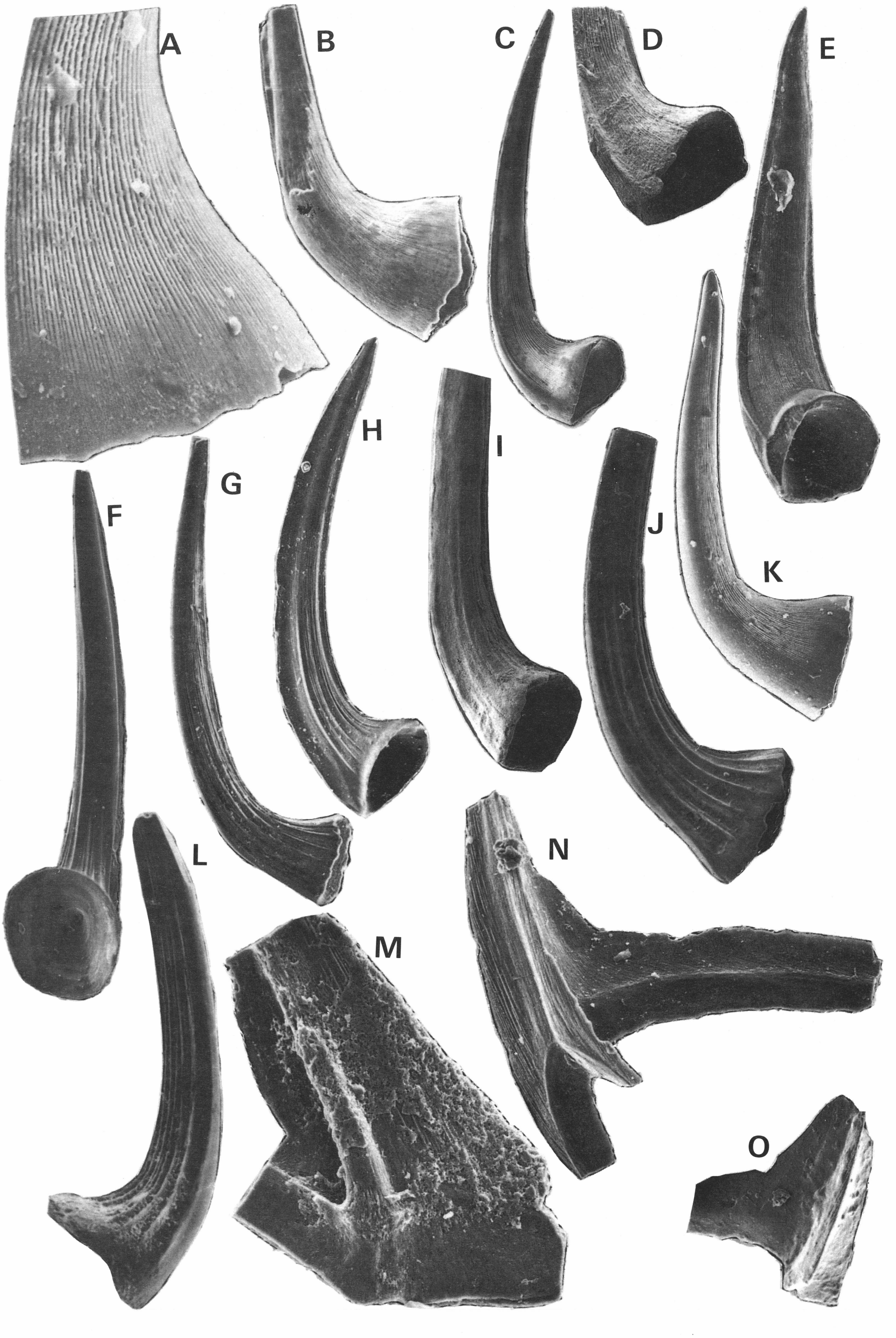
Trigonodus larapintinensis (Crespin). Cooper, 1981, p. 180, pl. 27, figs 5, 6, 11, 12, 16, 17 (synonymy to 1969).

