Late Silurian (Ludlow) and Early Devonian (Pragian) conodonts from the Cobar Supergroup, western New South Wales, Australia

DAVID MATHIESON, RUTH MAWSON, ANDREW J. SIMPSON & JOHN A. TALENT

Late Silurian and Early Devonian conodonts are documented from outcropping limestones at nine Cobar Supergroup localities: the Booth Limestone, the Mountain Dam Limestone, the Beloura Tank Limestone Member of the Baledmund Formation, the “Lerida Limestone Member” of the Amphitheatre Group, and limestones in Stoney Creek in the Gundabooka National Park, in the Troffs Formation in the Trundle Group and in the Derriwong Group at Myola. These (with the exception of Myola) and conodonts previously documented from the White Tank and Rookery limestone members of the Meryula Formation are Pragian in age, ranging from sulcatus Zone to the imprecisely defined pirenea Zone, with the uppermost part of one of them (the Booth Limestone) possibly extending into the earliest Emsian. The Derriwong Group carbonates are late Ludfordian, crispa Zone, in age and are the only remnants discovered to date of a Silurian marine incursion. Ages for the Devonian limestones are: Booth Limestone, late in the sulcatus Zone to “pirenea Zone” with the uppermost horizon possibly extending into the dehiscens Zone; Mountain Dam Limestone, sulcatus Zone with the uppermost preserved horizon inferred to have been late in the sulcatus Zone; the Beloura Tank Limestone Member, sulcatus Zone; the “Lerida Limestone Member”, sulcatus Zone; and limestones in Stoney Creek in the Gundabooka National Park, “pirenea Zone”. Conodonts previously documented from “The Rookery” – the White Tank and Rookery limestone members – are inferred to be sulcatus Zone. In terms of recently refined absolute ages, Devonian carbonate sedimentation in the Cobar Supergroup, though localised, thus spans a six-or-seven-million-year time slice. The Devonian limestones investigated were apparently deposited during a single, basin-wide sedimentary event that was conducive to accumulation of carbonate sediments at various loci. Several conodont species documented here are taxa found in Central Asia and Arctic North American localities. Previous examples of such apparent provincialism, based on conodont distribution, have been noted to occur in faunas from the pesavis and kindlei zones, the imprecisely defined pirenea interval, and now for the sulcatus Zone. A plethora of new species and subspecies identified from the Cobar Supergroup limestones appear in the middle to late portion of the sulcatus Zone, an interval from which conodonts have not been documented as copiously as from other time slots globally. New conodont taxa consist of one new genus, eight new species – one kept in open nomenclature – and six new subspecies: Helagnathus gen. nov. (type species Helagnathus parvilabiatus sp. nov.), Panderodus rhytiodus sp. nov., Panderodus sp. nov. A, Icriodus ampliatus sp. nov., Pelekgnathus inaequalis sp. nov., Oulodus australis sp. nov., Ozarkodina multistriola sp. nov., Ozarkodina scoliciformis sp. nov., Amydrotaxis corniculans truncus subsp. nov., Eognathodus sulcatus lanei subsp. nov., Eognathodus sulcatus sicatus subsp. nov., Ozarkodina selfi lenticula subsp. nov., Ozarkodina selfi lanceola subsp. nov. and Ozarkodina selfi cordata subsp. nov. Biometric data from this study indicate a separation in the ranges of Ozarkodina selfi and Eognathodus sulcatus. A polyphyletic origin of Eognathodus is suggested. Biometric data are presented to demonstrate that Icriodus ampliatus sp. nov. occupies a morphological gap between I. steinachensis and I. claudiae and its first appearance is a marker of the upper sulcatus Zone. • Key words: Australia, New South Wales, Cobar Supergroup, late Silurian, Early Devonian, conodonts, conodont phylogeny, Darling Basin.


David Mathieson, Department of Earth and Planetary Sciences, Macquarie University, North Ryde 2109, Australia; david.mathieson@mq.edu.au • Ruth Mawson, Department of Earth and Planetary Sciences, Macquarie University, North Ryde 2109, Australia; rmawson37@gmail.com • Andrew J. Simpson (corresponding author), Department of Ancient History, Macquarie University, North Ryde 2109, Australia; andrew.simpson@mq.edu.au • John A. Talent, Department of Earth and Planetary Sciences, Macquarie University, North Ryde 2109, Australia; jatalent32@gmail.com

DOI 10.3140/bull.geosci.1593
The Cobar Basin of western New South Wales (Fig. 1), flanking and perhaps viewed as continuing imperceptibly westwards into the largely subsurface Darling Basin (Talent et al. 2000), has been regarded traditionally as a NNW-trending half-graben formed during a regional crustal extension event. This event (or aggregate of events) is believed to have occurred during the latest Silurian to Early Devonian, affecting the western portion of the Lachlan Fold Belt in New South Wales (Glen 1990, 1991; Smith & Marshall 1992). The Cobar Basin has been viewed as having been flanked by shallow shelves separated by faults (Fig. 1) (Trigg 1987; MacRae 1989a, b; Glen 1990, 1991; Glendining et al. 1994, 1996; Gilligan & Byrnes 1995).

The latest Silurian to Early Devonian Cobar Supergroup (Pogson & Felton 1978) is viewed as having accumulated within the inferred Cobar Basin including its flanking shelves. Associated with these inferred shelves are small, shallow-water limestone bodies that were sampled for conodonts (primarily) and associated fauna. The limestones crop out in nine discrete areas (six are shown in Fig. 1, all nine are shown in Fig. 2) about 500 km NW of Sydney. A further occurrence of limestones, on a property known as “The Rookery”, about 35 km SE of Cobar, was cursorily examined; it has already been the focus of a significant conodont investigation by Pickett (1980). Another limestone occurrence – on Kopyje station, 70 km ESE of Cobar – produced 43 rather nondescript conodonts from a 12 kg sample, suggesting a late Přídolí age (Pickett 1976), but access to this property for further investigation as part of this study was refused.

During the 1980s and early 1990s, as a service to exploration companies and geologists of the Geological Survey of New South Wales mapping in the Bourke–Cobar–Condobolin region, Pickett produced a series of brief reports with identifications but not documentation of fossils (mainly conodonts) from spot samples (Pickett 1981, 1982, 1983, 1984, 1986, 1987, 1992). Because scores of stratigraphic units have been proposed for this vast region of Ordovician to Late Devonian clastics and occasional volcanics – most without a glimmer of compelling age control – no attempt is made herein to rationalise the stratigraphic fabric regionally nor attempt to chronicle and interpret its tectonostratigraphic evolution.

Largely because of mineral exploration, the literature is vast and diffuse but an overview of the palaeogeography of the region during Early Devonian time (Trigg 1987) provides a useful backdrop (Fig. 1) for considering the hypothesised sedimentary-tectonic settings of the areas probed for improved data from conodonts and their chronologic implications. That the areas lacking useful outcrop are vast, that the suggested palaeogeographic pattern is conjectural, and that the dearth of fossil localities providing even the most basic age control has been disheartening, should not be underestimated.

Most attention has been directed to the taxonomy of the 6000+ conodonts obtained from acid leaching using commercial acetic acid, and to evaluating their significance as regards stratigraphic alignments; they are comprehensively illustrated in Figs 8–32. Outcrops of Booth Limestone, especially in the vicinity of Beulah Tank on “Manuka” (Fig. 3), have produced poorly preserved (recrystallized, dolomitised, often rusty coloured) massive algae and stromatoporoids, but well preserved stromatoporoids are found on the eastern side of the strip of Booth Limestone along the Multagoona Antcline (Fig. 3); these are being investigated by Barry Webby. Inarticulate brachiopods and fish micro-remains obtained in acid leaching for conodonts have been made available to other workers and are not considered here. The generally sparse conodont faunas obtained from bores in the Darling Basin are discussed by Talent et al. (2003).

Of special interest are small occurrences of silicification at five spot localities in the Booth Limestone: 14, 15, 15E, 15W and 16A. Exhaustive collections from these spots, acid-leached with commercial acetic and dilute hydrochloric acid, have produced silicified rugose and tabulate corals, brachiopods and rare rostroconchs, ostracods and other organisms. These were illustrated by Mathieson (2003) and will be documented separately. No attempt has been made to study the sedimentary petrology of the various limestone occurrences.

**Stratigraphic units investigated for conodonts**

The outcropping limestones sampled in this study are noted below, and their latitudes and longitudes are given in Table 1.

**Booth Limestone**

Previously this unit has been referred to as the Booth Limestone Member of the Gundaroo Sandstone (MacRae 1989a, b). Though generally poorly exposed, this unit clearly overlies the Thule Granite nonconformably and is overlain in turn by the Gundaroo Sandstone (Fig. 3). Because it is substantial and conspicuous in the regional stratigraphy, the unit is herein regarded as a formation independent from the Gundaroo Sandstone.

The relationship between the Thule Granite, Booth Limestone and Gundaroo Sandstone is seen in two small north-west to south-east trending anticlinal structures (Fig. 3) that are informally named after local properties. Along the Manuka Antcline (new name), NNW from Beulah Tank, the Booth Limestone reaches a stratigraphic thickness of between 50 and 170 m. The maximum development of dolomitised limestones (often weathering rusty
Figure 1. Sedimentary-tectonic interpretation of the Cobar Supergroup and adjacent areas from Trigg (1987) with locations of six of the areas considered in this study. Note that the “Lerida Limestone Member” is located in a region interpreted by Trigg as basinal, the Booth Limestone and the Beloura Tank and Rookery (= White Tank) limestone members in areas interpreted as shelf, and the Mountain Dam Limestone and Stoney Tank limestones in regions thought to be possibly shallow shelf.
brown) with abundant massive calcareous algae, stromatoporoids and tabulate corals occurs in that area. The greater thickness than elsewhere, the dolomitisation and the abundance of frame-building organisms accords with the area having been very shallow – perhaps even including a transient palaeo-island or two – during Pragian times. It is also possible that the area included a locus or loci of carbonate buildup. These suggestions are speculative; the outcrops are poor and there is little in the way of dip information.

The generally very poorly outcropping tract of limestones along the Multagoona Anticline (new name), about 2 km west and southwest of the Manuka Anticline, could be interpreted as a lenticular development within the Gunbarroo Sandstone, but conodont data from this occurrence be interpreted as a lenticular development within the Gunbarroo Sandstone, but conodont data from this occurrence individually suggest (Pickett 1983); they aggregate about 11.5 m in thickness, based on a measured and sampled section variously offset to embrace the best outcrops. The stratigraphic column presented here (Fig. 4A) is a composite of two sections measured and sampled on the assumption of near verticality of the exposed sequence. Geopetal data subsequently indicated, however, that the exposed sequence was in fact horizontal. The limestones are abundantly fossiliferous, with stromatoporoids, massive calcareous algae, and tabulate and rugose corals, indicating very shallow platform conditions (Trigg 1987). Shelly fossils, apart from indeterminate gastropods, are rare. There were six spot samples collected for conodonts, 37 that were originally considered to come from a short stratigraphic interval, plus two additional spot samples. These samples produced a relatively abundant and diverse conodont fauna (Table 2 – online appendix).

Stoney Creek limestones, Gundeburra National Park

Limestones crop out intermittently in Stoney Creek, north of Stoney Tank in the Gundabooka National Park, approximately 70 km SW of Bourke (Mulholland 1940; Figs 1, 2). The poorly outcropping sequence consists of argillaceous, quartzose and calcareous sandstones and siltstones with rare, thin, grey limestone horizons a few centimetres thick. The fauna consists of stromatoporoids, tabulate corals, brachiopods, crinoid ossicles, bivalves, ostracods, conodonts and rarely bryozoans (Mulholland 1940, Sharp 1992). An early Lochkovian age was suggested on the basis of a low diversity conodont fauna (Pickett 1987).

Six spot samples (GUND 1 to 6) were collected from the tiny exposures along Stoney Creek (Fig. 4B). Of these, samples GUND 1 to 5 yielded inarticulate brachiopods, mainly fragments of discinids. Samples GUND 1 and 5 were from a limestone horizon with abundant crinoid ossicles and brachiopods; these were the stratigraphically lowest samples collected. GUND 2 and 4 were from thin beds (1–5 cm thick) of muddy limestone interbedded with mudrocks. GUND 4 was stratigraphically the highest sample. GUND 3 and 6 were loose blocks of muddy limestone. Five of these samples produced conodonts (Table 3– online appendix).

Mountain Dam Limestone

The Mountain Dam Limestone (Rayner 1969) is an isolated outlier of fine-grained Cobar Supergroup limestone resting unconformably on the Ordovician Tallebung Group. It crops out as a low hill about 90 km NW of Condobolin (Fig. 4A) and about 2 km NW from “Marobee” homestead. The limestones are subhorizontal, determined from geopetal orientations, rather than subvertical as previously suggested (Pickett 1983); they aggregate about 11.5 m in thickness, based on a measured and sampled section variously offset to embrace the best outcrops. The stratigraphic column presented here (Fig. 4A) is a composite of two sections measured and sampled on the assumption of near verticality of the exposed sequence. Geopetal data subsequently indicated, however, that the exposed sequence was in fact horizontal. The limestones are abundantly fossiliferous, with stromatoporoids, massive calcareous algae, and tabulate and rugose corals, indicating very shallow platform conditions (Trigg 1987). Shelly fossils, apart from indeterminate gastropods, are rare. There were 39 samples collected for conodonts, 37 that were originally considered to come from a short stratigraphic interval, plus two additional spot samples. These samples produced a relatively abundant and diverse conodont fauna (Table 2 – online appendix).

Beloura Tank Limestone Member of the Baledmund Formation

First identified by Curran (1888), the Beloura Tank Limestone Member (Pogson & Felton 1978; modified after Lloyd 1936) is a massive crinoidal limestone cropping out as a low hill approximately 20 km SE of Nymagee (Fig. 5A). It is believed to be conformably enclosed within the siltstones and fine-grained sandstones of the Baledmund Formation. It has produced numerous fossils including crinoids, rugose and tabulate corals, conodonts and brachiopods (MacRae 1987). Only three samples representing two localities were collected for conodonts: BTL 1 (BTL A is the same locality collected during initial field work) and BTL 2.

“Lerida Limestone Member”

The name Lerida Limestone Member was proposed by Glen (1987) for four small, rounded outcrops of massive, fine-grained limestone (Fig. 5B) inferred to occur within
Location of broad structural elements in the vicinity of the Darling Basin indicating locations of nine areas of outcrop investigated for this report. These are: 1 – the Booth Limestone of the Marigoona / Manuka anticlines, WSW of Nymagee; 2 – the Mountain Dam Limestone, WNW of Condobolin; 3 – the Stoney Creek Limestone in the Mt Gundabooka vicinity, SSW of Bourke; 4 – the Beloura Tank Limestone of the Balkindam Formation, SE of Nynagee; 5 – the “Lerida Limestone” in the vicinity of “The Bluff”, SSW of Cobar; 6 – the White Tank and Rookery limestone members of the Meryula Formation on “The Rookery” station, SE of Cobar; 7 – the “Myola” Limestone of the Derriwong Group, Myola Station, S of Trundle; 8 – the “Trundle” sample from the Trundle Group, SSW of Trundle; 9 – the “Troffs” sample (float) from the Trundle Group, N of Trundle. The map also indicates many bores in the region that have intersected Palaeozoic carbonates. Illite crystalinity data in combination with conodont Colour Alteration Index data in this study provides a guide to thermal maturity throughout a vast region of western New South Wales. These comprehensive data will be documented in a follow up study.
arenites of the lower Amphitheatre Group on “The Bluff”, about 25 km SSW of Cobar. Stromatoporoids, rugose corals, trilobites, conodonts, bivalves and crinoid ossicles have been reported but not documented (Sherwin 1975,1978a, b, 1980, 1995; Pickett 1979, 1981; Glen 1987). The lower Amphitheatre Group sandstones are either massive or show graded bedding, and are parallel- or cross-ripple laminated. These features accord with a turbiditic origin. The Lerida Limestone Member may thus be allochthonous in origin, representing limestone olistoliths shed from the Wind-duck Shelf to the west (based on palaeocurrent directions), or a more local, but now lost, palaeotopographic high (Glen 1987). Because of its probable allochthonous nature, the “Lerida Limestone Member” is referred to with inverted commas. Five spot samples (BLUFF 1 to 5) from three of these limestone bodies (Fig. 5B) produced conodonts (Table 3) as well as four species of inarticulate brachiopods.

White Tank and Rookery Limestone members of the Meryula Formation on “The Rookery” station

Outcrops of limestones on “The Rookery” station (Fig. 6), approximately 35 km SE of Cobar (Pickett 1980), have been grouped into two lithologically dissimilar members assumed to be conformably enclosed within siltstones of the Meryula Formation (Felton 1981). The White Tank Limestone Member was described by Felton (1981) as consisting of massively bedded, autochthonous coralline and stromatoporoidal limestones interpreted as a forereef facies grading laterally into well-bedded calcarenites and calcirudites of the Rookery Limestone Member –interpreted as backreef facies. Because the conodonts of these two units have been documented (Pickett 1980), our consideration of them has been limited to a cursory examination of the outcrops, reappraisal of the taxonomy of the forms illustrated by Pickett (1980) and reconsideration of their age-significance.

“Myola” Limestone

Limestones interpreted as part of the Derriwong Group have been previously reported from the vicinity of “Myola” station (Pickett & Ingpen 1990). These are considered part of the uppermost unit of the group, which consists of siltstones, minor sandstone and interbedded limestone. Pickett & Ingpen (1990) indicated that the Derriwong Group is separated by unconformities from the underlying Raggart Volcanics and the overlying Hervey Group. They (Pickett & Ingpen 1990, p. 9) used macrofossils to infer a broad correlation with the Quidong Limestone of far southeastern New South Wales.

For the present study, samples were collected from the roadside locality of Pickett & Ingpen (1990) as well as from a small number of isolated limestones on the “Myola” property itself (samples Myola 1 to 5). It is not possible to infer stratigraphic relationships between these samples on field evidence alone. It was thought they might represent a very small number of penecontemporaneous late Silurian limestone shelf deposits, or remnants of a single deposit. Our study reveals a slightly more diverse conodont fauna of approximately the same age as suggested by Pickett & Ingpen (1990). Subsequent investigations of areal imagery indicate that all the samples taken from “Myola” came from localities in close proximity to one another along strike.

Trundle and Troffs samples

The Trundle Group is an extensive sequence of mid-Paleozoic clastic, volcanioclastic and volcanic rocks exposed in the region of the New South Wales township of Trundle. Two primarily clastic units have been identified: the lower Connemarra Formation and the upper Troffs Formation (Sherwin 1996). The latter is described as a sequence of fine to coarse sandstones with mudstones. The former consists of siltstone, mudstone and marl with limestone lenses. Földvary (2000) documented rugose and tabulate corals, brachiopods and stromatoporoids from the Trundle Group and underlying Derriwong Group.

