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AUSTRALIAN DEVONIAN AND CARBONIFEROUS CONODONT FAUNAS

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The first report of conodonts from Australia was by Crespin (1943) who described two Ordovician species from the Waterhouse Range of Central Australia.

Australian Devonian conodonts were first illustrated by Müller (1956) from material collected by Glenister from the Canning Basin. This fauna was also reported by McWhae et al (1958), Glenister (1958, 1960), Glenister & Crespin (1959) and Glenister & Furnish (1962) and the detailed systematics was published by Glenister & Klapper (1966).

Carboniferous conodonts were first mentioned by McWhae et al (1958) and Glenister (1960) from the Bonaparte Gulf Basin, Western Australia. These faunas have been described by Jones & Druce (1966), Roberts et al (1967), and Druce (1969).

Subsequent studies on Upper Devonian and Lower Carboniferous conodont faunas have tended to be concentrated in Western Australia although a few faunas are known from eastern Australia (Jenkins, 1966; Druce, 1970a, b, c; Philip & Jackson, 1971; Pickett, 1972a). Western Australian specimens are usually amber coloured and are extremely well preserved; eastern Australian specimens tend to be black and some are strongly deformed.

Known Middle Devonian conodont faunas are virtually restricted to Eastern Australia and have been reported extensively by Philip (1966), Philip & Pedder (1964; 1967a, b), and Pedder, Jackson & Ellenor (1970).

Recently, correlation charts for the Australian Devonian (Strusz, 1972; Pickett, 1972b; Roberts et al, 1972) and Carboniferous (Jones et al, in press) have been published; conodont data were used extensively in their construction. A correlation chart (Fig. 1) for all Australian sequences which have yielded conodonts is used as the framework for this paper. It includes a range chart of key species. The localities mentioned on the chart and in the text are shown in Figure 2.

LOWER DEVONIAN

Emsian

For many years the Devonian sequence at Buchan in eastern Victoria and the Taemas-Cavan sequence in the Murrumbidgee Valley area of southern New South Wales were considered to be Middle Devonian.

However, a review of the macrofaunas (corals, brachiopods, and a dipnoan) and the recognition of conodonts led Philip & Pedder (1964) to conclude that these sequences are Lower Devonian, ranging from Siegenian to Emsian.

The Lower Devonian outcrops of eastern Australia consist of interbedded limestone and clastic rocks; most conodont recovery has been from limestone because of ease of extraction. Continuous calcareous sequences are unknown and the conodont record is built up from information from beds which are separated geographically and temporally.

The three subspecies of Polygnathus linguiformis Hinde recognized by Philip & Jackson (1967) are extremely useful in delineating the Emsian. Pedder, Jackson & Philip (1970) state that the earliest subspecies of P. linguiformis, dehiscens, is of earliest Pragian age because it is found 30 m above Monograptus yukonensis Jackson & Lenz which is closely comparable to a graptolite known from Czechoslovakia in strata of Pragian age. Because of the uncertainty of the correlation between the Siegenian-Emsian and the Pragian, Pedder et al (op. cit.) recognized a Siegenian-Emsian interval, rather than delineating the Siegenian horizon equivalent to the Emsian boundary in Australia. This interval is characterized by the presence of P. linguiformis dehiscens. The Siegenian is represented by the Spathognathodus sulcatus fauna (Philip & Pedder, 1967a).

P. linguiformis folveolatus Philip & Jackson is the middle member of the sequence exhibiting changes in the basal cavity and platform. Philip & Jackson (1967, p. 1264) compare it to Lower Emsian forms from Germany (Bischoff & Ziegler, 1957). Philip & Pedder (1967c) discuss the position of the Siegenian-Emsian boundary and note that 'the base of faunal unit E (Xystriphyllum mitchelli fauna) approximates to the entry of Polygnathus linguiformis foveolatus Philip & Jackson'; they consider that this is the oldest fauna of definite Emsian age.

Strusz (1972) considers that these ages require modification and P. linguiformis dehiscens may indicate earliest Emsian. It is joined by Polygnathus lenzi Klapper in the early Emsian and is replaced by P. linguiformis foveolatus in the late Emsian. Pedder, Jackson & Philip (1970) include P. lenzi forms within their concept of P. linguiformis dehiscens.

The P. linguiformis dehiscens and P. lenzi (probably earliest Emsian) fauna is known from the Cavan Limestone of the Burrinjuck area, southern New South Wales (Philip & Pedder, 1967b; Philip & Jackson, 1967; Pedder, Jackson & Philip, 1970), and the Lick Hole limestone of southern New South Wales (Flood, 1969); it has also been recorded from high in the Garra Formation, central New South Wales, by Philip & Pedder (1967c) and the Buchan Caves Limestone at Bindi, eastern Victoria (Bischoff, *fide* Strusz, 1972). It may also be present in the Loyola Limestone of the Eildon region, eastern Victoria (Cooper *fide* Strusz, 1972). The fauna includes *Spathognathodus* (pro *Eognathodus* - Klapper, 1969) *linearis* (Philip), *S. primus* subsp.nov. (Branson & Mehl) *S. steinhornensis exiguus* Philip, and *S. steinhornensis optimus* Moskalenko (= *S. steinhornensis buchanensis* Philip).