?Trigonodus larapintinensis (Crespin). Watson, 1988, p. 129, pl. 2, figs 12–14, 18–20, 22, 23.

Material studied. 72 specimens: 12 drepanodontiform, 14 acodontiform, 14 acontiodontiform, 6 distacodontiform, 12 oistodontiform and 14 erect scandodontiform elements.

Remarks. The basal cavity of *T. larapintinensis* is distinctive. It is relatively deep, with tip anterior of cusp midline when viewed laterally. The tip is drawn into a fine, anteriorly-directed cone which almost parallels the aboral margin. Posterior margin of cavity is almost straight, while anterior margin of cavity is markedly convex towards cavity. The acontiodontiform figured (Fig. 21D; Cooper, 1981, pl. 27, fig. 16) also has this basal cavity, and is

Figure 18. Magnification ×100 unless otherwise stated.
A–C, ***Drepanoistodus* sp. nov. A**, GEO 156/004. **A,** homocurvatiform element, CPC 23352, inner lateral view. **B,** suberectiform element, CPC 23353, lateral view. **C,** oistodontiform element, CPC 23354, inner lateral view. **D, E, G-K, *Protopanderodus? primitus*** Cooper. **D,** ×70, unigrooved element, CPC 23362, inner lateral view, GEO 123/006. **E,** ×70, asymmetrical acontiodontiform element, CPC 23361, lateral view, GEO 123/006. **G,** ×70, acontiodontiform element, CPC 23360, oblique lateral view, GEO 123/006. **H,** ×50, scandodontiform element, CPC 23363, lateral view, GEO 123/006. **I,** ×70, laterally compressed acontiodontiform element, CPC 23364, lateral view, GEO 123/006. **J,** same specimen as G, ×700, surface microstructure near groove. **K,** ×70, paltodontiform element, CPC 23365, inner lateral view, GEO 149/006. **F, *Paroistodus originalis*** (Sergeeva), ×75, drepanodontiform element, CPC 23359, lateral view, GEO 123/007/12. **L-Q, *Scandodus* sp. nov. A. L,** acontiodontiform element, CPC 23330, lateral view, GEO 123/003. **M,** oistodontiform element, CPC 23369, inner lateral view, GEO 132/016. **N,** distacodontiform element, CPC 23368, lateral view, GEO 132/016. **O,** acontiodontiform element, CPC 23367, posterior view, GEO 132/016. **P,** drepanodontiform element, CPC 23366, lateral view, GEO 132/016. **Q,** ×80, acodontiform element, CPC 23370, inner lateral view GEO 163/002.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considered to be part of the apparatus of *T. larapintinensis*. Watson (1988, 129) considered Cooper's figured oistodontiform element to be a drepanodontiform with a more erect cusp than normal within this apparatus. Aboral opening and postero-oral intersection are more consistent with morphology of drepanodontiform than oistodontiform elements, but are not totally inconsistent with elements occupying e position in (for example) the *Drepanodus concavus* apparatus (graciliform of Kennedy, 1980). It is, however, unusual within the *Triangulodus* apparatus, and the appropriate oistodontiform element may have been included within those assigned herein to *Triangulodus* sp. cf. *T. brevibasis*.

Distribution. *Triangulodus larapintinensis* is found throughout the Horn Valley Siltstone close to Alice Springs, Northern Territory, and upper Coolibah Formation of the Georgina Basin.

Conical elements, gen. et sp. indet.
Fig. 22A–G

Material studied. 13 specimens: 1 element I, 1 element II, 2 element III, 4 element IV, 1 element V and 4 element VI

Description. All specimens are conical, robust, with short, stout, coarsely striate cusp. A wide rim adjacent to aboral margin is not striate; striae parallel posterior margin, converge at lateral edges or in lateral region. All but scandodontiform element have compressed cusp, with greatest cusp thickness laterally. Oral and posterior margins are sharp-edged, anterior margin is smooth. Basal cavity conical with tip close to anterior margin, at top of base. Elements are hyaline, and may have a narrow growth axis subcentral to cusp.