Conodont faunas were reported by Pickett & McClatchie (1991) from the Trundle Beds (Trundle Group sensu Sherwin 1996) and the Jerula Formation (Jerula Limestone Member of the Gleninga Formation sensu Sherwin 1996 of the equivalent Yarra Yarra Creek Group). These faunas included Pandorinellina exigua philipi (Klapper), Ozarkodina renscheidensis (Ziegler) and Kimognathus alexei Mashkova. Burrow (2003, 2006) documented fish faunas from limestones of the Trundle region.

Two spot samples from the district were taken to augment the investigation of stratigraphic sections across the vast geographic area of this study. The “Trundle” sample was collected from a locality 10 km SSW of Trundle township from a small exposure of limestone, closely equivalent to locality 322 of Földvary (2000). The “Troffs” sample was collected as float from a roadside locality some 13 km north of Trundle township.

Biostratigraphic synthesis

The main focus of this study was to establish a broad chronological framework for isolated limestone outcrops over a vast geographical region of New South Wales. All units
Geology in the vicinity of Beulah Tank on “Manuka” station, based on mapping by Conzinc Rio Tinto Australia, Geopeko, Melissa Hurst and Elizabeth Brand [1994, unpub. B.Sc. (Hons) theses, Melbourne University] and by the authors with sites sampled for conodonts and silicified faunas. Note that portions of the boundaries between the Gundaroo Sandstone and the Booth Limestone, and between the latter and the Thule Granite, are accurate and based on rotary airblast drilling undertaken during mineral exploration.

Figure 3. Geology in the vicinity of Beulah Tank on “Manuka” station, based on mapping by Conzinc Rio Tinto Australia, Geopeko, Melissa Hurst and Elizabeth Brand [1994, unpub. B.Sc. (Hons) theses, Melbourne University] and by the authors with sites sampled for conodonts and silicified faunas. Note that portions of the boundaries between the Gundaroo Sandstone and the Booth Limestone, and between the latter and the Thule Granite, are accurate and based on rotary airblast drilling undertaken during mineral exploration.
investigated are Early Devonian in age with the exception of the Silurian (late Ludlow) limestone at Myola.

Conodont zonal schemes in the Lower Devonian have been the subject of much debate. The base of the Pragian was originally defined (Chlupáč & Oliver 1989) as coincident with the first appearance of the conodont *Eognathodus sulcatus* Philip as identified by the sulcate morphology of the Pa element. The previous work of Lane & Ormiston (1979) had established a broad tripartite division of the Pragian based on perceived evolutionary relationships within the genus *Eognathodus* (the oldest *sulcatus* and subsequent *kindlei* zones) and the later appearance of *Polygnathus pireneae* Boersma (youngest *pireneae* zone). This global standard was generally accepted as a framework for many subsequent investigations of Pragian conodont faunas around the world.

With more intensive sampling of sequences, growing dissatisfaction with both the positioning of upper and lower Pragian boundaries, and the viability of the conodont zonation have been expressed. Calls for a revision of the global standard scheme for the Pragian (e.g. Slavík et al. 2007) and also parts of the underlying Lochkovian (Valenzuela-Ríos & Murphy 1997, Valenzuela-Ríos et al. 2015) have been prompted by a combination of new data from European and North American sequences and proposed revisions of conodont systematics.

Nomenclatural revisions have been based on attributing taxonomic significance to single morphological variations from single elements (e.g. Pa element basal cavities; Bardashev et al. 2002) or a combination of features including the nature of sulcate morphologies (e.g. Murphy 2005) as a way of interpreting lineages. Change to taxonomic nomenclature has outpaced detailed apparatus reconstructions. For example, Bardashev et al. (2002) provided a revised interpretation of generic and suprageneric taxonomy that included separating some early eognathodid taxa into a new genus, *Gondwania*. Some authors have accepted this revised nomenclature despite criticisms of the methodology (e.g. Murphy 2005), while others considered *Gondwania* a junior synonym of *Eognathodus* (e.g. Lu et al. 2016).

Globally accepted biostratigraphic concepts should be based only on a sound, globally accepted taxonomy. Much of the taxonomic contention that has impacted Pragian biostratigraphic concepts is centred on alternative interpretations of eognathodid and polygnathodid conodont lineages. Debate about the evolutionary origin of the sulcate morphology includes the recovery of examples from beneath the Pragian base and the identification of an “incipient but not really developed” sulcus (Slavík et al. 2007).

In assessing the biostratigraphic utility of a Lochkovian lineage (*Lanea carlsi*), Slavík (2011) made the point that some features such as ornament on Pa elements can be a recurrent phenomenon within lineages, and that changes to other elements can be indicative of evolutionary change. Work on reconstruction of key Early Devonian conodont apparatuses and their biostratigraphic application continues.

Well-defined, easily recognisable, relatively abundant, cosmopolitan taxa, as the basis of a global scheme for the Pragian, appear elusive. Our study reports a high number of new taxa. Endemism may mean that a global standard is not possible (Slavík et al. 2007). Meanwhile, regionally based schemes proliferate (e.g. for the Barrandian of central Bohemia – Slavík 2004a; Nevada – Murphy 2005), as does discussion on the appropriate lower boundaries of the Early Devonian series (e.g. Pragian – Slavík 2004a, Valenzuela-Ríos et al. 2005; Emsian – Yolkin et al. 1997, Carls et al. 2008) and even on the viability of a Devonian standard conodont zonation (Bultynck 2007).

As an illustration of the current uncertainties, Becker et al. (2012, fig. 22.13) in their synthesis provided two biostratigraphic versions for the Pragian, namely the historically established tripartite standard zonation as currently accepted by the Subcommission on Devonian Stratigraphy and an alternative zonation based on more recent regional work. In the alternative zonation (Becker et al. 2012, fig. 22.10), no zonal boundary aligns with the commencement of the Pragian. The *Gondwania irregularis* Zone spans the latest Lochkovian and earliest Pragian.
Figure 4. Location maps. • A – position of composite stratigraphic section sampled through the Mountain Dam Limestone and stratigraphic column derived from amalgamating field data. • B – location of sampled limestones in Stoney Creek, north of Stoney Tank in the Gunderbooka National Park.
preceeding the subsequent *Gondwania kindlei* Zone that appears broadly aligned with the *kindlei* Zone in the standard zonation. Slavik *et al.* (2007), however, argued that, based on Barrandian sections, the *kindlei* Zone is broadly penecontemporaneous with the preceding *sulcatus* Zone, implying neither should be considered as definitively Pragian in age.

In Australia, progress on the documentation and analysis of Early Devonian conodont sequences has been summarised at various intervals (Mawson *et al.* 1988, 1992; Mawson & Talent 2000). The most extensively developed Pragian carbonate sequences are found in the southern regions of the Tasman Fold Belt. Philip (1965) first defined the genus *Eognathodus* from the Coopers Creek Formation in Victoria. Mawson & Talent (1994) documented conodonts from an extensive area including allochthonous units in the Walhalla Synclinorium, and indicated an age-range from the *sulcatus* Zone through the *kindlei* Zone to the early Emsian *dehiscens* Zone.

Druce (1971) first recovered an eognathodid from the Garra Limestone in New South Wales. Subsequent sequentially sampled sections have led others to conclude that the formation spans the Lochkovian–Pragian boundary. At Wellington it spans the *pesavis* to *pireneae dehiscens* zones (Wilson 1989), at Eurimbla it spans the *delta* to *sulcatus* zones (Sorrentino 1989). At the Gap, it was also interpreted as spanning the *delta* to *sulcatus* zones (Farrell 2003). Elsewhere in the Tasman Fold Belt, the Cavan Formation is interpreted as extending from the *pireneae* Zone to the *dehiscens* Zone (Mawson *et al.* 1992). Conodonts obtained from extensive debris flows, shed from the Molong High, indicate ages ranging from the *pesavis* to *dehiscens* zones (Talent & Mawson 1999). Pragian faunas have been reported in the Tamworth region (Dongol 1995) and the Ifford region (Colquhoun 1995). They are also known from the Point Hibs Formation in Tasmania (Winchester-Seeto & Carey 2000) and the Shield Creek Formation, Broken River Province, north Queensland (Jeppsson *et al.* 2007, fig. 3).

No distinctive, regional Early Devonian conodont zonation has emerged in Australia; authors have endeavoured to work within the frame of the global standard. In Europe, a lack of eognathodids has hampered correlations; Slavik *et al.* (2007) have expressed a preference for working with *Icriodus* and *Pelekysgnathus*. Despite the documentation herein of representatives of these genera, they are in general relatively poorly represented in Australian faunas prior to the late Emsian, as noted by Talent *et al.* (2000).

In the present study, the provincial nature of Pragian faunas is emphasised by the number of new taxa documented. However, we also propose a new interpretation of the evolution of *Eognathodus* through a closer analysis of basal cavity shapes in Pa elements. We note that the possibility of a polymorphic origin for the sulcate eognathid Pa element morphology suggests a lack of global heterochronity for this morphological innovation and makes for an unreliable marker at the base of a geological series. We also document the new species *Icriodus ampliatus* and interpret it as late *sulcatus* Zone in age.

As noted above the intention of this study was to establish a broad chronological alignment for widely dispersed, isolated carbonate units. None of the units investigated span any more than a single conodont zone with the possible exception of the Booth Limestone. In the absence of a regional zonal scheme for the Early Devonian in Australia and faunal differences from European and North American sequences, we report our findings in terms of the currently accepted global standard zonation. We do this without prejudice, realising that further work on Pragian conodont faunas in Australia and elsewhere may lead to reconsideration of faunal boundaries and the architecture of biostratigraphic zonations.

**Implications of conodont data**

**Booth Limestone**

As noted above, the Booth Limestone crops out in two anticlines (Fig. 3): the Manuka Anticline to the east and the Multagoona Anticline to the west. Conodonts from the easternmost limestone horizons of the Manuka Anticline, closest stratigraphically to the nonconformity between the Thule Granite and the Booth Limestone, are indicative of an age late in the *sulcatus* Zone. This opinion is based on the occurrence of *Icriodus ampliatus* sp. nov., but from horizon B 9 the fauna changes dramatically with the incoming of *Ozarkodina buchanensis* (Philip) and *Pandorinellina exigua philipi* (Klapper), forms that occur together in faunas dated as *pireneae* Zone (Mawson *et al.* 1992) – the still inadequately defined last interval (or intervals) of the Pragian – at Boulder Flat in eastern Victoria.

The Booth Limestone cropping out in the Multagoona Anticline has a similar fauna to the uppermost Booth Limestone in the Manuka Anticline but with the addition of *Oulodus astriatus* sp. nov. and *Oul. paucistriatus* Mawson, the latter described from the Lilydale Limestone of Victoria, a sequence that commences in the *kindlei* Zone but for the most part is “*pireneae Zone*” or conceivably younger in age (Wall *et al.* 1995). Two specimens from B 16L, the westernmost outcrop, are compared with *Pandorinellina exigua exigua* (Philip). If this identification can be confirmed with further sampling, it would indicate that the uppermost Booth Limestone extends into the *dehiscens* Zone and thus into the earliest Emsian, defined by the entry of *Polygnathus dehiscens* (Philip & Jackson) as approved by the International Commission on Stratigraphy (see Yolkin
Figure 5. Location maps. • A – geology in the vicinity of Beloura Tank showing location of samples acid-leached from the Beloura Tank Limestone Member of the Baledmund Formation. • B – geology in the vicinity of the four ‘olistoliths of limestone on which the “Lerida Limestone Member” of the lower Amphitheatre Group on “The Bluff” station was based (Glen 1987), and location of sample.
et al. 1997, 2000) and not rescinded. Polygnatus dehiscens is an especially well characterised, valid, and biostratigraphically useful species, *contra* confusing attempts to sideline it in favour of various forms proposed subsequently (Mawson 1998) and questionable taxonomic procedures with polygnathid conodonts (Bardashev et al. 2002; *cf*. Mawson & Talent 2003).

Mountain Dam Limestone

The 11 m section sampled for this study (Fig. 4A, Table 2) yielded over 1500 conodont elements. *Eognathodus sulcatus lanai* subsp. nov. and *Eo. sulcatus sicatus* subsp. nov. are present from the base to the top of the section, from MDAM 1 to MDAM 37; consequently, the entire section can be dated broadly as *sulcatus* Zone. In the uppermost sample, MDAM 37, however, the occurrence of *Icriodus ampliatus* sp. nov. with *I. sp. cf. I. celtibericus* suggests this level at least represents the topmost part of the *sulcatus* Zone.

Stoney Creek limestones, Gunderbooka National Park

The presence of *Ozarkodina buchanensis* (Philip) and *Oz. sp. cf. Oz. buchanensis* in three of the GUND samples (Table 3) together with species such as *Panderodus exigua philipi* (Klapper) and *Pand. steinhornensis miae* (Bultynck) indicates a late Pragian age ("pireneae Zone") attribution for these spot samples, an age that aligns with the upper Booth Limestone.

Beloura Tank Limestone Member

The two productive samples from the Beloura Tank Limestone Member, like those from the Stoney Creek limestones, show a fauna composed predominantly of simple cones (Table 3). This, with the occurrence of *Oulodus sp. cf. walliseri* and *Icriodus angustoides angustoides* Carls & Gandl, forms common to the ?olistoliths of the Mountain Dam Lime-
stone and “Lerida Limestone Member”, accords with these samples being referred – broadly – to the *sulcatus* Zone.

“Lerida Limestone Member”

The composition of the conodont faunas of the five samples of Lerida Limestone (Table 3) is very similar to those from the Mountain Dam Limestone section with a large proportion of the elements identified as simple cones. There is a dearth of icrioids and oulodids as was noted for the faunas from the Rookery Limestone Member. The occurrence of subspecies of *Oz. selfi* Lane & Ormiston in two of the samples accords with attribution of these ?olistoliths of the “Lerida Limestone Member” to the *sulcatus* Zone.
White Tank and Rookery limestone members of the Meryula Formation on “The Rookery” station

The age of the Rookery Limestone Member has been based on Pickett’s (1980) argument that a species of *Pedavis* from a sample bore core (MAL1, 215 m) put down on “The Rookery” station is *Ped. pesavis* (Bischoff & Sanneman). In the past 25 years, many papers have been written concerning the discovery and identification of new species of *Pedavis*; it is now clear that the only Rookery Limestone specimen illustrated as *Ped. pesavis* by Pickett (1980, text-fig. 4E) is a younger species. Specific assignment is somewhat problematic, but compared to *Ped. pesavis* (*sensu stricto*), the curvature of the posterior process is not as pronounced and the angle at which the lateral processes subextend the anterior process is much greater in the specimen he illustrated. The rest of the Rookery fauna is very similar to that from the first 10.95 m of the Mountain Dam Limestone: neither includes icriodids, and both have only a smattering of oulodids. The Rookery Limestone Member, however, has a greater proportion of *Amygdotaxis dru-ceana* (Pickett) than faunas from the Mountain Dam Limestone and has no eognathodontans or subspecies of *Ozarkodina selfi* Lane & Ormiston. Facies differences presumably account for this.

*Icriodus woschmidti* Ziegler was reported from the White Tank Limestone by Pickett (1980, fig. 3A–D) but the species is reinterpreted herein as *Icriodus ampliatius* sp. nov. Specimens illustrated as *Ozarkodina cf. eurekaensis* Klapper & Murphy by Pickett (1980, fig. 8A–M) are reinterpreted variously as a subspecies of *Eognathodus sulcatus* Philip and subspecies of *Ozarkodina selfi* Lane & Ormiston (see relevant species and subspecies in the systematics below). The White Tank Limestone is dated as upper *sulcatus* Zone in age.

Myola Limestone

The seven samples collected can all be ascribed a late Silurian age. More specifically, the samples Myola 0, 1 and 4 are latest Ludlow *crispa* Zone in age due to the occurrence of the index species. Strata of this age were previously reported in the Trundle region by Pickett & Ingen (1990), and are known elsewhere in southeastern Australia in the Yarrangobilly Limestone (Cooper 1977) and in the Cowombat Formation at Cowombat Flat (Simpson et al. 1993). Simpson (1995) revised the age of other Australian sequences through the late Ludlow to Přídolí interval based on a reinterpretation of previously published conodont data, macrofossil evidence and stratigraphic alignments.

The associated fauna in all the Myola samples is very similar and supports this age interpretation. *Ozarkodina confluens* (Branson & Mehl) occurs in Myola 0, 2, 3 and 4. This is a cosmopolitan conodont species with a highly variable Pa element known to range from the Ludlow *siluricus* Zone, through the late Ludlow *crispa* Zone and high into the Přídolí. The Pa elements of this taxon recovered from Myola are closest in morphology to the alpha morphotype of Klapper & Murphy (1975), and virtually identical to those recovered from *crispa* Zone faunas at Yarrangobilly and Cowombat.

*Pelevskygnathus?* sp. A was recovered in the samples Myola 2, 4 and 6. In Sardinia this taxon is restricted to the lower part of the *crispa* Zone (Corriga & Corradini 2009). It is different from the Nevada taxon *P. index* Klapper & Murphy which was recognized as extending through the *crispa* Zone and into overlying Přídolí strata and was the basis of an informal early Přídolí biostratigraphic interval (*P. index* fauna of Klapper & Murphy 1975). The species recovered in this study is poorly known but it is possible that it occupies a similar biostratigraphic range in Australia.

*Coryssognathus dubius* (Rhodes) is a Silurian species previously interpreted as having an uppermost range within the Ludlow (Simpson 1995), but Corradi & Serpagli (1999) reported occurrences high in the Přídolí (*detortus* Zone). The species was recovered in Myola 0, 1, 2, 5 and 6, and was previously reported in Australia in the Yass Basin (Link & Druce 1972), the Kildrummie Formation (De Deckker 1976), the Trundle region (Pickett & Ingen 1990), the Murda Syncline (Pickett & McClatchie 1991), Cowombat (Simpson et al. 1993), the Claire Creek–Stoney Creek area (a different Stoney Creek some 850 kms SSE of Gundabooka National Park) and Native Dog Plain in the Cowombat region (Simpson & Talent 1995), Broken River region (Sloan et al. 1995, Talent et al. 2002), the Boreenore Formation (Cockle 1999) and the Cobra Formation (Valentine et al. 2006). It has also been reported from numerous localities internationally.

Whilst it is likely that all the localities sampled are latest Ludlow in age, one sample, Myola 2, has a single Sb element tentatively identified as *Oulodus elegans detorta* (Walliser) because of the alternating denticulation on the partially preserved processes. This taxon has previously been associated with the late Přídolí (Jeppsson 1988). Carls et al. (2007), however, outlined a detailed biostratigraphic argument that this could represent a miscorrelation of an older interval, and if so this supports the contention that all samples from Myola were taken along strike and are age-equivalent. The Myola 2 sample has not yielded *Ozarkodina crispa* (Walliser), but its associated conodont fauna is similar to other Myola samples.

Two samples, Myola 2 and 6, contained unusual elements tentatively identified as *Erika divarica* Murphy & Matti. This taxon, originally based on Early Devonian material from Nevada (Murphy & Matti 1982), is poorly known. Miller & Märrs (1999) described some robust ele-
ments from the lower Pridoli Downton Castle Sandstone and, although noting some of their similarities to E. divarica, reconstructed them as Ozarkodina? hemensis.