Variation within these specimens includes cusp cross-section, shape and orientation of aboral opening, and extent of development of lateral edges.

A poorly defined transition may be represented by symmetry of basal opening. Elements with ovate aboral opening are generally more compressed than other elements. These former elements bear depressions on both posterolateral faces, but lateral edges are poorly developed. This is also true of elements with triangular aboral opening, but elements with subquadrate or circular aboral opening may have well developed, blocky but sharp-edged, lateral keels.

Scandodontiform elements similar, except an anterolateral edge is developed on base; this becomes more anteriorly situated distally. Cusp is biconvex, aboral opening ovate but long axis is in postero-anterior direction rather than lateral as in other elements.

Remarks. These elements are distinguished from conical elements of Landing & others (1986), and from *Oneotodus* sp. of Cooper (1981), by striate cusp, moderately deep basal cavity and hyaline nature. Scandodontiform elements are included in this association because of their similarity in surface micromorphology, basal cavity, robust nature, and hyaline elements.

It is possible that an almost complete apparatus is herein described. However, considerably more abundant material is required before evaluation of affinities is attempted. Some elements are similar to *Scolopodus warendensis* Druce and Jones, which has a considerably longer cusp and shallower basal cavity than those described above. Comparable, but considerably less robust, elements were described by Abaimova (1971) as *Oneotodus mitra* from southeastern Siberian Platform. These have a reduced cusp, and are probably not conspecific with Coolibah Formation specimens.

Distribution. These specimens were all located in lower to middle Coolibah Formation of the Georgina Basin.

Additional taxa. The following conodont species also occur in the Coolibah Formation, but were found in very low abundance. Their occurrence within studied sections is indicated on range charts (Figs 2–10). Selected elements are illustrated, as shown below in parentheses. All identified species correspond closely with original descriptions, and all taxa listed below are found in the Coolibah Formation only in upper part: *Aurilobodus serratus* Xiang & Zhang, 1983 (Fig. 16I), known from the Majiagou Formation of North China. Only one specimen was located. *Erraticodon tangshanensis* Yang & Xu, 1883 (Fig. 21B,C) ranges through much of the Majiagou Formation of North China (An & others, 1983). This species is also known from the Mandal Formation of North Korea (?Lower to Middle Ordovician; Lee, 1975b), and the Maggol (Arenig; Lee, 1976) and Yeongheung (Middle Ordovician, Lee, 1979) formations of South Korea. Only four specimens were located.

'Oepikodus' maggolensis Lee, 1976 (Fig. 20M), also occurring in the Maggol Formation of South Korea (Lee, 1976) and lower Majiagou Formation of North China (An & others, 1983). Three specimens found.

Oistodus multicorrugatus Harris, 1962 (Fig. 21A,G), present in many of the early Middle Ordovician carbonates of North America (Ethington & Clark, 1981), upper San Juan Formation of Argentina (Serpagli, 1974), Kimaian strata on the Siberian Platform (Moskalenko, 1982), Majiagou Formation of North China (An & others, 1983), and Horn Valley Siltstone of the Amadeus Basin, Australia (Cooper, 1981). Five specimens located.

Protoprioniodus nyinti Cooper, 1981 (Fig. 19M-O), known from the Juab Formation of western Utah, El Paso Group of west Texas, Eleanor River Formation of Arctic Canada, Horn Valley Siltstone of the Amadeus Basin, Australia (Cooper, 1981), found on Mt Arrowsmith in New South Wales, Australia, and in the Nora and upper Coolibah formations of the Georgina Basin (Cooper, 1981; this study). Eight specimens found.