Our study reveals a slightly more diverse conodont fauna in the Myola Limestone than previously reported and concurs with Pickett & Ingpen’s (1990) original age determination.

“Trundle” and “Troffs” samples

Samples from Troffs yielded Ozarkodina remsccheidensis remsccheidensis (Ziegler) and Pandorinellina exigua philipi (Klapper). The incoming of the latter is considered to be indicative of the pireneae Zone.

The Trundle sample also has Oz. rem. remsccheidensis but is much more diverse and includes the taxa Ozarkodina paucidentata Murphy & Matti (emended herein), Ozarkodina excavata excavata (Branson & Mehl) and Eognathodus sulcatus lanei subsp. nov., all of which indicate a broad sulcatus Zone age. The presence of Icriodus ampliatus sp. nov., as in the Mountain Dam Limestone, suggests the topmost part of the sulcatus Zone may be present.

Comments on Colour Alteration Indices of conodont fauna

Colour Alteration Indices data from conodonts has been used as a proxy for thermal maturity. This technique has not been widely applied in the Lachlan Fold Belt, although Brime et al. (2003) compiled extensive CAI data with illite crystallinity data from the Townsville hinterland, in the northern part of the Tasman Orogen.

Earlier reconnaissance reports of conodont faunas from the Darling Basin by the Geological Survey of New South Wales suggested the possibility of low thermal maturity and of oil and gas prospectivity at some locations. A corpus of new CAI and illite crystallinity data was accumulated over the period of our investigation. It indicates that thermal maturity is highly variable over the extensive geographic range of the Darling Basin. These data, which will be documented in detail elsewhere, build on earlier prospectivity studies (Brown et al. 1982, Stewart & Alder 1995, Alder et al. 1998, Cooney & Mantaring 2007) and facies analysis (e.g. Khalifa 2005, Khalifa et al. 2015) of the Darling Basin.

Systematic palaeontology

Discussion of conodonts is restricted to genera, species and subspecies that are new or of particular stratigraphic or taxonomic interest. Other conodont taxa have been identified (Tables 2, 3), briefly commented on, and are illustrated in Figs 8 to 32. The classification of conodonts used herein follows Sweet (1988). Type and figured specimens are deposited in the microfossil collection of the Geological Survey of New South Wales (MMMC), housed at the W.B. Clarke Geoscience Centre at Londonderry (outer western Sydney).

Abbreviations. – The following abbreviations are used for conodont genera throughout the text, on figures and in the distribution charts: Amy. – Amydrotaxis; Anc. – Ancyrodelloides; B. – Belodella; E – Erika; Eo. – Eognathodus; L. – Icriodus; H. – Heliagnathus; Oul. – Oulodus; Oz. – Ozarkodina; Pand. – Panderodus; P. – Pandorinellina; Pel. – Pelekysgnathus; Ps. – Pseudooneotodus.

Abbreviations used for stratigraphic sections and as prefixes for sample numbers are: MDAM – Mountain Dam Limestone; B – Booth Limestone; BLUFF – samples collected in the “Lerida Limestone Member”; GUND – samples collected in stratigraphic order near Stoney Tank, Gunderbooka National Park; BTL – spot samples from the Beloura Tank Limestone Member in the vicinity of Beloura Tank.

Order Protopanderontida Sweet, 1988
Family Protopanderodontidae Lindström, 1970

Genus Pseudooneotodus Drygant, 1974

Type species. – Oneotodus? beckmanni Bischoff & Sannemann, 1958.

Remarks. – Corradini (2008) discussed the history of taxonomic concepts for this genus, including the multi-element reconstructions of Barrick (1977), and concluded on the basis of the stratigraphic distribution of elements that the apparatus was unimembrate. Elements recovered in our study provide no taxonomic insights into this question.

Pseudooneotodus beckmanni (Bischoff & Sannemann, 1958)

Figure 8Q–S

1958 Pseudooneotodus beckmanni n. sp.; Bischoff & Sannemann, p. 98, pl. 5, figs 22–25.
1966 Gen. et sp. indet. A; Philip, p. 113, pl. 8, figs 1–4. For further synonymy to 1984 see:
1985 Pseudooneotodus beckmanni (Bischoff & Sannemann). – Wang, p. 159, pl. 1, fig. 19. For synonymy to 1990 see:
1994 *Pseudooneotodus beckmanni* (Bischoff & Sanne-

mann). – Mawson & Talent, fig. 15J–L.

1995 *Pseudooneotodus beckmanni* (Bischoff & Sanne-

mann). – Furey-Greig, pl. 1, fig. 3.

1999 *Pseudooneotodus beckmanni* (Bischoff & Sanne-

mann). – Cockle, p. 119, pl. 1, figs 1, 2.

1999 *Pseudooneotodus beckmanni* (Bischoff & Sanne-


2000 *Pseudooneotodus beckmanni* (Bischoff & Sanne-

mann). – Furey-Greig, p. 139, fig. 6.11.

2000a *Pseudooneotodus beckmanni* (Bischoff & Sanne-

mann). – Güngücüğlu & Kozur, figs 5.3, 5.5–5.7, 6.9, 6.10, 7.2, 8.5.

2000b *Pseudooneotodus beckmanni* (Bischoff & Sanne-

mann). – Güngücüğlu & Kozur, figs 5.2, 5.5.

2003 *Pseudooneotodus beckmanni* (Bischoff & Sanne-

mann). – Mawson et al., pl. 5, figs 13, 14.

2003 *Pseudooneotodus beckmanni* (Bischoff & Sanne-

mann). – Pyle & Barnes, fig. 17.24, 17.25.

2004 *Pseudooneotodus beckmanni* (Bischoff & Sanne-


2007 *Pseudooneotodus beckmanni* (Bischoff & Sanne-

mann). – Suttner, pp. 18–19, pl. 6, figs 16, 17; pl. 7, figs 1–4.

2008 *Pseudooneotodus beckmanni* (Bischoff & Sanne-

mann). – Corradini, pp. 142–143, pl. 1, figs 1–7 (with extensive synonymy).

2008 *Pseudooneotodus (?) beckmanni* (Bischoff & Sanne-


2009 *Pseudooneotodus beckmanni* (Bischoff & Sanne-

mann). – Kleffner et al., pl. 1, fig. 13.

2009 *Pseudooneotodus beckmanni* (Bischoff & Sanne-

mann). – Berkyová, fig. 10A–D.

2010 *Pseudooneotodus beckmanni* (Bischoff & Sanne-


2010 *Pseudooneotodus beckmanni* (Bischoff & Sanne-

mann). – Corradini & Corriga, pl. 1, fig. 21.

2011 *Pseudooneotodus beckmanni* (Bischoff & Sanne-

mann). – Corriga et al., fig. 5.12.

2012 *Pseudooneotodus beckmanni* (Bischoff & Sanne-

mann). – Corriga et al., fig. 5.4.

2012 *Pseudooneotodus beckmanni* (Bischoff & Sanne-

mann). – Slavik & Carls, fig. 3U, DD.

2013 *Pseudooneotodus beckmanni* (Bischoff & Sanne-

mann). – Wang, p. 60, pl. 2, figs 19–26; pl. 62, figs 8, 9.

2014 *Pseudooneotodus beckmanni* (Bischoff & Sanne-

mann). – Corriga et al., fig. 5K, L.

Remarks. – According to Barrick (1977), the apparatus of *Pseudooneotodus*, specifically *Ps. beckmanni*, is possibly made up of two elements: a slender form and a squat form. Barrick based his suggestion on the work of Jentzsch (1962) who observed both forms in Early Devonian hori-

zons in Thuringia. Both forms have a single apical denticle and commonly occur elsewhere in horizons also of Early Devonian age. Specimens encountered in our study are the squat form.

Specimens of *Ps. beckmanni* illustrated from the TAN section in the lower Cunningham Formation on the western flank of the Hill End Trough (Talent & Mawson 1999) oc-

cur low in the section below the incoming of *Icriodus steinachensis* eta morph and *Pedavis marianneae*. As Tal-

ent & Mawson (1999) used these two species to date the section “to be most likely kindlei Zone”, there remains the possibility that the lower part of the TAN section may be of late sulcatus Zone age.

Corradini (2008, fig. 2) noted that in Italian collections this species is rare prior to the Ludfordian, then is present through to the Early Devonian and is found in large numbers in the Pragian.

Family Panderodontidae Lindström, 1970

Genus *Panderodus* Ethington, 1959

Type species. – Paltodus unicostatus Branson & Mehl, 1933.

Remarks. – Simpson & Talent (1995, p. 114) discussed some of the taxonomic history of the genus. Smith *et al.* (1987) compared a number of reconstructions of the apparatus, for example those given by Bergström & Sweet (1966), Cooper (1975) and Barrick (1977). More recently, Wang & Aldridge (2010, pp. 34–36) discussed the genus including varying opinions concerning the presence of a tortiform element in the apparatus of some species. The scheme proposed by Barrick (1977) with Sa, Sb, Sc and M elements plus a tortiform element suggested by Sweet (1979) is used herein. We refer to the tortiform element as the T element. We identify two new species, one based on distinctive cone morphology and the other on the distinct shape of the basal cavity. The latter is kept in open nomenclature because of the small number of specimens obtained.

*Panderodus recurvatus* (Rhodes 1953)

Figure 81–M

1953 *Paltodus recurvatus* n. sp. Rhodes; p. 297, pl. 23, figs 219, 220.

1995 *Panderodus recurvatus* (Rhodes). – Simpson & Ta-

lent, pp. 117–118, pl. 1, figs 21–27 (see for further synonymy).

Figure 8. A–E, N–P – *Panderodus unicostatus* (Branson & Mehl, 1933). • A, B, N, lateral views of Sa elements; A – MMMC 4423 from MDAM 35; B – MMMC 4424 from MDAM 26; N – MMMC 4425 from B 15W. • C, D – lateral views of Sb elements; C – MMMC 4426 from B 11B; D – MMMC 4427 from MDAM 4. • E – lateral view of M element MMMC 4429 from MDAM 37. • O – lateral view of Sc element MMMC 4428 from MDAM 24. • P – lateral view of ?tortiform element MMMC 4430 from MDAM 35. • F–H – *Panderodus* sp. nov. A; lateral, lower and enlargement of lateral view of Sa element MMMC 4436 from MDAM 10. • I–M – *Panderodus recurvatus* (Rhodes, 1953). • I – lateral view of Sc element MMMC 4435 from MDAM 34. • J, K – lateral views of M elements; J – MMMC 4434 from B 15W; K – MMMC 4435 from MDAM 35. • L, M – lateral views of Sb elements; L – MMMC 4431 from MDAM 6; M – MMMC 4432 from GUND 1. • Q–S – *Pseudooneotodus beckmanni* (Bischoff & Sanneman, 1958), squat element MMMC 4437 attached to a specimen of *Pand. unicostatus* from B15W. Q, R – upper views; S – lateral view. Scale bar = 0.1 mm.
1995 *Panderodus recurvatus* (Rhodes). – Dongal, fig. 50.
2003 *Panderodus recurvatus* (Rhodes). – Farrell, p. 122, pl. 1, fig. 2.
2003 *Panderodus recurvatus* (Rhodes). – Pyle & Barnes, fig. 17.19.
2005 *Panderodus recurvatus* (Rhodes). – Trotter & Talent, pl. 18, fig. 22.
2010 *Panderodus recurvatus* (Rhodes). – Corradi & Corriga, pl. 1, figs 15–18.
2012 *Panderodus recurvatus* (Rhodes). – Corradi & Corriga, fig. 6A.

**Remarks.** – Elements from the Mountain Dam and Booth sections and from a spot locality at Gunderbooka that are sharply recurved, with the point of recurvature approximately at the mid-length of the cone, are referred to *Pand. recurvatus* Rhodes. In some etched specimens the typical longitudinal costae are difficult to see and in some other specimens have disappeared completely.

Specimens of this taxon are generally rare in comparison with other panderodontids. This species is often seen as closely related to or even synonymous with *Pand. panderi*. Recurved panderodontid elements such as these are found sporadically in faunas of Ordovician to Devonian age and are possibly restricted by ecological conditions (Barrick et al. 2010). We choose to use the name *Pand. recurvatus* as the type material is Ludlow in age (Rhodes 1953).

**Panderodus rhytioidus** sp. nov.

*Figure 9*

**Holotype.** – Sb element, specimen MMMC 4439 (Fig. 9B–D), from MDAM 11.

**Type locality and horizon.** – Sample MDAM 11 from the Mountain Dam Limestone, MDAM section on “Marobee” station approximately 90 km NW of Condobolin, central New South Wales, Australia.

**Etymology.** – *Rhytium* (Greek), a drinking horn; in reference to the horn-like shape of the elements and their large, trumpet-like basal cavities.

**Diagnosis.** – A species of *Panderodus* in which, in lateral view, the elements of this quinquemembrate apparatus are horn-shaped and are characterised by a large, open basal cavity.

**Description.** – M element relatively broad, erect and gently recurved falciform with a straight basal margin and a rounded semi-quadrate basal cavity. In some specimens, a low, sharp costa is developed along the posterior margin of the upper surface.

Sa element erect, gently recurved similiiform cone with a broadish base. Basal margin is gently curved with a small posterobasal heel and a large, open oval basal cavity. A deep, narrow furrow, commencing from the apex of the element towards the posterior margin, runs diagonally down the cone towards the antero-basal corner of the element, gradually becoming indistinct as it approaches the basal margin.

Sb element a broad, squat, recurved asimiliform element with the point of recurvature less than half the height of the unit. Basal margin curves up towards a slight heel at the postero-basal corner and a large, open basal cavity is developed. A prominent furrow parallel to and close to the posterior margin is developed on the upper surface, running parallel to the margin until the point of recurvature where it continues in a gentle curve to terminate close to mid-width and just above the basal marginal wrinkle zone. A prominent, sharp costa extends down the lower surface of the cone commencing at the apex at mid-width and paralleling the posterior margin into the wrinkle zone.

Sc element a broad, squat, recurved arcuate cone with the point of recurvature about three-quarters the height of the element. Basal margin is gently curved towards a slight heel at the postero-basal corner and a large, open basal cavity is developed. The basal cavity is evenly rounded except for a flattening towards the anterior margin of the upper surface where there is a slight flattening close to the termination of the costa developed on the upper surface. The costa commences close to the posterior margin of the apex of the element and runs in an even curve towards the antero-basal corner of the cone fading out close to the upper extent of the wrinkle zone.

T element a broad-based but slender recurved cone with the point of recurvature less than half the height of the element. The basal margin is straight and the basal cavity is elongately oval with the upper and lower surfaces slightly flattened. A narrow, sharp costa runs down the centre of the cone from the apex of the cusp and, from the point of recurvature, parallels the posterior margin.

**Remarks.** – This species is assigned to *Panderodus* on the grounds of its having longitudinal grooves and at least one costa on most lateral surfaces and a prominent wrinkle zone of striations along the basal margin. The groove and costae of the Sb element of *Pand. rhytioidus* are reminiscent of those on elements of *Decoriconus*, but lack the coverage of striae on the upper and lower surfaces (cf. Farrell 2003, pl. 12, figs 12, 17).

**Panderodus unicostatus** (Branson & Mehl, 1933)

*Figures 8A–E, N–P, 32A, B*

1933 *Palodus unicostatus* n. sp.; Branson & Mehl, p. 42, pl. 3, fig. 3.
1995 *Panderodus unicostatus* (Branson & Mehl). – Simpson & Talent, pp. 118–119, pl. 2, figs 1–32; see for further synonymy and add:


1995 *Panderodus unicostatus* (Branson & Mehl). – Colquhoun, pl. 3, fig. 3.


1999 *Panderodus unicostatus* (Branson & Mehl). – Cockle, p. 120, pl. 5, figs 1–8.

2000a *Panderodus unicostatus* (Branson & Mehl). – Göncüoğlu & Kozur, fig. 5.9, 5.10, 5.12.

2000 *Panderodus unicostatus* (Branson & Mehl). – Winchester-Seeto & Carey, fig. 7M–P.

2001 *Panderodus unicostatus* (Branson & Mehl). – Richards et al., fig. 2n.


2003 *Panderodus unicostatus* (Branson & Mehl). – Pyle & Barnes, fig. 17.20–17.23.


2005 *Panderodus unicostatus* (Branson & Mehl). – Talent et al., fig. 6E, F.

2005 *Panderodus unicostatus* (Branson & Mehl). – Trotter & Talent, pl. 18, figs 26, 27.

2006 *Panderodus unicostatus* (Branson & Mehl). – Valentine et al., pp. 229–230, fig. 11a, b.

2007 *Panderodus unicostatus* (Branson & Mehl). – Suttner, p. 21, pl. 5, figs 11, 12, pl. 6, figs 2–5.


2009 *Panderodus unicostatus* (Branson & Mehl). – Corrigan & Corradini, fig. 6O.


2010 *Panderodus unicostatus* (Branson & Mehl). – Wang & Aldridge, pl. 6, figs 1–16.

2012 *Panderodus unicostatus* (Branson & Mehl). – Barnov, pl. 1, fig. 30.

2013 *Panderodus unicostatus* (Branson & Mehl). – Wang, p. 66, pl. 6, figs 1–18.

**Remarks.** – Simpson & Talent (1995) prepared an extensive synonymy for this globally distributed species; it is often abundantly represented in *Panderodus* faunas. It has been argued that it may be either closely related to or synonymous with *Pand. simplex* and *Pand. equicostatus*. We use the broad term “*unicostatus*” in this study as we have observed no obvious biostratigraphic significance in the distribution of these forms throughout the faunas, but we recognise that further study may reveal that this grouping includes more than a single taxon.

**Panderodus sp. nov. A**

Figure 8F–H

?1980 “Drepanodus” sp.; Pickett, fig. 15Q.

?2007 Unassigned coniform element; Suttner, pl. 5, fig. 13.

**Description.** – The Sa element illustrated here has a tall, erect cusp that curves abruptly at about three-quarters of the unit height. The postero-basal margin extends downwards. The surface of the unit is covered by extremely fine striae that become more prominent in the wrinkle zone close to its basal margin. The inner face is slightly convex to planar with a prominent costa running close to and parallel with the anterior margin. The outer face is rounded towards the anterior margin but is constricted as it approaches the posterior margin. In basal view, the cavity has a “keyhole” shape, with constriction at the outer margin, rather than at the inner margin as is commonly the case in panderodids.

**Remarks.** – Three elements of this species were identified from the MDAM section: one Sa (similiform) element, one Sb (asimiliform), and one Sc (arcuatiform) element. All have a “keyhole” basal cavity with the constricted portion at the posterior-basal margin of the unit. The basal cavity morphology is a distinctive characteristic of the species. Despite the fact that all or almost all of the S series is represented in this collection, the species is left in open nomenclature because of the small number of specimens.

The element illustrated by Suttner (2007, pl. 5, fig. 13) appears to have a prominent costa close to the anterior margin and a “keyhole-shaped” basal cavity. It is only tentatively placed in synonymy here because it has a more pronounced postero-basal extension than our specimens. The element illustrated by Pickett (1980, fig. 15Q) is tentatively included in the synonymy for the same reasons.

Order Prioniodontida Dzik, 1976
Family Distomodontidae Klapper, 1981

**Genus Coryssognathus** Link & Druce, 1972

**Type species.** – *Cordylodus? dubius* Rhodes, 1953.
Coryssognathus dubius (Rhodes, 1953)

Figure 30A–G

1993 Coryssognathus dubius (Rhodes). – Miller & Aldridge, pp. 242–253, pl. 1, figs 1–14, pl. 2, figs 1–18, pl. 3, figs 1–12, pl. 4, figs 1–15. Includes extensive synonymy.


1995 Coryssognathus dubius (Rhodes). – Miller, pl. 1, figs 9, 12.


1998a Coryssognathus dubius (Rhodes). – Corradini et al., pl. 3,3.1, fig. 15.

1999 Coryssognathus dubius (Rhodes). – Cockle, p. 120, pl. 4, fig. 20.

1999 Coryssognathus dubius (Rhodes). – Viira, pl. 1, figs 9–12.


2001 Coryssognathus dubius (Rhodes). – Rickards et al., fig. 2w.

2003 Coryssognathus dubius (Rhodes). – Talent et al., pl. 1, figs 1, 2.


2006 Coryssognathus dubius (Rhodes). – Valentine et al., pp. 225–227, fig. 11e, f.

2006 Coryssognathus dubius (Rhodes). – Farrell, fig. 5C, G–J.

2009 Coryssognathus dubius (Rhodes). – Corriga & Corradini, p. 166, fig. 6L–L.

2009 Coryssognathus dubius (Rhodes). – Corriga et al., pl. 2, fig. 8.

2010 Coryssognathus dubius (Rhodes). – Corradini & Corriga, pl. 1, figs 8–11.

2012 Coryssognathus dubius (Rhodes). – Corradini & Corriga, fig. 6E, F.

Remarks. – Miller & Aldridge (1993) reconstructed this taxon as a septimembrate apparatus including three element types in the P position, and discussed means of discriminating this taxon from species of Pelekysgnathus. Simpson & Talent (1995) partially reconstructed the taxon from Claire Creek and compiled an extensive synonymy. In our study no Pa elements were recovered, but Pa elements ascribed to Pelekysgnathus were recovered in a number of samples. None of these Pa elements has the characteristic basal cavity tips beneath each denticle suggesting progressive accretion of coniform structures during ontogeny, and are therefore kept separate herein. The above synonymy builds on that of Miller & Aldridge (1993) and Talent & Simpson (1995).

Australian occurrences of Coryssognathus dubius have previously been considered to have an upper range within the Ludlow (Simpson 1995), but Serpagli et al. (1997) reported an upper range extending into the Přídolí in Sardinia. In Australia this species has been obtained from the Yass Basin (Link & Druce 1972), the Trundle region (Pickett & Inigo 1990), the Murda Syncline (Pickett & McClatchie 1991), the Kildrummie Formation (De Decker 1976), the Claire Creek limestone (Simpson & Talent 1995), Cowombat Flat (Simpson et al. 1993) and the Cobra Formation (Valentine et al. 2006), occurrences that all appear to be restricted to the Ludlow according to associated faunas. Simpson & Talent (1995, p. 165) reported an occurrence of C. dubius at Native Dog Flat in strata above a single occurrence of Ozarkodina remanscheidensis eosteinhornensis. Farrell (2004) reported the highest occurrence of C. dubius in the Camelford Limestone some 66 m below the first occurrence of a specimen reported as Icriodus woschmidtii hesperius, but there were no Přídolí index taxa reported from this interval. In a subsequent study of “tectonically emplaced” strata from the Camelford Limestone, Farrell (2006) recorded C. dubius some 25m above an occurrence of O. r. eosteinhornensis. It is therefore likely that C. dubius extends into the Přídolí in Australia as well as in Sardinia although the orientation of Farrell’s (2006) section is unclear.

Family Icriodontidae Müller & Müller, 1957

Genus Icriodus Branson & Mehl, 1938

Type species. – Icriodus expansus Branson & Mehl, 1938.

Icriodus ampliatus sp. nov.

Figures 11, 32C, D

1980 Icriodus woschmidtii Ziegler. – Pickett, p. 70, fig. 3A–D.

Holotype. – 1 element, specimen MMMC 4451 (Fig. 11A–C), from MDAM 37.

Type locality and horizon. – Sample 37 from the Mountain Dam Limestone in the MDAM section on “Marobee” station approximately 90 km NW of Condobolin, central New South Wales, Australia.

Etymology. – Ampliatus (Latin), enlarged, expanded, widened; in reference to the obtuse angle (120° or more) formed between the outer lateral process and the medial row of nodes of the Pa element.

Diagnosis. – A species of Icriodus characterised by the I
element being spindle- or tower-shaped and having a well-developed denticulate outer lateral process connecting to the posteriormost medial denticle that extends posteriorly beyond the lateral nodes at an angle of at least 120°.

Description. – The main process of representative I elements is generally spindle-shaped (eta morph) or cone-shaped (beta morph) with high, pointed lateral nodes extending transversely to form ridges that meet at the base of smaller, less distinct medial nodes. In upper view the lateral and medial nodes appear as continuous ridges, but in lateral view the lateral nodes can be seen to be much higher and larger than the medial nodes to which they are connected. A very narrow, even hair-like, median longitudinal ridge connects the diminutive medial nodes. The spacing between the rows of nodes is considerably wider anteriorly than towards the posterior of the spine. A well-developed denticulate outer lateral process connects with two or three medial denticles that extend posteriorly beyond the lateral nodes, forming an angle in excess of 120°. An unornamented inner spur is developed on the upper surface of the rectangular basal cavity. The upper surface of the outer basal cavity is rounded opposite the spine, becoming rapidly narrower from the junction of the spine with the spur.

Remarks. – This species shares several characteristics of _Icriodus steinachensis_ eta and beta morphs and some features of _I. claudiae_ alpha morph. It also has a similarly proportioned spindle and spacing of the transverse denticle rows, and a similar basal cavity to _I. steinachensis_ gamma morph, but in all cases the angle at which the posterior process diverges from the spindle axis is considerably greater, in excess of 120°. Although the spindle of _I. claudiae_ alpha morph is more slender than in the morphs of _I. steinachensis_, the angle at which the outer posterior process meets the medial denticle row is greater in _I. claudiae_, approaching the size of the angle in this new species.

Murphy & Matti (1982, p. 58) pointed out that, although conodont faunas of middle _sulcatus_ Zone age in Nevada display a full range of variation between _I. claudiae_ alpha morph and _I. steinachensis_ beta morph, there is a “morphological gap ... between _I. claudiae_ and _I. steinachensis_ in the upper _sulcatus_ Zone”. Being intermediate between the two species, _I. ampliatus_ closes this “morphological gap”. Based on evolutionary arguments, we conclude that the age of this new species falls into the upper part of the _sulcatus_ Zone and may extend into the _kindlei_ Zone.

In their study of _I. steinachensis_ and _I. claudiae_ lineages, Murphy & Cebecioğlu (1984, fig. 4) plotted length versus width of specimens from UCR localities 8576 and 8973 in central Nevada. The results show a gap between the data for the two species. Data from _I. ampliatus_, when added to Murphy & Cebecioğlu’s scatter diagram, show that the new species plots between _I. steinachensis_ and _I. claudiae_, in the “morphological gap” mentioned by Murphy & Matti (see Fig. 7 herein).

_Icriodus angustoides angustoides_ Carls & Gandl, 1969

Figure 10A, B

1969 _Icriodus angustoides angustoides_ n. ssp.; Carls & Gandl, p. 176, pl. 15, figs 15, 16.
1969 _Icriodus angustoides angustoides_ Carls & Gandl. – Carls, pp. 325–326, pl. 3, figs 13, 14, pl. 4, fig. 2.
1975 _Icriodus angustoides angustoides_ Carls & Gandl. – Carls, p. 414, pl. 3, fig. 48.
1975 _Icriodus angustoides angustoides_ Carls & Gandl. – Ziegler in Ziegler, pp. 71, 72, _Icriodus_ pl. 6, figs 8, 9.
1980 _Icriodus cf. angustoides_ Carls & Gandl. – Pickett, pp. 70–71, fig. 3E–G.
1985 _Icriodus angustoides angustoides_ Carls & Gandl. – Wang, p. 153, pl. 2, figs 21, 23.
2002 _Icriodus angustoides angustoides_ Carls & Gandl. – García-López et al., pl. 1, fig. 16.

Remarks. – The I element of _I. a. angustoides_ illustrated by Wang (1985, pl. 2, fig. 23) from Inner Mongolia has a greater number of rows of nodes than are usually seen in this taxon, at least seven, but this might be a gerontic specimen. Pickett (1980, fig. 3F, G) figured a poorly preserved I element from the White Tank Limestone, western New South Wales, as _I. cf. angustoides_, and stated that the posterior-most denticle of the crest “is not appreciably higher that the one in front of it”. Although no lateral view of the specimen was shown, it appears from the illustration that it indeed has a higher posterior denticle and can therefore be assigned to _I. a. angustoides_.

_Icriodus angustoides angustoides_ has been reported together with _I. curvicauda_ from horizons of _sulcatus_ Zone age in Spain, in the East Iberian Chain, Aragon (Carls & Gandl 1969, Carls 1975) and in the Sierra de Guadarrama (Bultynck 1976).

_Icriodus curvicauda_ Carls & Gandl, 1969

Figure 10C–M

1969 _Icriodus huddlei curvicauda_ n. subsp.; Carls & Gandl, pp. 180–182, pl. 16, figs 10–15 (only).
1975 _Icriodus huddlei curvicauda_ Carls & Gandl. – Carls, p. 413, pl. 3, figs 49–53.
1976 _Icriodus curvicauda_ Carls & Gandl. – Bultynck, pl. 6, fig. 6.
1994 _Icriodus curvicauda_ Carls & Gandl. – Valencia-Rios, pp. 95–96, pl. 8, fig. 30.
1999 Caudicriodus curvicauda (Carls & Gandl). – Benfrika, p. 316, pl. 1, fig. 13.
2002 Icriodus curvicauda Carls & Gandl. – García-López & Sanz-López, pl. 1, figs 1, 2.
2004b Caudicriodus curvicauda (Carls & Gandl). – Slavík, fig. 11.4–5.

Remarks. – The I element of I. curvicauda is very narrow with three distinct rows of cone-shaped denticles that are wider apart anteriorly than posteriorly. These contrast with the denticles of I. a. angustoides that form almost continuous horizontal bars. In I. curvicauda the extension of the median row of denticles curves gently to form a lateral process.

Ziegler (in Ziegler 1975) recorded the stratigraphic range of I. curvicauda as sulcatus to dehiscens zones.

Icriodus sp. aff. I. celtibericus (Carls & Gandl, 1969)
Figure 10N–R


Remarks. – The I element illustrated (Fig. 10P–R) from near B 15E is strikingly similar to the specimen from McColley Canyon, Nevada (Klapper & Johnson 1980, pl. 2, figs 18, 24) in having wider spacing of lateral row denticles in the anterior part of the platform than in the posterior part of the platform. The Nevada specimen, however, has eight rows of denticles compared to five rows on the platform of the Booth Limestone specimen, and the Nevada specimens illustrated are considerably larger and therefore more mature than those illustrated herein. Klapper & Johnson (1980) recorded an age of sulcatus and kindlei zones for horizons from which they obtained their material. Our specimens also bear some resemblance to Caudicriodus ruthmawsonae Drygant (2010, pl. 3, figs 1, 2, 6) but they are less elongate, the lateral extension of the basal cavity is clearly anteriorly oriented, and there are fewer rows of denticles.

Genus Pelekysgnathus Thomas, 1949

Type species. – Pelekysgnathus inclinatus Thomas, 1949.

Pelekysgnathus inequalis sp. nov.
Figure 12G–O

Holotype. – I element, specimen MMCC 4461 (Fig. 12G, H), from B 16C.

Type locality and horizon. – Sample B 16C from the Booth Limestone on Multagoona Anticline, 2 km southwest of Beulah Tank, “Manuka”.

Etymology. – Inequalis (Latin), unlike, different, unequal; in reference to the irregular shape of the basal cavity and the profile of denticles in lateral view of the I element.

Diagnosis. – A species of Pelekysgnathus with its I ele-
ment, in lateral view, characterised by the denticles in the posterior half being high and individual, and in the anterior half lower, fused and irregular.

Description. – The I element in lateral view has its denticles in the posterior portion high, discrete, pointed and laterally compressed. Denticles in the anterior half are fused and somewhat irregular in profile. The basal cavity in the posterior half is narrow and rounded at the posterior extremity. At midpoint the basal cavity expands abruptly making an ear-like lobe on the inner margin that decreases in width rapidly at about three-quarters the length of the unit and continues as a narrow groove to the anterior end. Simultaneously, at mid length the basal cavity expands rapidly on the outer margin and tapers more evenly to the anterior end of the blade.

Figure 10. A, B – Icriodus angustioides angustioides Carls & Gandl, 1969; upper and lateral views of I element MMMC 4444 from B 11D. • C–M – Icriodus curvicauda Carls & Gandl, 1969. • C–E – upper, inner lateral and outer lateral views of I element MMMC 4445 from GUND 1. • F–H – upper, lateral and anterior views of I element MMMC 4446 from GUND 1. • I, J – upper and inner lateral views of I element MMMC 4447 from BTL B. • K–M – upper, upper oblique and inner lateral views of I element MMMC 4448 from BTL 1. • N–R – Icriodus sp. aff. I. celtibericus (Carls & Gandl, 1969). • N–P – upper, lateral and lower views of I element MMMC 4449 from MDAM 37. • Q, R – upper and outer lateral views of I element MMMC 4450 from B 15E. Scale bar = 0.1 mm.
S₂ element is acodinan with a keel on either one or on both margins. The base of the unit is slightly elliptical to semiquadrate in shape.

M₂ element is a simple cone with the surface and especially the base covered in fine striations. The base of the unit is slightly elliptical.

Remarks. – Little attention has been given to Early Devonian pelekysgnathans so, despite relatively low numbers of elements, we decided that this assemblage of pelekysgnathan elements from the Booth and Mountain Dam limestones should be described as a new species. Note that the S₂ elements show slight morphological variations and could represent the three members of a symmetry transition series.

Irregularity of the denticles and the shape of the basal cavity separate *P. inequalis* from other species of *Pelekysgnathus* that might normally be found in faunas of this age, namely *P. serratus* (Jentzsch, 1962) and *P. klamatensis* (Savage, 1977). As in many *Pelekysgnathus* species the basal cavity in the scaphate I element is flared, but in this case the expansion is markedly asymmetric. This asymmetry is similar to that seen in Pa elements of *Amydrotaxis* but is less pronounced.

Based on the occurrence of *P. inequalis* in horizons with *I. ampliatus* and *Oz. buchanensis*, the new species has a time range from late in the *sulcatus* Zone to the *pireneae* Zone.

**Pelekysgnathus sp. cf. Pel. furnishi** Klapper, 1969

Figure 12A–E

cf. 1969 *Pelekysgnathus furnishi* Klapper; pp. 11–12, pl. 2, figs 12–21, 28, 29.
1972 *Pelekysgnathus furnishi* Klapper. – Klapper & Philip, pl. 102, pl. 3, figs 15–17.
1979 *Pelekysgnathus furnishi* Klapper. – Chatterton, p. 203, pl. 7, fig. 29.

Remarks. – The two juvenile I elements from the Mountain Dam and Booth limestones resemble the specimen of *P. furnishi* illustrated by Chatterton (1979, pl. 7, fig. 29). One of our specimens (Fig. 12D) appears close in morphology to *P. serratus brunsvicensis* Valenzuela-Ríos. The specimen, however, appears incomplete and it is not possible to ascertain the nature of the posteriormost primary denticle in relation to the others, one of the diagnostic features of that subspecies. *Pelekysgnathus serratus brunsvicensis* has been used to correlate Barrandian Pragian strata
with the Spanish Pyrenees (Slavík et al. 2007). Greater sampling is required to establish whether the taxon is present in the Booth Limestone.

**Pelekysgnathus sp. cf. Pel. sp. A**
Uyeno & Bultynck, 1993

*Figure 12F*

**Remarks.** – One damaged specimen resembles the I element of the new but unnamed species illustrated by Uyeno & Bultynck (1993, pl. 2.4, fig. 13) from the lower Middle Devonian of the Kwatooboahegan Formation, northern Ontario. The denticles of the specimen from the Booth Limestone (locality BTSW) are more regular, although the nature of the free pointed tips and the proportions of the blade are similar.

**Pelekysgnathus** sp. A? Corriga & Corradini, 2009

*Figure 30H–J*

1995 *Pelekysgnathus* index Klapper & Murphy. – Barca et al., pl. 4, figs 4, 5.

1998 *Pelekysgnathus* index Klapper & Murphy. – Serpagli et al., p. 110, pl. 1.1.2, figs 4, 5.

?2006 *Pelekysgnathus* serratus cf. *elata* Carls & Gandl. – Farrell, fig. 5K–M.

?2009 *Pelekysgnathus* sp. A. – Corriga & Corradini, pp. 165–166, fig. 6M.

**Remarks.** – A small number of distinctive Pa elements was obtained in this study. The elements are arched, with compressed and partly fused denticles. The basal cavity is narrow, has a distinctively rounded posterior margin and occupies only one-third to one-half the length of the blade.
This is a poorly known taxon and the classification of the Myola specimens is considered tentative. They are not grouped with any of the S elements in this study as Miller & Aldridge (1993) noted that symmetry transition elements of *Pelekysgnathus* are coniform with rounded cusps unlike *Coryssognathus*. The Pa elements closely fit the description given by Corriga & Corradini (2009, pp. 165–166), in particular the small symmetrical basal cavity in comparison with the larger flared basal cavity of *P. index* Klapper & Murphy. The illustration of their single specimen (Corriga & Corradini 2009, fig. 6M), however, is incomplete and does not show the shape of the basal cavity; it also does not appear as strongly arched as the Myola specimens. Except for the arching, morphology is similar to the Early Devonian *Pelekysgnathus serrata elongata* Carls & Gandl.

Farrell (2006, fig. 5K–M) illustrated some specimens from limestone blocks within the Barnby Hills Shale in New South Wales. Those specimens are also incomplete but are very close in morphology to the Myola specimens. The above synonymy is therefore considered provisional at this stage until complete elements from different areas can be compared.

This species in Sardinia is restricted to low in the *crispa* Zone (Corriga & Corradini 2009). It co-occurs with the index species well below the first appearance of taxa typically associated with Přídolí strata such as *Ozarkodina eosteinhornensis* s.l. (Corriga & Corradini 2009, table 1). The pelekysgnathid reported by Farrell (2006, table 1), however, is recorded as occurring stratigraphically higher than *Ozarkodina remscherdensis eosteinhornensis*. Farrell’s sections did not produce faunas indicative of either late Ludlow or Early Devonian strata, and their orientation in a complexly deformed region may require reassessment. The true biostratigraphic utility of this species is therefore yet to be established.