Figure 19. Magnification ×70 unless otherwise stated.
A–E, K, ***Scolopodus*** **sp. aff.** ***S. filosus*** Ethington & Clark. **A,** ×250, planoconvex element, CPC 23373, surface microstructure, GEO 165/002. **B,** ×100, equidimensional paltodontiform element, CPC 23375, lateral view, GEO 163/002. **C,** keeled scandodontiform element, CPC 23377, lateral view, GEO 163/002. **D,** ×100, scandodontiform element, CPC 23376, posteroaboral view, GEO 163/002. **E,** ×80, acontiodontiform element, CPC 23374, posterolateral view, GEO 163/002. **K,** planoconvex element, same specimen as A, inner lateral view. **F–J, L,** ***Scolopodus multicostatus*** Barnes & Tuke. **F,** equidimensional paltodontiform element, CPC 23381, aboral view, GEO 132/016. **G,** ×60, laterally compressed paltodontiform element, CPC 23378, lateral view, GEO 123/003. **H,** keeled scandodontiform element, CPC 23383, posterolateral view, GEO 132/016. **I,** scandodontiform element, CPC 23382, inner lateral view, GEO 123/003. **J,** planoconvex element, CPC 23379, lateral view, GEO 123/003. **L,** acontiodontiform element, CPC 23380, lateral view, GEO 132/016. **M–O,** ***Protoprioniodus nyinti*** Cooper. **M,** ×150, cordylodontiform element, CPC 23386, lateral view, GEO 123/005. N, ×100, gothodontiform element, CPC 23387, inner lateral view, GEO 123/005. **O,** ×100, trichonodelliform element, CPC 23388, anterolateral view, GEO 165/004.