Order Prioniodinida Sweet, 1988
Family Prioniodinidae Bassler, 1925

**Genus Erika** Murphy & Matti, 1982


**Erika divarica** Murphy & Matti, 1982

Figure 30K, L

1982 *Erika divarica* n. sp.; Murphy & Matti, pp. 41–44, pl. 6, figs 1–13.


**Remarks.** – This taxon was originally reported from the Early Devonian *delta* Zone and reconstructed as a seximembrate apparatus lacking a platform element. Only two elements of the symmetry transition series were obtained in our study. Both have the diagnostic alternating divergent denticles on both processes. Miller & Märss (1999) tentatively reconstructed similar elements from the Přídolí Down-town Sandstone as an ?ozarkodinid taxon. From the illustrations, however, their S elements do not clearly show alternating divergent denticles (*e.g.* Miller & Märss 1999, pl. 1, fig. 13). The Myola specimens are therefore considered as the first Silurian documentation of this species. Jeppson (pers. comm. 2009) found the same taxon from the lower Ludlow of Gotland. It therefore appears to be a long ranging but rare taxon poorly represented in conodont faunas.

**Genus Oulodus Branson & Mehl, 1933**

*Type species.* – *Cordylyodus serratus* Stauffer, 1930.

**Remarks.** – A possible evolutionary sequence of the three species *Oulodus tenustriatus* Pickett, *Oul. paucistriatus* Mawson and *Oul. astriatus* sp. nov. is suggested by morphological changes, namely a reduction in striations, and by stratigraphic criteria.

Three broken elements (Fig. 31G–I) are tentatively included in this genus; we reference some visual similarity with previously illustrated forms but retain open nomenclature.

**Oulodus sp. cf. Oul. walliseri** (Ziegler, 1960)

Figure 13A–I

cf. 1980 *Delotaxis walliseri* (Ziegler). – Pickett, pp. 79–81, fig. 10A–M.
Oulodus astriatus sp. nov.

Figure 13J–O

Holotype. – Pa element, specimen MMC 4475 (Fig. 13J), from B 16L.

Type locality and horizon. – Sample B 16L from the Booth Limestone, Multagoona Anticline, “Manuka”.

Etymology. – Astricus (Latin), without striations, in reference to the lack of striations present on the main cusp of each element of the apparatus.

Diagnosis. – A species of Oulodus in which all elements are characterised by a lack of longitudinal ridges or striations adorning the main cusps and by having only a few, stubby denticles set along lateral processes, generally at irregular intervals.

Description. – Pa element digyrate with anterior and posterior processes slightly twisted with respect to one another, each bearing one or two peg-like denticles; main cusp slightly proclined and oval in cross-section. The ovate basal cavity beneath the main cusp tapers to a groove in both slightly twisted relative to each other, and bent downwards to form an angle of approximately 90° beneath the main cusp. Each lateral process bears up to three small, irregularly spaced, blunt peg-like denticles. The basal cavity is similar to that of the Pa element.

Remarks. – Pickett (1980, p. 81) recognised all six elements of Oul. walliseri as having a “strongly exert basal cavity”. Those identified by Mawson & Talent (1994) as Oul. cf. walliseri from the BOO and TQ sections through the Cooper Creek Limestone, at the Boola and Tyers quarries, Victoria, and from spot localities from the Tyers–Boola, Deep Creek, and Marble Creek areas, differ from Oul. walliseri in having basal cavities that are more elongate and lack the pronounced lip of the basal cavity referred to by Pickett (1980).

Oulodus paucistriatus Wall, Mawson, Talent & Cooper, 1995

Figure 14A–F


Remarks. – The presence of few (up to six) striations on the main cusps of each element of the apparatus separates this species from other species of the genus. The digyrate Pa element from Booth 16C (Fig. 14A) has the anterior and posterior processes slightly twisted with respect to each other. The main cusp is somewhat procline, circular in shape, and bipennate elements, all with narrow processes with few irregularly spaced, short, peg-like denticles. All elements have relatively smaller basal cavities than the Pa and Pb elements but are somewhat expanded beneath the main cusp and taper towards the distal extremities.

Symmetry transition series consists of alate, digyrate and bipennate elements, all with few irregularly spaced, short, peg-like denticles. All elements have relatively smaller basal cavities than the Pa and Pb elements but are somewhat expanded beneath the main cusp and taper towards the distal extremities.

Remarks. – Despite the paucity of specimens representative of the new species, it has been described here to illustrate what superficially looks to be an evolutionary sequence from Oul. tenustriatus, to Oul. paucistriatus, to Oul. astriatus, three species developing a few stubby denticles along the lateral processes. The first of this sequence, Oul. tenustriatus, was described by Pickett (1980) from the Rookery Limestone Member in association with conodonts of supposed pesavis Zone age but is argued here to be from the sulcatus Zone. Oulodus tenustriatus has up to 12 longitudinal striations on the main cusp of all elements in the apparatus. The next species in the sequence, Oul. paucistriatus, was described by Mawson (in Wall et al. 1995) from the Lilydale Limestone, Victoria, from horizons of kindlei or pireneae zone age. However, the last species, Oul. astriatus from the upper Booth Limestone, is associated principally with conodonts of pireneae zone age, thus indicating a possible evolutionary pattern developed in this lineage. Larger collections of material are essential to verify this hypothesis.
cross-section and has an ornament of only two marginal striations. The Pb element from Booth 16A (Fig. 14C) is also digyrate and has short, stout processes twisted in relation to one another with up to three stubby denticles on each.

**Oulodus paucistriatus** can be separated from *Oul. tenuistriatus*, described by Pickett (1980) from horizons identified by him as being late Lochkovian, pesavis Zone age (but now referred to the *sulcatus* Zone), by having fewer striations on the main cusp of the elements – up to six compared to approximately twelve. Both these forms are easily distinguished from *Oul. astriatus* sp. nov. which has no striations on the main cusp of all elements of the apparatus.

Other occurrences of *Oul. paucistriatus* in Australia include those at Boola Quarry, Victoria, from horizons dated as *sulcatus* and *kindlei* zones (Mawson & Talent 1994) and from the Lilydale Limestone, Victoria, from horizons dated as *kindlei* and *pireneae* zones (Wall et al. 1995).

**Oulodus elegans detorta?** (Walliser, 1964)

Figure 30M

**Remarks.** – A single Sb element was obtained from Myola 2. It shows a small denticle adjacent to the cusp on one process similar to the alternating denticle size seen in *Oul. elegans detorta*, but the specimen is very poorly preserved and the identification must be considered provisional.

**Oulodus? Apparatus A**

Figure 14G–M

**Remarks.** – These elements, having a morphology that suggests an association within the same apparatus, are tentatively placed within *Oulodus*. The denticles are not always separated by “U-shaped” spaces along processes nor are they always well rounded in cross section. *Oulodus?* Apparatus A is distinguished by its evenly distributed, well-packed, sharp, relatively tall, pointed denticles on the bars of all elements. The processes are thickened close to the base of the denticles, which may be compressed in cross-section. There is a prominent “lip” over the basal cavity of the Sa element (Fig. 14I, J) and possibly the Sc element (Fig. 14L) where the basal cavity “hood” is constricted so that it appears as a diminuitive third process.

Elements tentatively grouped together in this apparatus are similar to those illustrated by Drygant & Szaniawski (2012, fig. 8A–M) as “unassigned taxa” from the Lochkovian to Pragian Ivanye Formation of Podolia. In particular, the pronounced basal cavity extension in the Sa element (Fig. 14I, J) is similar to that developed in the Sb element (Drygant & Szaniawski 2012, fig. 8E). The Pb element of *Oulodus?* Apparatus A (Fig. 14H), however, has an angled lower margin unlike the gently curved lower margin of the Pb elements illustrated by Drygant & Szaniawski (2012, fig. 8A, B, D). One Sa element of *Oulodus?* Apparatus A (Fig. 14I) also has some similarities to an element illustrated by Drygant (2010, pl. 22, fig. 20) as “Hibbardella sp.”, such as denticulation, the small angle between processes and the thickening of the blade below the cusp. Our Sa element also has similarities to one figured by Suttner (2007, pl. 13, fig. 14) as an “Sb element of “Apparatus A” from the Lochkovian Rauchkofel Formation, although Suttner’s specimen shows much finer and more closely packed denticulation.

**Oulodus? Apparatus B**

Figure 14N–P

**Remarks.** – A small number of oulodid elements with narrow processes are tentatively grouped into this apparatus. Denticles are separated by broad U-shaped spaces in accordance with the characteristics of the genus. The denticles are longer and finer that those of *Oulodus?* Apparatus A, and the basal cavity is longer and not as wide. The Pb elements are gently arched and twisted, as also seen in many of the elements of *Aspelundia* as originally defined by Savage (1985) and amended by Armstrong (1990). Certainty concerning the generic identification requires greater numbers of specimens.

These elements have been obtained from horizons of the *sulcatus* and *kindlei* zones, stratigraphically beneath those that have yielded *Oulodus?* Apparatus A.

Order Ozarkodina Dzik, 1976

Family Spathognathodontidae Hass, 1959

**Genus Amydrotaxis Klapper & Murphy, 1980**

**Type species.** – *Spathognathodus johnsoni* Klapper, 1969.

**Amydrotaxis druceana** (Pickett, 1980)

Figure 15

1980 *Ozarkodina druceana* nom. nov.; Pickett, pp. 73–77, figs 5A–W, 6A–U, 7A–C. See also for early synonymy.


1992 Amidrotaxis (sic) druceana (Pickett). – Bardashev & Ziegler, pl. 2, figs 1, 2.
1994 Amidrotaxis druceana (Pickett). – Mawson & Talent, p. 49, fig. 10A–P.
1999 Amidrotaxis druceana (Pickett). – Talent & Mawson, pl. 4, figs 10–21, pl. 5, fig. 10, pl. 8, figs 3, 5, 7, 15, pl. 11, fig. 8.
2005 Amidrotaxis druceana (Pickett). – Trotter & Talent, pl. 18, figs 10, 13–18.
2008 Amidrotaxis druceana (Pickett). – Gaetani et al., p. 280, pl. 1, fig. 3.

Remarks. – Pickett (1980) identified the various elements of the apparatus of Amidrotaxis druceana from collections from the Rookery Limestone Member at “The Rookery”, ca 35 km SE of Cobar. Our study accords with Pickett’s (1980) reconstruction.

Amydrotaxis corniculans truncus subsp. nov.

Figure 16A–Q

Holotype. – Pa element, specimen AMF 130512 (Fig. 16A, B), from MDAM 31.

Type locality and horizon. – Sample MDAM 31 from the Mountain Dam Limestone on “Marobee” station, approximately 90 km NW of Condobolin, central New South Wales.

Etymology. – Truncus (Latin), trunk or stump; in reference to the stubby, stump-shaped nature of most elements of the apparatus in comparison with the nominotypical subspecies.

Diagnosis. – A subspecies of Amydrotaxis corniculans having relatively low, stubby, horn-shaped denticles on most of the elements of the apparatus.

Description. – Pa element spathognathodan, straight with a single row of stubby denticles with those posterior to the basal cavity being distinctly lower, less distinct and more knob-like. Terminal denticles slightly higher than other posterior ones. Basal cavity lobes expanded at mid-length and tending to be swept forwards towards the anterior of the unit.

Pb element ozarkodiniform with main cusp broad and flattened. Five or six anterior denticles are blunt and stubby. Posterior denticles are ill defined if indeed present, with a low, horn-shaped knob or thickening at the posterior extremity. Basal cavity asymmetrically widened beneath the main cusp.

?M element short with high main cusp and one well-developed process; other denticles indistinct with terminal denticle knob-like. Basal cavity is well developed and similar in shape to those of Pb elements (cf. Fig. 16Q with 16J, M).

Symmetry transition series consists of alate, bipennate and digyrate elements, all with narrow processes bearing a few irregularly spaced, short denticles. All elements have relatively small basal cavities somewhat expanded beneath the main cusp and tapering towards the distal extremities.

Remarks. – Mawson (1986, p. 50) first recognised this species in the Windellama Limestone of southeast Australia, the diagnostic characteristic being a tiny anterior denticle preceding relatively even denticulation on the rest of the blade. Mawson postulated that the relatively symmetrical basal cavity and unfused denticles may mean that A. corniculans was ancestral to A. johnsoni. The retention of the diagnostic feature in this taxon (Fig. 16A) and the relatively symmetrical but restricted basal cavity in comparison with the Windellama taxon, lead us to interpret this as a new subspecies of A. corniculans.

The novelty of Amy. corniculans truncus lies in the nature of the stubby denticles and the deep, clearly defined basal cavities present on each element of the apparatus.

Amydrotaxis sp. A

Figure 16R–U

Remarks. – Pa elements are long (up to 2.1 mm) and in lateral view have three slightly higher anterior denticles. Denticles in the mid-section of the unit appear fused and, in the posteriorly most quarter, decline to the base at an angle of approximately 45°. In upper view, expansion of the basal cavity occurs at a point anterior to mid-length of the blade. The outer basal cavity lobe is rounded to oval in shape and the inner lobe is more restricted and ear-shaped from its anterior extremity. Basal cavity asymmetrically widened beneath and the main cusp.

The shape of the basal cavity is similar to that of the alpha element ozarkodiniform with main cusp broad and flattened. Five or six anterior denticles are blunt and stubby. Posterior denticles are ill defined if indeed present, with a low, horn-shaped knob or thickening at the posterior extremity. Basal cavity asymmetrically widened beneath the main cusp.

Genus Ancyrodelloides Bischoff & Sannemann, 1958

Type species. – Spathognathodus trigonicus Bischoff & Sannemann, 1958.

Remarks. – Murphy & Valenzuela-Ríos (1999) split the generic Ancyrodelloides concept based on whether terraces
developed on the basal cavity lobes are ornamented or not. Those with unornamented terraces were the basis of the genus *Lanea*, regarded as ancestral to those with ornamented terraces that were retained in *Ancyrodelloides*.

The Pragian forms with unornamented terraces obtained by Mawson & Talent (1994) from Boola and Tyers in Victoria were interpreted by Murphy & Valenzuela-Ríos (1999) as a heterochronously convergent form superficially similar in morphology to *Lanea*. More recently, Corriga et al. (2014, p. 192) pointed out that the diagnoses of *Ancyrodelloides* and *Lanea* are not clear and overlap each other. Furthermore, they raised doubts about the assignment of species to each genus by Slavík (2011), and indicated that full reconstructions are needed to resolve the differing interpretations. While we acknowledge that the phyletic scenario proposed by Murphy & Valenzuela-Ríos (1999) may well be valid, we can only work with the morphology of the collections available to us in this study and therefore choose to retain the original nomenclature without prejudice.

**Ancyrodelloides omus** Murphy & Matti, 1982

Figure 21A–F

1982 *Ancyrodelloides omus* Murphy & Matti; pp. 16–20, text-fig. 5a, b, pl. 2, figs 14, 18–29.

For synonymy prior to 1990, see Klapper in Ziegler (1991).

1990 *Ancyrodelloides omus* α morphotype Murphy & Matti. – García-López et al., pl. 1, figs 11–14.

1994 *Ancyrodelloides omus* Murphy & Matti. – Mawson & Talent, pp. 51–53, fig. 12A–N.


1999 *Ancyrodelloides omus* Murphy & Matti. – Talent & Mawson, pl. 5, figs 6–9, pl. 7, fig. 13, pl. 8, fig. 4, pl. 12, fig. 10.

2002 *Lanea omoalpha* Murphy & Valenzuela-Ríos. – García-López et al., pl. 3, fig. 11.

2004 *Lanea omoalpha* Murphy & Valenzuela-Ríos. – Farrell, p. 976, pl. 8, figs 12, 13.

2004 *Lanea aff. omoalpha* Murphy & Valenzuela-Ríos. – Slavík & Hadlík, p. 147, pl. 1, fig. 10.

2005 *Lanea omoalpha* Murphy & Valenzuela-Ríos. – Valenzuela-Ríos et al., pl. 1, figs e, f.

2007 *Lanea omoalpha* Murphy & Valenzuela-Ríos. – Suttner, pp. 31–32, pl. 19, figs 5, 8, 10.

2008 *Ancyrodelloides omus* Murphy & Matti. – Kim et al., pl. 16, figs 1, 3, 5.

2012 *Lanea omoalpha* Murphy & Valenzuela-Ríos. – Corriga et al., fig. 5.5, 5.6.

2012 *Lanea omoalpha* Murphy & Valenzuela-Ríos. – Drygant & Szaniawski, fig. 13M, P, T.

2013 *Lanea omoalpha* Murphy & Valenzuela-Ríos. – Mavrinskaya & Slavík, fig. 5A–C.

Remarks. – Murphy & Matti (1982) argued that *Ancyrodelloides* was derived from *Ozarkodina remschiedensis*, and that their new species *Anc. omus* was the oldest representative of *Ancyrodelloides*. They claimed *Anc. omus* was restricted to low in the Early Devonian (latest *eurekaensis* Zone to *delta Zone*, an age later confirmed by Klapper (in Ziegler 1991). Chlupáč et al. (1985, fig. 17), however, had previously shown that in the Barrandian and Carnic Alps “*Anc.* omus” first appeared late in the early Lochkovian and extended through to early in the late Pragian. Subsequently, Klapper (in Ziegler 1991) included in the synonymy of “*Anc.* omus” specimens from Tyers in Victoria first illustrated and described by Philip (1965) as “*Spathognathodus steinhornensis*”. From two sections in the Tyers area, Mawson & Talent (1994) obtained over 450 specimens of this species and confirmed that they occur in horizons dated as *sulcatus* and *kindlei* zones. Mawson & Talent (1994, p. 51) also recorded reservations as to the generic placement of the species based on persistence of its open basal cavity. In the area under study, *Anc. omus* occurs in horizons of *sulcatus* Zone age in the MDAM section, and of *kindlei* Zone age in the BOOTH section.

**Genus Eognathodus Philip, 1965**

Type species. – *Eognathodus sulcatus* Philip, 1965.

Remarks. – Philip’s original diagnosis of *Eognathodus* was based on Pa elements from the Tyers area, eastern Victoria. Both Philip (1965) and Klapper et al. (1981) emphasized that *Eognathodus* was characterised by a double row of nodes on its upper surface with a depression or trough between the rows. As further collections were made from the
same time slice it became evident that there were variations to the “double row of nodes”. In amending Philip’s diagnosis of Eognathodus, Murphy et al. (1981, p. 765) referred to “…a sulcus between rows of nodes or ridges, or an irregular pattern of nodes and ridges on the crest of the P unit”. Earlier, Lane & Ormiston (1979, p. 47) noted that some specimens had developed “…two parallel white-matter ridges, the distinction of the original individual denticles being lost completely”. What is important is that the introduction of two rows of denticles or two parallel ridges with a sulcus between is the novel feature that distinguished an egnathodontan from an ozarkodinan. Such variation in a genus, however, suggests that more than one pathway of evolution is likely for Eognathodus, in a similar way as suggested for Polygnathus by Klapper & Johnson (1975) and Mawson (1987).

Debate on the derivation of Eognathodus is not new; its origin and progenitors have often been discussed (e.g. Mawson 1998). Based on collections from the Salmontrout River area, east-central Alaska, Lane & Ormiston (1979) suggested that egnathodontans arose from an ozarkodinan stock via their new species Oz. selfi. Murphy et al. (1981, p. 770) contended that the earliest form of the genus, Eo. sulcatus eta morph, “is characterized by a thick blade with a rounded crest on which blunted terminated denticles are irregularly arranged...”. In justifying their phyletic interpretation of the development of Eognathodus sulcatus from the pandora stock, Murphy et al. (1981, p. 753) suggested that Ozarkodina selfi is a juvenile of Eo. sulcatus rather than a separate species that gave rise to the Eo. juliae → Eo. s. kindlei lineage. Their principal arguments for such suppression of Lane and Ormiston’s species were its small size and the coincidental stratigraphic range of Eo. sulcatus ssp. and Oz. selfi. It is, however, shown herein (Table 3) that two new subspecies of Oz. selfi occur in faunas dated as pireneae Zone, such as the specimens in limestones from Stoney Tank, whereas subspecies of Eo. sulcatus do not occur in faunas dated as younger than kindlei Zone, for example in the limestones from the Manuka Anticline. This is contrary to the coincident age argument given by Murphy et al. (1981).

Evidence from our study shows that, taking into consideration additional morphological features of Oz. selfi and Eo. sulcatus, such as the shape of the basal cavity, the lateral profile and the nature of the denticles, several subspecies with a range of morphologies can be identified within each species. The new subspecies of Eo. sulcatus are based on the shape of the basal cavity and the nature of the denticles along the crest of the blade.

From their studies of conodonts from Early Devonian sequences in central Nevada, Murphy & Matti (1982, p. 8) discriminated a pi morph of Ozarkodina pandora based on the Pa element having non-tuberculate platform lobes and a spear-shaped basal cavity that “occupies a little more than half of the element”. Because of the distinct narrow, spear-shaped basal cavity, it is suggested that this form may have been the origin of the lineage Oz. pandora pi morph → Oz. selfi lanceola → Eo. sulcatus sicatus.

Eognathodus sulcatus Philip, 1965

Remarks. – It is generally accepted (e.g., Philip 1965, p. 99; Sweet 1988) that Eognathodus sulcatus has two rows of irregular nodes arranged laterally along the unit, producing a trough or sulcus in between. In contrast, Ozarkodina has a single row of denticles arranged longitudinally along the crest of the Pa element (Klapper 1977, p. 111). The concept of species of Eognathodus with a single row of denticles, irregularly arranged and at times irregularly shaped, was introduced by Murphy et al. (1981, p. 770) for E. sulcatus eta morph, and Murphy (1989, p. 62) for the subspecies E. s. eosulcatus. Weddige (1987) described the evolution of Eognathodus sulcatus from Ozarkodina pandora in terms of the nodes on the crest of the upper platform broadening transversely, becoming two humped, then separating to form a trough or sulcus.

Murphy (1989, p. 62, fig. 1) in his diagnosis of E. s. eosulcatus pointed to the unaligned nature of the denticles as being the defining characteristic of the subspecies, inferring that further evolutionary change and divergence of the denticles led to formation of the sulcus. Murphy (1989) seemed to differ from Weddige’s (1987) hypothesis for sulcus formation; both interpretations were supported with their respective specimen illustrations.

Eognathodus sulcatus lanei subsp. nov. illustrates a third way of deriving an egnathodontan from an ozarkodinan by the dimpling of denticles leading to short elongate troughs that eventually developed into two smooth ridges on either side of the sulcus.

Figure 16. A–Q – Amydrotaxis corniculans truncus subsp. nov. • A, B – lateral and upper views of Pa element, holotype MMMC 4507 from MDAM 34. • C, D – lateral and upper views of Pa element MMMC 4508 from MDAM 4. • E, F – lateral and lower views of Pb element MMMC 4509 from MDAM 31. • G, H – lateral and lower views of Pb element MMMC 4510 from MDAM 4. • I–K – lateral, oblique lower and upper views of Pb element MMMC 4511 from MDAM 24. • L, M – lateral and lower views Pb element MMMC 4512 from MDAM 12. • N – lateral view of Sb element MMMC 4513 from MDAM 4. • O – lateral view of Sc element MMMC 4514 from MDAM 4. • P, Q – lateral and upper views of /M element MMMC 4515 from MDAM 18. • R–U – Amydrotaxis sp. A. • R, S – lateral and upper views of Pa element MMMC 4516 from MDAM 28. • T, U – upper and lower views of Pa element MMMC 4517 from MDAM 19. Scale bar = 0.1 mm.

616
Although no specimens of *Eo. sulcatus juliae* (Lane & Ormiston, 1979) were obtained from acid-insoluble residues processed for our study, we consider that one of the specimens illustrated as this subspecies by Lane & Ormiston (1979, pl. 3, figs 22, 23) actually belongs to *Ozar-kodina selfi lanceola* (see below).

**Eognathodus sulcatus lanei** subsp. nov.

Figures 17A–M, 18, 32E–G, J

?1980 *Ozar-kodina cf. eurekaensis* Klapper & Murphy. –

Pickett, p. 77, fig. 8C (only).

2003 *Ozar-kodina pandora* zeta morphotype Murphy *et al.* –

Farrell, pp. 136–137, pl. 7, figs 15–19.

**Holotype.** – Pa element, specimen MMMC 4518 (Fig. 17A–D), from MDAM 11.

**Type locality.** – Sample MDAM 11 from the Mountain Dam Limestone Member on “Marobee” station, approximately 90 km NW of Condobolin, central New South Wales.

**Etymology.** – Named for H. Richard Lane who with Allen R. Ormiston first recognised the development of the two smooth, parallel ridges on the crest of some forms of *Eognathodus sulcatus* (Lane & Ormiston 1979, p. 47).

**Diagnosis.** – A subspecies of *Eognathodus sulcatus* with Pa elements having a sulcus bounded on either side by smooth ridges situated in the mid third of the unit and having a large, wide, oval basal cavity occupying two-thirds to three-quarters of the unit.

**Description.** – The Pa element is characterized by the centralthird of the denticles appearing to be completely fused, forming a relatively deep sulcus mid-blade bounded by parallel ridges and extending slightly towards the posterior end. In upper view, the crest, at times, can be curved or sinuous although the sulcus remains straight. The blade is relatively broad, short and high. In lateral view, the posterior margin of the blade slopes relatively steeply as the two to four denticles decline in height. Close to its lower margin, just above the basal cavity, the blade may appear to be pinched, producing a longitudinal bulge and groove (Fig. 17C, F, I, K). Five or six laterally compressed anterior denticles of medium height are fused almost to the top, curving at their tips towards the posterior. The basal cavity is broad, oval in shape and occupies the posterior two-thirds to three-quarters of the unit.

**Remarks.** – *Eognathodus sulcatus lanei* is characterised by its relatively deep sulcus bounded by two smooth ridges with no sign at the surface of denticles associated with the sulcus. A specimen from B 11D, photographed with reflected light and dark field and with transmitted light, shows “submerged” denticles (Fig. 18). The two smooth ridges derived from the rows of denticles are now seen as incipient individual denticles beneath the surface of the specimen. This is in accord with the observations by Lane (in Lane & Ormiston 1979). *Eognathodus sulcatus lanei* varies from other subspecies of *Eo. sulcatus* in having a more rounded and extensive basal cavity occupying up to three-quarters the length of the unit, as well as in the smooth ridges bounding the trough.

The specimen from the White Tank Limestone illustrated by Pickett (1980, fig. 8C) is tentatively included in the synonymy. It has sulcate upper element morphology with two distinct ridges developed over a broad basal cavity; however, judging from the illustration the ridges may not be continuous.

**Eognathodus sulcatus sicatus** subsp. nov.

Figure 17N–V

?1994 *Eognathus sulcatus* Philip. –

Mawson & Talent, pp. 53–55, fig. 8A, B (only).

**Holotype.** – Pa element, specimen MMMC 4524 (Fig. 17N–O), from sample B 11C.

**Type locality and horizon.** – Sample B 11C from the Booth Limestone ca 700 m NNW of Beulah Tank on “Manuka” station.

**Etymology.** – *Sica* (Latin), a dagger, in reference to the narrow, dagger- or spear-like shape of the basal cavity.

**Diagnosis.** – A subspecies of *Eognathodus sulcatus* with Pa elements having a narrow sulcus bounded on either side by smooth ridges situated in the mid-third of the
unit and having a narrow dagger- or spear-shaped basal cavity.

Description. – The Pa element is characterized by having a relatively long, low blade. Approximately the central third of the denticles appear to be fused forming a sulcus mid-blade bounded by smooth, parallel ridges. Three to five discrete, triangular anterior denticles, higher than the rest of the unit, tend to form a low fan; three or four discrete, triangular posterior denticles decrease in height towards the posterior extremity of the unit. In upper view, the blade is straight but becomes curved in gerontic forms. Five or six laterally compressed anterior denticles of medium height are fused almost to the top, curving at their tips towards the posterior. The basal cavity is narrow, dagger- or spear-shaped and occupies the posterior two-thirds of the unit.

Remarks. – Eognathodus sulcatus sicatus is characterised by its narrow sulcus bounded by two smooth ridges, and its narrow, spear-shaped basal cavity. Because of its narrow, spear-shaped basal cavity, it appears to belong to a lineage involving Ozarkodina pandora → Ozarkodina selfi lanceola → Eognathodus sulcatus sicatus as discussed above. Despite the small number of specimens available, the form is distinctive.

Genus Ozarkodina Branson & Mehl, 1933

Type species. – Ozarkodina typica Branson & Mehl, 1933.

Remarks. – Murphy et al. (2004), citing in part historical evidence on the development of conodont taxonomy, argued for reconsideration of the generic concept of Ozarkodina, in particular those taxa spanning the Silurian–Devonian boundary, by splitting it into the genera Warmiella, Zieglerodina and Genus “W”, and retaining the concept of Ozarkodina only for taxa associated with the type species. The viability of such a reconfiguration has been discussed elsewhere (e.g. Suttner 2009, Corriga & Corradini 2009). Cladistic studies such as that by Donoghue et al. (2008) support the contention of a polyphyletic nature of this group. Our study is primarily biostratigraphic in nature and our faunas add nothing to the generic-level taxonomic discussions about Ozarkodina. We therefore retain the original genus concept without prejudice, but recognize the potential for subdivision of this group.

Ozarkodina buchanensis (Philip, 1966)

Figure 19A–N


Remarks. – Ozarkodina buchanensis, although resembling in many ways Ozarkodina perbonus, can be easily distinguished from the latter by having a shorter, higher blade and a more centrally situated basal cavity of the Pa element.

Klapper & Philip (1972) described the apparatus of Ozarkodina buchanensis as a Type 1 apparatus, basing their reconstruction on material collected by Philip (1966). In the Buchan area of Victoria it was demonstrated that the youngest occurrence of Ozarkodina buchanensis was in the dehiscens Zone (Mawson 1987), but more recently it has been found in horizons dated as perbonus Zone (Mawson et al. 1992). At Loyola, Victoria, Cooper (1973) recorded this species as occurring with Polygnathus pireneae, a species indicative of the pireneae Zone, the last, poorly defined interval of the Pragian. Mawson et al. (1992) documented the occurrence of Ozarkodina buchanensis in pre-dehiscens horizons low in the Buchan Caves Limestone in eastern Victoria. Its range thus appears to be from the pireneae Zone to the perbonus Zone.

Ozarkodina sp. cf. Ozarkodina buchanensis (Philip, 1966)

Figure 19O–Q

Remarks. – A few ozarkodinans identified from the area of study are very similar to Ozarkodina buchanensis in having a centrally located basal cavity but differ from typical members of the species by having denticles that vary more in size.

Ozarkodina confluens (Branson & Mehl, 1933)

Figure 30O–Q

1995 Ozarkodina confluens (Branson & Mehl). – Simpson & Talent, pp. 142–146, pl. 7, figs 26, 27, pl. 8, figs 1–6 (contains extensive synonymy).

1995 Ozarkodina confluens (Branson & Mehl). – Miller, pl. 1, fig. 11.
Figure 18. *Eognathus sulcatus lanei* subsp. nov., specimen MMMC 4694 from the Booth Limestone, locality B11D, photomicrographs taken with an optical microscope, showing denticles buried within the body of the conodont element (cf. Fig. 17A–D).

- A – image taken with reflected light and dark field, × 120.
- B – image taken with reflected light and dark field, × 320.
- C – image taken with transmitted light, × 200.


1998a *Ozarkodina confluens* (Branson & Mehl). – Corradini et al., pl. 3.3.1, fig. 9.

1998b *Ozarkodina confluens* (Branson & Mehl). – Corradini et al., pl. 1.3.1, fig. 2.


1998 *Ozarkodina confluens* (Branson & Mehl). – Ferretti et al., pl. 2.2.2, fig. 3.

1998 *Ozarkodina confluens* (Branson & Mehl). – Serpagli et al., pl. 1.2.2, fig. 2.
Remarks. – Pa elements obtained closely resemble the alpha morphotype of this species (Klapper & Murphy 1975) but also show some characteristics of the beta morphotype. The denticles are mostly narrow and generally erect although some are slightly inclined posterior to the cusp. They are very similar to elements from the fauna at Cowombat Flat (Simpson, 1993). Simpson & Talent (1995) provided extensive discussion of this species. Specimens illustrated by Corradini & Corriga (2010, pl. 3, figs 22, 23) are only tentatively included in the above listing because the Pa element has a lateral profile more like Oz. martinsonni auriformis Simpson, diagnosed by the nature of the basal cavity which is unclear in their illustration.

Ozarkodina crispa (Walliser, 1964)

Remarks. – Ozarkodina eberleini is characterized by having three groups of two or three higher denticles at the anterior, middle and posterior of the blade and a small, fairly restricted basal cavity beneath the middle group of higher denticles. Savage (1977) showed this species to occur in
sulcata and kindlei zones in southern Alaska. Savage & Gehrels (1984) obtained 29 Pa elements from horizons of kindlei Zone age, also from southern Alaska. Specimens of Oz. eberleini from the Booth Limestone have come from horizons of kindlei and pireneae age thus extending its known range.

**Ozarkodina excavata excavata** (Branson & Mehl, 1933)

Figures 20, 30W, X, 32L–Q

1933 *Prioniodus excavatus* n. sp.; Branson & Mehl, p. 45, pl. 3, figs 7, 8.
1933 *Trichognathus excavata* n. sp.; Branson & Mehl, p. 51, pl. 3, fig. 35.
1933 *Ozarkodina simplex* n. sp.; Branson & Mehl, p. 52, pl. 3, figs 46, 47.
1934 *Ozarkodina excavata* (Branson and Mehl). − Valenzuela-Rios, pp. 69–70, pl. 4, fig. 4.
1935 *Ozarkodina excavata excavata* (Branson & Mehl). − Simpson & Talent, pp. 147–152, pl. 8, figs 16–25, pl. 9, figs 1–24 (includes extensive synonymy).
1935 *Ozarkodina excavata excavata* (Branson & Mehl). − Colquhoun, pl. 1, fig. 16.
1935 *Ozarkodina excavata excavata* (Branson & Mehl). − Carey & Bolger, pp. 79–81, fig. 3G, H.
1935 *Ozarkodina excavata excavata* (Branson & Mehl). − Dongal, fig. 4G–J.
1935 *Ozarkodina excavata excavata* (Branson & Mehl). − Miller, pl. 1, fig. 8.
1935 *Ozarkodina excavata excavata* (Branson & Mehl). − Sloan et al., pl. 12, figs 15, 18.
1935 *Ozarkodina excavata excavata* (Branson & Mehl). − Furey-Greig, pl. 1, figs 12–14.
1938 *Ozarkodina excavata excavata* (Branson & Mehl). − Percival, fig. 4.2.
1938 *Ozarkodina excavata excavata* (Branson & Mehl). − Ferreti et al., pl. 2.2.1, fig. 1.
1938 *Ozarkodina excavata excavata* (Branson & Mehl). − Serpagli et al., pl. I.2, figs 4, 5.
1938b *Ozarkodina excavata excavata* (Branson & Mehl). − Corradini et al., pl. I.3.1, fig. 1.
1939 *Ozarkodina excavata excavata* (Branson & Mehl). − Talent & Mawson, pl. 4, figs 1, 3, 4, pl. 5, figs 1–4, pl. 6, figs 19–22, pl. 7, fig. 14, pl. 9, figs 8, 9, pl. 11, figs 12–14, pl. 12, figs 1–4.
1999 *Ozarkodina excavata excavata* (Branson & Mehl). − Cockle, p. 120, pl. 3, figs 1–14.
1999 *Ozarkodina excavata excavata* (Branson & Mehl). − Talent et al., pl. 2, fig. 1.
2002 *Ozarkodina excavata excavata* (Branson & Mehl). − Talent et al., pl. 2, figs R, S, pl. 3, fig. S, pl. 4, fig. K.
2003 *Ozarkodina excavata excavata* (Branson & Mehl). − Mawson et al., pl. 3, figs 1–19, pl. 4, figs 1–15.
2004a *Ozarkodina excavata excavata* (Branson & Mehl). − Slavik, pl. 1, figs 10, 11.
2004b *Ozarkodina excavata excavata* (Branson & Mehl). − Slavik, fig. 11.25.
2004 *Ozarkodina excavata* (Branson & Mehl). − Farrell, p. 970, pl. 9, figs 1–16.
2004 *Wurmiella excavata* (Branson & Mehl). − Murphy et al., fig. 2.29–2.36.
2005 *Ozarkodina excavata excavata* (Branson & Mehl). − Talent et al., p. 282, figs 6D, 8C, D, F.
2005 *Ozarkodina excavata excavata* (Branson & Mehl). − Weddige et al., pl. 1, fig. 2.
2005 *Ozarkodina excavata excavata* (Branson & Mehl). − Trotter & Talent, pl. 18, figs 2, 7–9.
2006 *Ozarkodina excavata excavata* (Branson & Mehl). − Valentine et al., p. 299, fig. 11i–m.
2007 *Ozarkodina excavata excavata* (Branson & Mehl). − Suttner, pp. 33–36, pl. 1, fig. 3, pl. 12, figs 1, 7, pl. 13, figs 3, 5, 8, 9, pl. 14, figs 2–11, pl. 16, figs 1–7, pl. 17, figs 1–3, 5.
2008 *Ozarkodina excavata excavata* (Branson & Mehl). − Gaiani et al., pp. 280–281, pl. 1, fig. 4.
2009 *Ozarkodina excavata excavata* (Branson & Mehl). − Boncheva et al., text-fig. 4.4, 4.8, 4.10.
2009 *Ozarkodina excavata excavata* (Branson & Mehl). − Martín-Algarra et al., fig. 8.4–8.8.
2009 *Ozarkodina excavata excavata* (Branson & Mehl). − Suttner, pl. 1, fig. 15.