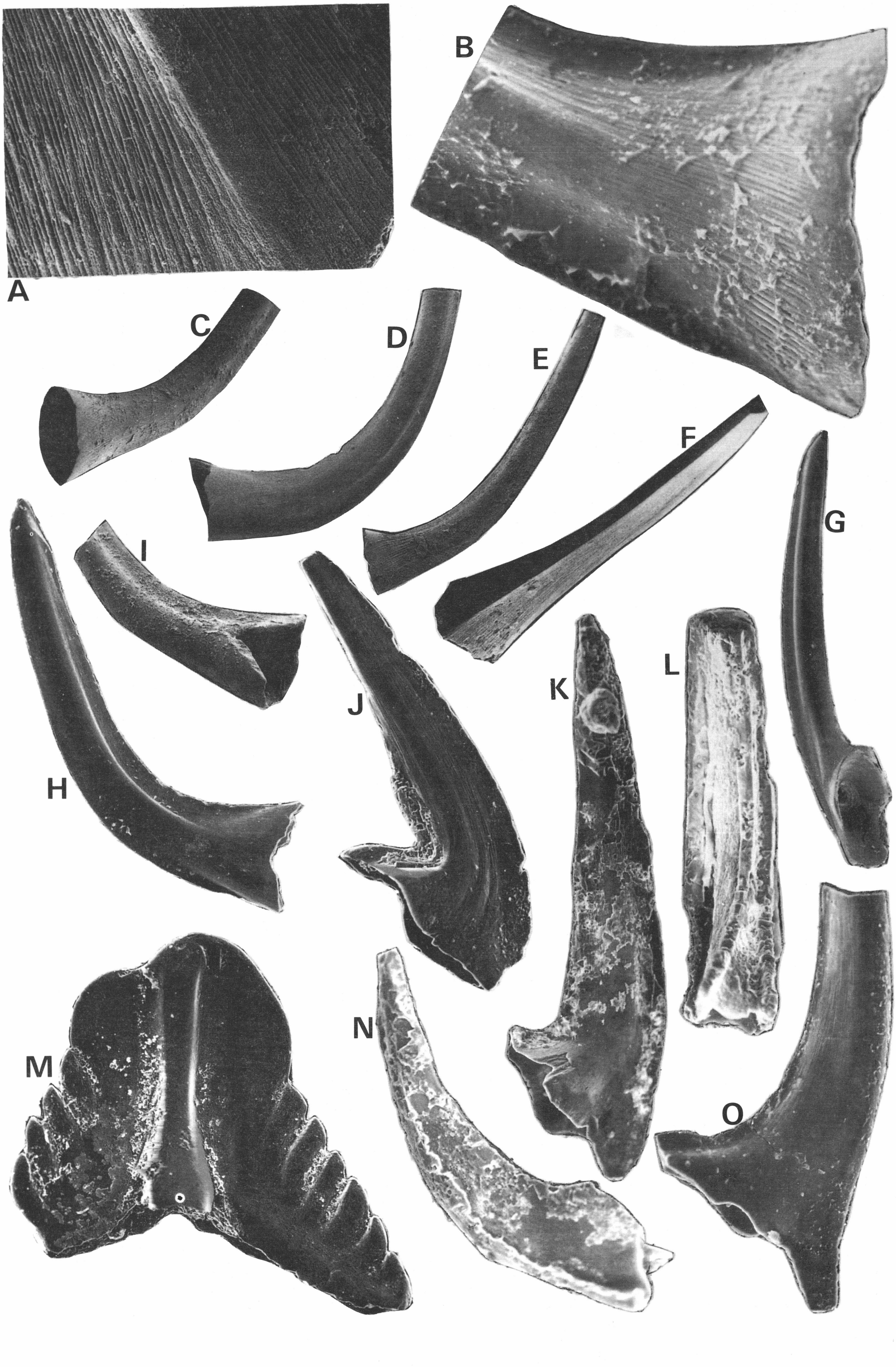
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Figure 20. Magnification ×50 unless otherwise stated.
A–I, *Tokoconus wheelamanensis* gen. et sp. nov. A, ×400, acontiodontiform element, paratype, CPC 23392, microstructure of cusp posterior region, GEO 123/003. **B,** ×250, scandodontiform element, paratype, CPC 23397, microstructure of cusp near basal opening, GEO 132/016. **C,** drepanodontiform element, paratype, CPC 23390, oblique lateral view, GEO 132/016. **D,** gothodontiform element, paratype, CPC 23391, inner lateral view, GEO 165/004. **E,** scandodontiform element, same specimen as in B, lateral view. **F,** acontiodontiform element, same specimen as in A, posterior view. **G,** distacodontiform element, holotype, CPC 23393, posteroaboral view, GEO 123/007. **H,** distacodontiform element, same specimen as in G, lateral view. **I,** acodontiform element, paratype, CPC 23395, lateral view, GEO 123/003. **J–L, N, O, *Triangulodus* sp. cf. *T. brevibasis*** (Sergeeva). **J,** ×90, oistodontiform element, CPC 23403, inner lateral view, GEO 132/014. **K,** ×90, erect scandodontiform elment, CPC 23404, lateral view, GEO 148/005. **L,** ×120, paltodontiform element, CPC 23402, posterior view, GEO 148/005. **N,** ×120, roundyaform element, CPC 23401, lateral view, GEO 148/005. **O,** ×120, drepanodontiform element, CPC 23398, lateral view, GEO 148/005. **M, *'Oepikodus' maggolensis*** Lee, symmetrical element, CPC 23389, posterior view, GEO 132/005.

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Figure 21. Magnification ×90 unless otherwise stated.
A, G, *Oistodus multicorrugatus* Harris, GEO 132/014. **A,** ×120, trichonodelliform element, CPC 23358, lateral view. **G,** ×80, d element, CPC 23357, lateral view. **B, C, *Erraticodon tangshanensis*** Yang & Xu. **B,** ×120, b element, CPC 23356, lateral view, GEO 139/001. **C,** ×180, neoprioniodontiform element, CPC 23355, inner lateral view, GEO 156/004. **D–F, H–J, *Triangulodus larapintinensis*** (Crespin). **D,** acontiodontiform element, CPC 23408, oblique lateral view GEO 139/001. **E,** erect scandodontiform element, CPC 23411, lateral view, GEO 139/001. **F,** acodontiform element, CPC 23407, inner lateral view, GEO 165/005. **H,** oistodontiform element, CPC 23410, lateral view, GEO 165/005. **I,** drepanodontiform element, CPC 23406, lateral view, GEO 165/005. **J,** distacodontiform element, CPC 23409, posterolateral view, GEO 165/005. **K, *Triangulodus* sp. cf. *T. brevibasis*** (Sergeeva), ×120, acodontiform element, CPC 23400, outer lateral view, GEO 148/005.