**Figure 20. Ozarkodina excavata excavata** (Branson & Mehl, 1933). • A–C – lateral oblique, upper and lateral views of Pa element MMMC 4539 from B 13. • D – lateral view of Pa element MMMC 4540 from B 15 W. • E, F – lateral and basal views of Pa element MMMC 4541 from B 15 W. • G, H – lateral and lower views of Pa element MMMC 4542 from B 11D. • I – lateral view of Pb element MMMC 4543 from MDAM 14. • J – lateral view of Sa element MMMC 4544 from BE (Booth East). • K – lateral view of Sc element MMMC 4545 from MDAM 15. • L – lateral view of Sc element MMMC 4546 from MDAM 10. • M – lateral view of Sc element MMMC 4547 from MDAM 17. • N – lateral view of M element MMMC 4548 from GUND 3. Scale bar = 0.1 mm.

624
three-quarters the length of the platform. Anterior denticles ing a long, lenticular basal cavity occupying two-thirds to
Diagnosis
elements of this species.

the many fine striae on the surface of the denticles of all
type locality and horizon.

(Spampionship, 1975). Other elements are easily distinguished by their
other unit; it is very narrow and lenticular, tapering evenly to
the posterior extremity.

Ph element is distinguished by having, in lateral view,
high posterior denticles curved towards the wide main
cusp, which also is curved towards the anterior. The ante-
dior denticles are much higher than the posterior denticles
and also have a tendency to curve towards the main
dentine. Denticles are narrow and long with their individ-
ual shape defined by the striations down their length.

M, Sb and Sc elements all have a high main cusp with
long, discrete, striate denticles with striae defining the
shape. Sa element not so far identified.

Remarks. – Ozarkodina excavata excavata is recognised as
a long-ranging species with its Pa element exhibiting a high
degree of variation (e.g. Jeppsson 1975, Klapper & Mur-
phy 1975). Other elements are easily distinguished by their
unique “excavated” basal cavities.

Ozarkodina multistriola sp. nov.

Figure 22

Holotype. – Pa element, specimen MMMC 4565
(Fig. 22A–C), from MDAM 11.

Type locality and horizon. – Sample MDAM 11 from
Mountain Dam Limestone Member on “Marobee” station,
approximately 90 km NW of Condobolin, central New
South Wales.

Etymology. – Striola, diminutive of stria (Latin) meaning
furrow, channel, stripe, hollow, fluting, line, referring to
the many fine striae on the surface of the denticles of all
elements of this species.

Diagnosis. – A species of Ozarkodina with Pa elements hav-
ing a long, lenticular basal cavity occupying two-thirds to
three-quarters the length of the platform. Anterior denticles
are backwardly deflected towards the posterior. Denticles
of all elements are long and narrow; all are finely striated.

Description. – All elements are characterised by being fi-
nely striated with the striae being more prominent towards
the top of the tapering denticles.

Pa element is characterised by a long, low blade with an
anterior crest of approximately six or seven denticles being
only slightly shorter than the anterior denticles and just a
little higher that the posterior denticles. All but the
denticles in the posteriormost quarter of the platform tend
to curve towards the posterior. Denticles are narrow and
long with traces of their depth highlighted by exterior
striations evident for most of their length. The slightly
asymmetrical basal cavity begins anterior of mid-length of
the unit; it is very narrow and lenticular, tapering evenly to
the posterior extremity.

Ph element is distinguished by having, in lateral view,
high posterior denticles curved towards the wide main
cusp, which also is curved towards the anterior. The ante-
dior denticles are much higher than the posterior denticles
and also have a tendency to curve towards the main
dentine. Denticles are narrow and long with their individ-
ual shape defined by the striations down their length.

M, Sb and Sc elements all have a high main cusp with
long, discrete, striate denticles with striae defining the
shape. Sa element not so far identified.

Remarks. – The striate ornament on the denticles of all
elements of Oz. multistriola separate it from other ozarko-
dinans. Klapper & Barrick (1983, pp. 1234–1237,
figs 10K, N, 11A–W) described the late Eifelian Oz. raas-
chi, a species with Pa and Pb elements with striated den-
ticles but having the M element and symmetry transition
series smooth.

Ozarkodina paucidentata (Murphy & Matti, 1982)
emended herein

Figure 32H, I

?1964 Spathognathodus steinhornensis remscheidensis
Ziegler. – Walliser, pl. 20, fig. 26.

Figure 21. A–F – Ancyrodelloides omus Murphy & Matti, 1983. • A, B – lateral and upper views of Pa element MMMC 4549 from B 11C.
1975 *Ozarkodina* n. sp. E. – Klapper & Murphy, pl. 7, figs 6, 9, 10.

1982 *Ozarkodina paucidentata* n. sp.; Murphy & Matti, pp. 9–10, pl. 1, figs 25–32, 39, 40.

2003 *Ozarkodina* sp. cf. *O. paucidentata* Murphy & Matti – Mawson et al., p. 93, pl. 4, figs 19, 20.


2012 *Zieglerodina paucidentata* (Murphy & Matti). – Drygant & Szaniawski, fig. 11R.

2012 *Zieglerodina* cf. *paucidentata* (Murphy & Matti). – Drygant & Szaniawski, fig. 11S, T.

2013 “Ozarkodina” aff. *paucidentata* (Murphy & Matti). – Mavrinetska & Slavík, fig. 6J–L.

Emended diagnosis. – A species of *Ozarkodina* characterised by a Pa element with a high conical cusp and no, or only rudimentary, development of denticles on a posterior process that is markedly lower adjacent to the cusp.

Remarks. – This species was originally diagnosed and named by Murphy & Matti (1982, p. 9) based on material previously documented in open nomenclature by Klapper & Murphy (1975). The diagnosis included the rudimentary nature of denticle development on the posterior process, but also stated that the number of denticles was three or four. The holotype, however, appears to have seven denticles on the posterior process (Murphy & Matti 1982, pl. 1, figs 25–27, most obvious in upper view, fig. 26). The diagnosis also notes the almost circular nature of platform lobes in top view. While this is true of the holotype, other specimens show a distinct asymmetry (e.g. Murphy & Matti 1982, pl. 1, fig. 31). The diagnosis is therefore emended to exclude these two characteristics and include the unifying characteristic of the relatively low posterior process.

A small number of Pa elements in this study fall within the emended diagnosis. Other specimens previously reported as having affinities with the species as originally diagnosed or compared with it, as captured in the above synonymy, now fall within the amended diagnosis.

*Ozarkodina selfi* Lane &Ormiston, 1979

Remarks. – In their original description of *Ozarkodina selfi*, Lane & Ormiston (1979) indicated that one of the diagnostic features of the species was the “heart- to oval-shaped” basal cavity. Materials from western New South Wales indicate that several subspecies can be identified on the basis of the shape of the basal cavity: *Oz. selfi lenticula* with a rounded, oval-shaped basal cavity; *Oz. selfi laceola* with a lancet-shaped basal cavity; and *Oz. selfi cordata* with a heart-shaped basal cavity similar to that of the specimen chosen as the holotype of the species by Lane & Ormiston (1979, pl. 3, figs 18–20) but tapering more evenly towards the posterior extremity.

*Ozarkodina selfi lenticula* subsp. nov.

Figures 23, 24A–L

1980 *Ozarkodina* cf. *eurekaensis* Klapper & Murphy – Pickett, p. 77, figs 8A, B, D, J, L, M (only).

1999 *Ozarkodina selfi* Lane & Ormiston. – Talent & Mawson, pl. 12, fig. 5.

Holotype. – Pa element, specimen MMMC 4577 (Fig. 23A–C), from MDAM 18.

Type locality and horizon. – Sample MDAM 18 from the section through the Mountain Dam Limestone on “Maroboo” station, approximately 90 km NW of Condobolin, central New South Wales.

Etymology. – *Lenticula* (Latin), a little lens, in reference to the broadly lenticular shape of the basal cavity.

Diagnosis. – A subspecies of *Ozarkodina selfi* with Pa elements having a broadly lenticular basal cavity with rounded posterior extremities. Some denticles in the mid-third of the unit may be dimpled or show signs of coalescence of one or more dimpled denticles.

Description. – The Pa element is characterised by having a long, low blade with an anterior crest of approximately five or six laterally compressed denticles. In lateral view, the posterior margin tapers at an angle of 50° to 65° with two to four posterior denticles decreasing in height toward the posterior extremity. The mid and posterior section of denticles arch over a downwardly curved, unornamented...
platform. Most denticles are fused almost to their tips but may retain discrete tips that are dimpled at times. The slightly asymmetrical basal cavity beginning anterior of mid-length is broadly lenticular with the posterior margin remaining rounded rather than pinched in where it reaches the posterior extremity.

Based on the nature of the mid-crest denticles, a range of morphologies of *Ozarkodina selfi lenticula* can be recognised. Mid-crest denticles may be either arched or somewhat flattened with most of the individual denticles pointed and complete. Other individual denticles tend to be dimpled. This morphology ranges to Pa elements in which denticles in the mid-crest area are flattened in lateral view by formation of dimples at their tops, and there are signs of coalescence between denticles. There was no observable stratigraphic trend within this range of morphologies in the collection studied.

**Remarks.** – Specimens of *Oz. pandora* zeta morph that exhibit mid-blade arching and fusion of mid-blade denticles were described and illustrated by Murphy et al. (1981, pl. 7, fig. 20), but the specimens from Mountain Dam Limestone differ in having a much narrower basal cavity.

Specimens from the White Tank Limestone and Baledmund Formation illustrated by Pickett (1980) are included in the synonymy because of the lenticular shape of the basal cavity.

**Ozarkodina selfi lanceola** subsp. nov.

Figures 25, 26A–O, 32J

1979 *Eognathodus sulcatus juliae* subsp. nov. – Lane & Ormiston, pp. 52–53, figs 22, 23 (only).

**Holotype.** – Pa element, specimen MMMC 4591 (Fig. 25A–D), from MDAM 17.

**Type locality and horizon.** – Sample MDAM 17 from the Mountain Dam Limestone on “Marobee” station, approximately 90 km NW of Condobolin, central New South Wales.

**Etymology.** – *Lanceola* (Latin), a little spear; in reference to the narrow, spear-shaped basal cavity.

**Diagnosis.** – A subspecies of *Ozarkodina selfi* with Pa elements having a narrow, spear-shaped basal cavity and, in lateral view, a posterior margin sloping at an angle from 60° to 90°.

**Description.** – Viewed laterally, the Pa element has a relatively low, flat profile with the anterior denticles being slightly higher than the rest. The anterior denticles decrease in size and elevation towards the centre of the unit and appear to be laterally compressed to a greater degree than the posterior denticles. In upper view the unit is straight or slightly curved. The basal cavity tends to be narrow, lancet-shaped, occupying more than half of the unit and, approaching the posterior extremity of the unit, it is somewhat “pinched in”.

Based on the nature of the central denticles a range of morphologies of *Ozarkodina selfi lanceola* can be recognised. Mid-crest may be either arched or somewhat flattened with most of the individual denticles cylindrical, round at the top and commonly dimpled, resembling cow teats in shape. This morphology ranges to Pa elements in which an incipient sulcus has formed by coalescence of dimpled denticles in the mid-third of the unit resulting in flattening of the crest of the blade in lateral view. The basal cavity is narrow and lancet-shaped with posterior extremities that are “pinched in” as they approach the posterior margin.

**Remarks.** – Specimens from Mountain Dam Limestone, the Booth Limestone and the “Lerida Limestone Member” are similar in some respects to *Oz. pandora* pi morph illustrated by Murphy & Matti (1982, pl. 1, figs 10–24). However, many of the specimens from the Mountain Dam Limestone show dimpled denticles in the central part of the unit and, in lateral view, the unit is somewhat flattened mid-crest, whereas none of the specimens illustrated from central Nevada shows these attributes.

A single specimen illustrated by Lane & Ormiston (1979) is included in the synonymy as it has a single row of denticles that are partially fused and dimpled in the central area forming an incipient sulcus, and the basal cavity as shown in upper view is narrow and lanceolate. Other specimens illustrated by Lane & Ormiston (1979) as *Eognathodus sulcatus juliae* are more sulcate and/or have a broader basal cavity.

Some of the specimens illustrated by Pickett (1980) are included in the synonymy on the basis of denticle and basal cavity morphology.

**Ozarkodina selfi cordata** subsp. nov.

Figure 26P–T

**Holotype.** – Pa element, specimen MMMC 4604 (Fig. 26P–R), from MDAM 23.

**Type locality and horizon.** – Sample MDAM 23 from the Mountain Dam Limestone Member on “Marobee” station, approximately 90 km NW of Condobolin, central New South Wales.
Ozarkodina selfi lenticula subsp. nov. • A–C – upper, enlarged upper and lateral views of Pa element, holotype MMMC 4577 from MDAM 18. • D–F – upper, enlarged upper and lateral views of Pa element MMMC 4578 from B 12. • G–I – upper, lateral and lower views of Pa element MMMC 4579 from MDAM 13. • J, K – upper and lateral views of Pa element MMMC 4580 from MDAM 15. • L, M – upper and lateral views of Pa element MMMC 4581 from GUND 5. • N–P – upper, lateral and lower views of Pa element MMMC 4582 from MDAM 31. • Q, R – upper and lateral views of gerontic Pa element MMMC 4583 from B 15W. • S, T – upper and lateral views of gerontic Pa element MMMC 4584 from MDAM 15. • U, V – upper and lateral views of Pa element MMMC 4585 from GUND 2. Scale bar = 0.1 mm except in B, E.
Etymology. – *Cordata* (Latin), heart-shaped, in reference to the heart-shaped basal cavity.

Diagnosis. – A subspecies of *Ozarkodina selfi* with the Pa element having a heart-shaped basal cavity that tapers to the posterior extremity and, in lateral view, a posterior margin sloping abruptly at an angle from 80° to 90°.

Description. – The single row of denticles appears, in lateral view, to be a little flattened or slightly arching in the central half of the unit. Central denticles are fused almost to their tips but most retain discrete tips. Posterior denticles are taller and more discrete. In lateral view, the posterior margin of the unit is almost perpendicular to the base. The basal cavity is heart-shaped, slightly asymmetrical, tapers

---

Figure 24. *Ozarkodina selfi* lenticula subsp. nov. • A–D – upper, enlarged upper, lateral and lower views of Pa element MMMC 4586 from MDAM South. • E, F – upper and lateral views of Pa element MMMC 4587 from MDAM 17. • G, H – upper and lateral views of Pa element MMMC 4588 from GUND 5. • I, J – upper and lateral views of Pa element MMMC 4589 from MDAM 17. • K, L – upper and lateral views of Pa element MMMC 4590 from MDAM 15. Scale bar = 0.1 mm.

Figure 25. *Ozarkodina selfi* lanceola subsp. nov. • A–D – upper, lateral and two enlarged upper views of Pa element, holotype MMMC 4591 from MDAM 17. • E, F – upper and lateral views of Pa element MMMC 4592 from MDAM 23. • G–I – lateral, upper and lower views of Pa element MMMC 4693 from MDAM 22. • J, K upper and lateral views of Pa element MMMC 4594 from B 15W. • L, M – upper and lateral views of Pa element MMMC 4595 from MDAM 17. • N–P – upper, lateral and lower views of gerontic Pa element MMMC 4596 from MDAM 12. • Q, R – upper and lower views of Pa element MMMC 4597 from MDAM 15. Scale bar = 0.1 mm except in C, D.
evenly to the posterior margin, and occupies a little more than the posterior half of the unit.

Remarks. – The basal cavity of the holotype of Oz. selfi (sensu stricto) (Lane & Ormiston 1979, pl. 3, figs 18–20) differs from that of the new subspecies in that the former shows the heart-shaped basal cavity tapering to a point about one-quarter the length of the unit from the posterior margin and continuing as a groove to the posterior extremity. The heart-shaped basal cavity of Oz. selfi cordata tapers more evenly.

Because of the heart-shaped basal cavity of Oz. selfi cordata, it is suggested that it gave rise to Eognathodus sulcatus juliae with its basal cavity tapering more evenly than that of Oz. selfi (sensu stricto).

**Ozarkodina remscheidensis remscheidensis**
(Ziegler, 1960)

Figures 27, 32K

1960 *Spathognathodus remscheidensis* n. sp.; Ziegler, pp. 194–196, pl. 13, figs 1, 2, 4, 5, 7, 8, 10, 14.
2001 *Ozarkodina remscheidensis remscheidensis* (Ziegler). – Slavik, pl. 2, fig. 9.
2003 *Ozarkodina remscheidensis remscheidensis* (Ziegler). – Mawson et al., pp. 90–92, pl. 2, figs 1–19, pl. 4, figs 17, 18 (with synonymy to 2003).
2004 *Zieglerodina remscheidensis* (Ziegler). – Murphy et al., p. 13, fig. 3.1–3.8.
2005 *Ozarkodina remscheidensis remscheidensis* (Ziegler). – Weddige et al., pl. 1, fig. 1.
2005 *Ozarkodina remscheidensis remscheidensis* (Ziegler). – Trotter & Talent, pl. 18, figs 1, 3–6, 8.
2007 *Ozarkodina remscheidensis remscheidensis* (Ziegler). – Suttner, pp. 39–42, pl. 12, figs 5, 6, 8, pl. 17, figs 6–13, pl. 18, fig. 1 (with synonymy to 2007).
2007 *Ozarkodina remscheidensis remscheidensis* (Ziegler). – Benfríka et al., fig. 8A.
2008 *Ozarkodina remscheidensis remscheidensis* (Ziegler). – Gaetani et al., p. 281, pl. 1, fig. 1.
2008 *Ozarkodina remscheidensis remscheidensis* (Ziegler). – Kim et al., pl. 16, figs 6, 7.

Remarks. – Following the introductory comments made by Simpson & Talent (1995), Mawson et al. (2003) continued discussions on the chronologic significance and phylogenetic relationships of the highly variable *Ozarkodina remscheidensis* plexus. Based on the fact that Oz. r. remscheidensis *sensu stricto* can be identified by its irregular denticulation with a large cusp and a group of large denticles along the anterior of the blade, and with an enlarged denticle about mid-way above a heart-shaped (rather than an ear-shaped) basal cavity, we have synonymised several forms recently described as new species.

One form (Fig. 27U, V) differs from most of our other specimens in having denticles that are arranged in an irregular row and having basal cavity lobes that are decidedly different in width compared with Oz. r. remscheidensis. It is included in Oz. r. remscheidensis as an aberrant form.

**Ozarkodina scoliciformis** sp. nov.

Figure 28A–I

1994 *Ozarkodina* sp.; Mawson & Talent, fig. 13M.

Holotype. – Pa element, specimen MMMC 4621 (Fig. 28C, D), from MDAM 15.

Type locality and horizon. – Sample MDAM 15 from the Mountain Dam Limestone on “Marobee” station, approximately 90 km NW of Condobolin, central New South Wales.

Etymology. – *Scolex* (Latin) and *formis* (Latin), worm-like, in reference to the appearance of the Pa element.

Diagnosis. – A species of *Ozarkodina* with the Pa element...
having a proportionally long, narrow and thickened blade giving the unit the appearance of a slug or worm.

Description. – In lateral view the thickened blade is long and extremely narrow with its base tending to bow downwards in the posterior half of the unit, giving it a worm-like or slug-like appearance. In lateral view, the denticles are short and closely packed with the denticles in the anterior third of the unit forming a slightly higher crest. Denticles in the posterior third of the unit are fused almost to their tips and decrease in height rapidly. The basal cavity is long and very narrow, occupying the posterior three-quarters of the unit.

Remarks. – Because of the extremely narrow basal cavity of this species, it is suggested that Oz. scoliciformis may have been derived from the ozarkodinan Ozarkodina scotti Farrell (2003) from a Lochkovian horizon in the Garra Limestone at The Gap, New South Wales.

Genus Pandorinella Müller & Müller, 1957

Type species. – Pandora insita Stauffer, 1940.

Pandorinella exigua exigua? (Philip, 1966)

Figure 21M–P

Remarks. – Pandorinella exigua exigua has an age range from at least the dehiscens Zone through to the top of the seritinous Zone (Klapper & Johnson 1980) whereas P. e. philipi has been reported from horizons dated as salcatus Zone through to the perbonus/gronbergi/notthperbonus Zone. Therefore, if with further sampling the queried identification of the two specimens from B 16L horizon can be confirmed as unequivocally P. e. exigua, the highest horizon of the Booth Limestone cropping out in the Multagoona Anticline is dehiscens Zone in age.

Pandorinella exigua philipi (Klapper, 1969)

Figures 21J–L, 31A–F

1969 Spathognathodus exiguis philipi n. ssp.; Klapper, pp. 16–18, pl. 4, figs 30–38.
1977 Pandorinella exigua philipi (Klapper). – Savage et al., pl. 1, figs 1–12.

---

Figure 27. Ozarkodina remscheidensis remscheidensis (Ziegler, 1960). • A, B – lateral and upper views of Pa element MMC 4606 from MDAM 36. • C, D – lateral and lower views of Pa element MMC 4607 from MDAM 7. • E, F – lateral and lower views of Pa element MMC 4608 from MDAM 36. • G, H – lateral and upper views of Pa element MMC 4609 from MDAM 35. • I, J – lateral and upper views of Pa element MMC 4610 from BLUFF 1. • K, L – lateral and lower views of Pa element MMC 4611 from B 9. • M, N – lateral and upper views of Pa element MMC 4612 from B 15W. • O – lateral view of Pb element MMC 4613 from MDAM 35. • P – lateral view of Pb element MMC 4614 from MDAM 33. • Q – lateral view of Pb element MMC 4615 from MDAM 35. • R – lateral view of Sb element MMC 4616 from MDAM 23. • S – lateral view of Sc element MMC 4617 from B 15W. • T – lateral view of M element MMC 4618 from GUND 3. • U, V – upper and lateral views of Pa element MMC 4619 from BLUFF 1. Scale bar = 0.1 mm.

Figure 28. A–I – Ozarkodina scoliciformis sp. nov. • A, B – lateral and lower views of Pa element MMC 4620 from MDAM 24. • C, D – lateral and lower views of Pa element, holotype MMC 4621 from MDAM 15. • E – lateral view of Pa element MMC 4622 from MDAM 26. • F, G – lateral and lower views of Pa element MMC 4623 from MDAM 15. • H, I – lateral and lower views of Pa element MMC 4624 from MDAM 29. • J–S – Heliagnosthus parvobilabatus sp. nov. • J, K – lateral and oblique lower views of Pa element, holotype MMC 4625 from MDAM 31. • L – lateral outer view of Pb element MMC 4626 from BE. • M – lateral inner view of Pb element MMC 4627 from GUND 5. • N – lateral view of Sa element MMC 4628 from B 16G. • O – lateral view of M element MMC 4629 from MDAM 34. • P – lateral view of broken Sc element MMC 4630 from MDAM 37. • Q – lateral view of Sb element MMC 4631 from MDAM 14. • R, S – lateral and oblique lower views of Sb element MMC 4632 from MDAM 31. Scale bar = 0.1 mm.

Figure 29. A–I – Apparatus A. • A, B – lateral and lower views of Pb element MMC 4633 from B 12. • C, D – lateral and lower views of Pb element MMC 4634 from MDAM 4. • E, F – lateral and lower views of Pb element MMC 4635 from BE. • G, H – lateral view and enlarged portion of posterior three denticles showing annealing of broken denticles of Pb element MMC 4636 from B 16C. • I – oblique lateral view of Sa element MMC 4637 from BE. • J–L, N–P – unassigned “ozarkodinan” elements. • J – lateral view of broken Sa element MMC 4638 from MDAM 36. • K – lateral view of Sb element MMC 4639 from MDAM 33. • L, M – lateral view of Sb element MMC 4640 from MDAM 36. • N – lateral view of Sa element MMC 4641 MDAM 17. • O – lateral view of Sa element MMC 4642 from MDAM 8. • P – lateral view of Pb element MMC 4643 from B 16L. • M, Q–T – unassigned elements. • M – lateral view of Sb element MMC 4644 from MDAM 5. • Q – lateral view of Sb element MMC 4645 from MDAM 15. • R – lateral view of Pb element MMC 4646 from MDAM 10. • S, T – lateral and lower views of icriodontid M2 element MMC 4647 from BE. Scale bar = 0.1 mm.
1977 Pandorinellina exigua philipi (Klapper). – Savage, p. 281, pl. 1, figs 33, 34.
1979 Pandorinellina exigua philipi (Klapper). – Lane & Ormiston, p. 59, pl. 6, figs 1–3.
1985 Pandorinellina exigua philipi (Klapper). – Savage et al., pl. 1, figs 16, 17.
1990 Pandorinellina exigua philipi (Klapper). – Uyeno, p. 96, pl. 6, figs 1–6, 41.
1991 Pandorinellina exigua philipi (Klapper). – Uyeno, pl. 1, fig. 20.
1992 Pandorinellina exigua philipi (Klapper). – Bardashev & Ziegler, pl. 1, figs 40, 46.
1992 Pandorinellina exigua philipi (Klapper). – Mawson et al., figs 9K, L, 11R (non fig. 13O = Pandorinellina? sp.).
1994 Pandorinellina exigua philipi (Klapper). – Sobolev, pl. 13, figs 4, 5.
1995 Pandorinellina exigua philipi (Klapper). – Colquhoun, pl. 2, figs 1, 3, 4.
1999 Pandorinellina exigua philipi (Klapper). – Talent & Mawson, pl. 7, fig. 9, pl. 9, fig. 10, pl. 12, figs 6, 8, 9.
2003 Pandorinellina exigua philipi (Klapper). – Mawson & Talent, p. 347, pl. 1, fig. 19.
2008 Pandorinellina exigua philipi (Klapper). – Kim et al., pl. 20, fig. 12, pl. 24, figs 10, 11.
2012 Pandorinellina philipi (Klapper). – Baranov, pl. 1, figs 26–29, pl. 4, figs 20, 21.
2013 Pandorinellina exigua philipi (Klapper). – Mavrinetskaya & Slavik, fig. 6H.

Remark. – This subspecies is easily distinguished from P. e. exigua by the latter having a less restricted basal cavity. Pandorinellina exigua philipi was first recognised by Klapper (1969) from Royal Creek in the Yukon Territory, Canada, in horizons dated as sulcatus Zone, and has been reported from Solo Creek also in the Yukon Territory (Fähræus 1971). Elsewhere in continental North America, P. e. philipi has been recognised in Alaska by Lane & Ormiston (1979), Savage (1977) and Savage et al. (1977). Outside of continental North America it has been reported in eastern Australia by Pedder et al. (1970), Mawson et al. (1992), Wilson (1989) and Colquhoun (1995), and from Central Asia by Apekina & Mashkov (1978), Bardashev & Ziegler (1992) and Sobolev (1994). From these occurrences, this subspecies appears to have an age range from sulcatus Zone to perbonus Zone.

Mawson (in Talent et al. 2000) noted that Kimognathus, a monospecific conodont genus found in the pesavis Zone in terranes now located in Tadjikistan, Uzbekistan, Australia and Arctic North America, may be taken as indicative of former close juxtaposition of the crustal blocks in question or the former existence of circulation patterns facilitating migration between these blocks. It was also shown (Talent et al. 2000) that restricted distribution of certain conodont species occurred in the pirenaeae and dehiscens intervals. From the occurrences noted above for subspecies of P. exigua such endemism also occurred in the sulcatus and kindlei zones.

Pandorinellina steinhornensis miae (Bultynck, 1971) Figure 21Q–Z

1971 Spathognathodus steinhornensis miae; Bultynck, pp. 25–31, pl. 4, figs 13–20, pl. 5, figs 1–14.

1980  Pandorinellina steinhornensis miae (Bultynck). – Klapper & Johnson, p. 451; see for additional synonymy.
1990  Ozarkodina steinhornensis miae (Bultynck). – Bultynck, pl. 6, figs 10, 11.
1991  Pandorinellina steinhornensis praeoptima (Mashkova) sensu Lane & Ormiston 1979. – Uyeno, pl. 21, fig. 19.
1992  Pandorinellina miae (Bultynck). – Bardashev & Ziegler, pl. 1, figs 41, 47.
1994  Pandorinellina steinhornensis miae (Bultynck). – Mawson & Talent, pp. 55–57, fig. 11A–G.
1995  Pandorinellina steinhornensis miae (Bultynck). – Furey-Greig, pl. 1, fig. 18.
1995  Pandorinellina steinhornensis miae (Bultynck). – Colquhoun, pl. 2, figs 7–9.
1999  Ozarkodina steinhornensis miae (Bultynck). – Benfrika, p. 316, pl. 1, fig. 19.
2003  Pandorinellina cf. miae (Bultynck). – Farrell, p. 150, pl. 12, figs 5, 6.
2004b  Ozarkodina steinhornensis miae (Bultynck). – Slavik, fig. 11.7–11.11.
2007  Pandorinellina miae (Bultynck). – Suttner, pp. 44–45, pl. 20, fig. 7.
2008  Pandorinellina steinhornensis miae (Bultynck). – Gaetani et al., pl. 1, figs 2, 10.
2009  Ozarkodina steinhornensis miae (Bultynck). – Martin-Algarra et al., fig. 8.11, 8.12.
2012  Pandorinellina miae (Bultynck). – Baranov, pl. 2, figs 6–9.
2016  Pandorinellina steinhornensis miae (Bultynck). – Lu et al., pp. 281–283, fig. 3Q.

Remarks. – This form was originally described from Spanish collections dated as dehiscens Zone (Bultynck 1971). Mawson & Talent (1994) obtained 694 specimens from sampled sections of sulcatus–kindlei age at Tyers and Boola in east-central Victoria, Australia. Although it has a more centrally situated basal cavity, one specimen from GUND 3 (Fig. 21Y, Z) is included here with P. s. miae as an abberant form.

Family unknown

Heliagnathus gen. nov.

Type species. – Heliagnathus parvilabiatus sp. nov.

Etymology. – Helias, daughter of the Greek god Helios, and gnathus (Greek), jaw, in reference to the semi-sun-like arrangement of denticles of the Pa, Pb and Sa elements of the apparatus.
Diagnosis. – A seximembrate apparatus with P positions occupied by carminate and alate elements, a dolabrate M element and a symmetry-transition series consisting of alate, digyrate and bipennate elements. All elements are characterised by having short, tightly spaced denticles set on relatively wide processes and, in many cases, arranged symmetrically, giving a hemi-sun-like appearance.

Figure 32. Conodont elements from Trundle sample. • A, B – *Panderodus unicostatus* (Branson & Mehl, 1933). • A – lateral view of Sa element MMC 4681. • B – lateral view of Sb element MMC 4682. • C, D – *Icriodus ampliatus* sp. nov. • C – upper view of I element MMC 4683. • D – upper view of I element MMC 4684. • E–G – *Eognathodus sulcatus lanei* subsp. nov. • E – oblique upper view of damaged specimen MMC 4685. • F, G – upper and lateral views of Pa element MMC 4686. • H, I – *Ozarkodina paeicidentata* Murphy & Matti, 1983, upper and lateral views of Pa element MMC 4687. • J – *Ozarkodina selfi lanceola* subsp. nov., upper view of Pa element MMC 4688. • K – *Ozarkodina remscidenensis remscidenensis* (Ziegler, 1960), lateral view of Pa element MMC 4689. • L, M – *Ozarkodina excavata excavata* (Branson & Mehl, 1933). • L, M – upper and lateral views of damaged Pa element MMC 4690. • N – lateral view of Sc element MMC 4691. • O – lateral view of Sc element MMC 4692. • P – lateral view of M element MMC 4693. • Q – lateral view of Sb element MMC 4694. Scale bar = 0.1 mm.
Occurrence. – Lower Devonian (Pragian), sulcatus to pireneae zones.

Heliagnathus parvilabiatus sp. nov.
Figure 28J–S

Holotype. – Pa element, specimen MMMC 4625 (Fig. 28J, K), from MDAM 31.

Type locality and horizon. – Sample MDAM 31 from the Mountain Dam Limestone Member on “Marobee” station, approximately 90 km NW of Condobolin, central New South Wales.

Etymology. – Parvus (Latin), and labiatus (Latin), lipped, in reference to the small, restricted basal cavity common to many elements of the apparatus.

Diagnosis. – As for genus.

Description. – Pa element symmetrically fan-shaped with small, free denticles diminishing in height from above the basal cavity towards the anterior and posterior extremities of the unit. The arrangement of the denticles is reminiscent of a half-exposed, rising or setting sun. Basal cavity small, expanded beneath the main denticle, thereafter becoming tightly restricted to become a groove extending to the anterior and posterior of the unit.

Pb element symmetrical with a high main cusp and two enlarged denticles to the anterior and posterior with three or four small, free denticles continuing to the anterior and posterior of the unit. Basal cavity expanded beneath the main denticle, thereafter becoming tightly restricted to become a groove extending to the anterior and posterior.

M element has an apparently robust main denticle (the one specimen found in this study has a broken main denticle but the breakage point shows the base of such a denticle). The wide processes have small, evenly spaced denticles along both. Expansion of basal cavity is restricted to below main cusp, thereafter running as a groove to the extremities of the unit.

Symmetry transition series consists of alate, digyrate and bipennate elements, all with wide processes with evenly spaced, free denticles. All elements have smaller basal cavities expanded beneath the main cusp compared to the Pa, Pb and M elements; the cavity continues as a groove towards the extremities of the units. The Sa element has an extremely large and high main denticle with contrastingly tiny denticles developed on each process and is spectacul- larly distinguished by the penultimate denticle of both processes being greatly enlarged, mimicking the development of the two denticles on either side of the main cusp in the Pb element. The basal cavity of the Pa element has prominent “lips”. The Sb and Sc elements have a large main cusp with the other denticles similar to those of the other elements.

Remarks. – The designated Pb element for the apparatus (Fig. 28L) bears some resemblance to the Sa element of Amydrotaxis johnsoni (see Klapper & Murphy 1980, fig. 3.13) and to the ?Sa element of the Ludlow Apparatus A of Ueno (1980, p. 48, pl. 9, fig. 3), but has a more restricted basal cavity and a greater number of denticles set on a broader blade and, additionally, has three or more prominent medial denticles.

Genus and species unknown

Apparatus A
Figure 29A–I

Remarks. – A small number of distinctive elements were recovered from the Mountain Dam Formation. They are characterised by thick angulate blades, stout triangular denticles, a small but flared basal cavity and a distinctive asymmetry on either side of the cusp. Many of these elements (e.g. Fig. 29A, B) are only very slightly bowed, whereas others are bowed more strongly (e.g. Fig. 29C). They probably occupied one of the P positions in the apparatus. These elements have some similarity to those of the Silurian genus Ctenognathodus but they are left in open nomenclature here because of their small numbers.

Acknowledgements

David Alder and Noreen Clark, then employed in the petroleum exploration section of the Geological Survey of New South Wales, drew our attention to carbonate horizons within the Devonian sequences of the Darling Basin that they suspected might yield biostratigraphically useful and even age-constraining information, and went to considerable trouble to provide us with samples for acid-leaching from various bores in the basin. Soon thereafter, Evan Leitch, formerly of the University of Technology Sydney, sent a limestone sample (B 16L herein) to Ruth Mawson and John Talent. This sample, from a small area of outcrop of the Booth Limestone on the Multagoona Anticline on “Manuka” station, proved unexpectedly productive of well-preserved conodonts. This prompted a Masters investigation by one of us (Mathieson), completed in 2006, which subsequently expanded into a much greater regional investigation incorporating additional field investigations. The project benefited greatly from Peter Molloy’s expertise with the acid-leaching of numerous samples, Ron Oldfield’s expert guidance in optical microscopy and Deborah Birch’s skill with a near-gerontic Scanning Electron Microscope. Dean Oliver used his amazing skill of turning mud-map drawings into elegant text-figures. Stuart and Nancy Moseley of “Manuka”, Diane Whiteman of “The Rookery”, John, Linda and Dino Mekritzis of “The Bluff”, and David and Pam Smith of...
“Marobee” generously allowed access to their properties to collect samples, provided stimulating conversation, and numerous re-inventing cups of tea. The New South Wales National Parks and Wildlife Service obligingly gave permission to sample in the Stoney Tank area of the Gundabooka National Park. Ian Percival, Geological Survey of New South Wales, assisted with providing access to subsurface cores through relevant horizons. The project in the earlier phase as a Masters dissertation was facilitated by two research grants: a postgraduate one from Macquarie University, and another from the Joyce Vickery Fund of the Linnean Society of New South Wales. We thank colleagues at the Geological Survey of New South Wales for access to much unpublished data that greatly assisted with this project and opens up new research opportunities to build on this work.

We extend sincere thanks to the two reviewers Ladislav Slavík and John Pickett who through a combination of international perspectives and deep local knowledge were able to make constructive comments and suggestions about both the minutiae and global picture that urged us to rethink the structure of the manuscript leading to a greatly improved final result. Our thanks also to our patient handling editor David Holloway for his meticulous work in facilitating the coherence and logic of the final product.

We are grateful to our MUCEP friends and colleagues over many years for their good cheer, encouragement and lively engagement when our own “liveliness” was flagging. We specifically thank Peter Cockle, Michael Engelbreten, James Valentine and George Wilson for numerous courtesies with the computer and in the acid-leaching facility that helped the project towards completion.

References


BARBANOVA, V.V. 2012. Lower Devonian conodont zonation in arc-related sequences and in the acid-leaching facility that helped the project towards completion.


BRANTZ, E.B. & MEHL, M.G. 1933. Conodont studies No. 1: Conodonts from the Harding Sandstone of Colorado; Bainbridge (Silurian) of Missouri; Jefferson City (Lower Ordovician) of Missouri. University of Missouri Studies 8(1), 7–72.


CORRIGA, M.G., SUTTNER, T.J., CORRADINI, C., KIDO, E.,


Furey-Gregg, T.M. 2000. Late Ordovician (Eastonian) conodonts from the Early Devonian Drik Drik Formation, Woolomin area, eastern Australia. Records of the Western Australian Museum Supplement 58, 133–143.


DOI 10.1080/0812009908728143


DOI 10.1016/j.earscirev.2006.01.001


DOI 10.1080/03115518.2016.1129490