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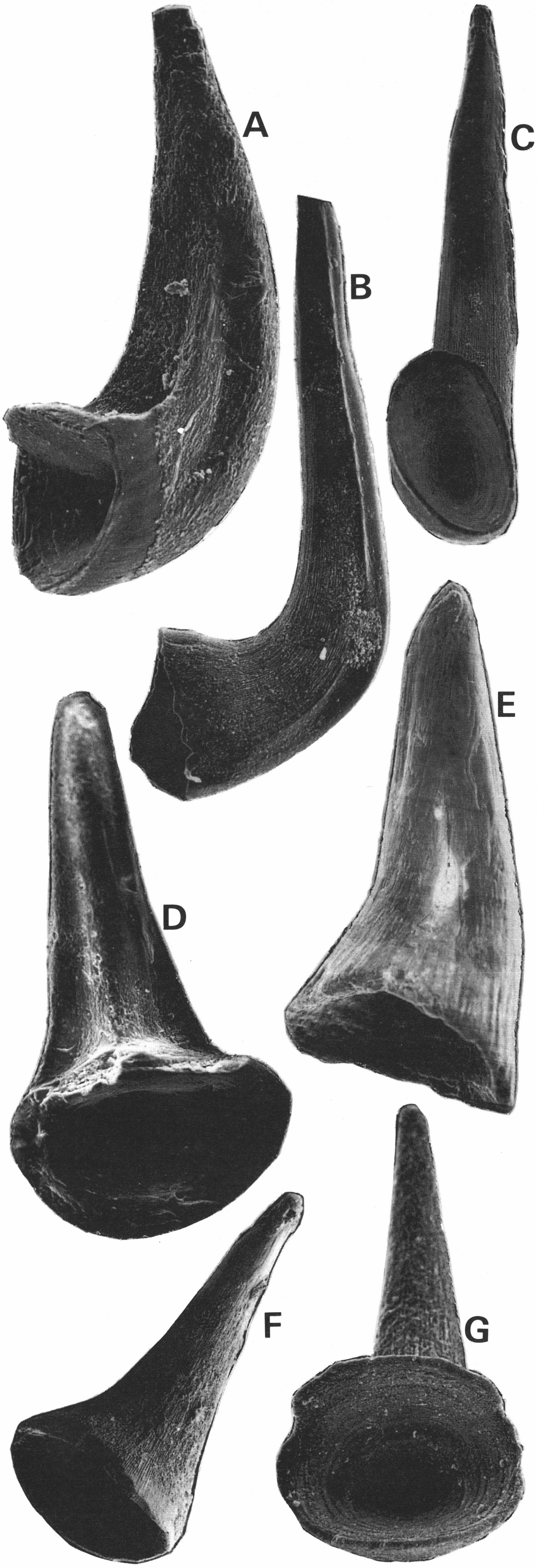

Figure 22. Conical elements.
Magnification ×100 unless otherwise stated.
A, ×120, element III, costate element with subrectangular aboral opening, CPC 23414, lateral view, GEO 148/005. **B,** ×90, same specimen, inner lateral view. **C,** ×90, element II, scandodontiform element, CPC 23413, aboral view, GEO 132/026. **D,** element V, costate element with ovate aboral opening, CPC 23416, posterior view, GEO 123/007. **E,** element IV, acostate element with triangular aboral opening, CPC 23415, posterolateral view, GEO 123/003. **F,** element VI, acostate element with ovate aboral opening, CPC 23417, posterior view, GEO 132/026. **G,** ×150, element I, acostate element with circular aboral opening, CPC 23412, aboral view, GEO 163/002.