The *Polygnathus linguiformis foveolatus* fauna (probably middle Emsian) is more extensive in its occurrence; it overlies the *dehiscens-lenzi* fauna at both Burrinjuck, New South Wales (Taemas Limestone, central and upper part (Pedder, Jackson & Philip, 1970) and Bindi, Victoria (Taravale Formation) (Bischoff, *fide* Strusz, 1972). It is also known from the Buchan district of eastern Victoria (Taravale Formation and Murrindal Limestone Member) (Philip, 1966b). Philip & Pedder (1967c) list the species from unnamed strata near Lake Bathurst (60 km northeast of Canberra), New South Wales.

Pickett (1972b) also records the *foveolatus* fauna from the Jesse Limestone (about 23 km north-northeast of Bathurst, New South Wales) and the Mount Knowles Limestone of the Dubbo area, New South Wales. The fauna has also been recorded from North Queensland in the Dip Creek Limestone Member of the Broken River Formation some 240 km northwest of Charters Towers (Telford *in* Pickett, 1972b) and the Douglas Creek Limestone of the Clermont area (Philip & Pedder, 1967c).

The *Polygnathus linguiformis foveolatus* fauna includes *Spathognathodus linearis* (Philip) and *Spathognathodus steinhornensis optimus* Moskalenko. *S. steinhornensis exiguus* is rare.

The recognition of an Emsian/Eifelian boundary in Australia is difficult. Strusz (1972) points out that the Emsian/Eifelian boundary in the Rhineland correlates with a level within the Couvinian (Co1b) in the Ardennes. The conodont sequence in Belgium appears to lack the early subspecies of *P. linguiformis*; the fauna changes from icriodids (including *I.* cf. *I. corniger*) in the late Emsian, to *Icriodus corniger* Wittekindt and *Polygnathus* cf. *webbi* Stauffer in the earliest Couvinian (Co1a) with *P. linguiformis* Hinde making an appearance in Co1b (= base of Eifelian, (Bultynck, 1970).

In Australia, however, *P. linguiformis* s.s. first appears in the late Emsian in association with *Spathognathodus linearis* (Philip), *S. steinhornensis exiguus* Philip, and abundant *S. steinhornensis optimus* Moskalenko (Pedder, Jackson & Philip, 1970). This fauna is known from the upper part of the Taemas Limestone at Wee Jasper, southern New South Wales (Pedder et al., *op. cit.*).

MIDDLE DEVONIAN

Eifelian

Strusz (1972) demonstrates that the Emsian/Eifelian boundary cannot be recognized in Australia because sections which are thought to cross the boundary have not yielded diagnostic fossils.

The boundary is probably represented by the extinction of the Spathognathodus steinhornensis group (Philip & Pedder, 1967c) and Polygnathus linguiformis foveolatus Philip & Jackson (Strusz, 1972, p.436) and the incoming of Icriodus corniger Wittekindt and Polygnathus webbi Stauffer (Pedder, Jackson & Ellenor, 1970). The latter authors point out that the association of P. webbi, P. linguiformis s.s., and I. corniger is known from the latest Emsian Heisdorfer Schicten of the Eifel. However, Bultynck (1970, p. 103) considers that I. corniger is no older than Middle Devonian.

The earliest Eifelian conodont fauna recognized in Australia is the Icriodus corniger assemblage which is equated with Wittekindt's (1966) corniger-Zone. This occurs at the base of the Timor Limestone which is exposed 25 km northeast of Murrundi, New South Wales (Pedder, Jackson & Ellenor, 1970). The Timor Limestone spans most of the Middle Devonian, and Pedder et al (op. cit.) recognize four successive conodont assemblanges.

The I. corniger assemblage is followed, albeit after a short break, by the Polygnathus kockelianus australis assemblage comprising the name giver, P. angustipennatus Bischoff & Ziegler, P. pseudofoliatus Wittekindt, P. robusticostatus Bischoff & Ziegler (s.l.) and a few

Spathognathodus bidentatus s.s. Bischoff & Ziegler and S. intermedius Bultynck (= S. bidentatus transitans Bultynck) (Pedder et al, op. cit., p. 249). This fauna is correlated with that of the bidentatus-Zone of Wittekindt and is considered to be of middle Eifelian age. In Belgium S. bidentatus makes a later appearance with P. kockelianus s.s. Bischoff & Ziegler but the Timor assemblage appears to be equivalent to Couvinian 2cIII (Bultynck, 1970).

A fauna described by Druce (1970a) from the Mount Holly Beds at Marmor yielded Polygnathus linguiformis s.s.; originally I considered it to be late Emsian because of the presence of simple cone species; with increased knowledge of the distribution of Devonian cones there is no reason why it could not be Eifelian.

Givetian

In the Timor Limestone the australis assemblage is followed, after a slight gap, by the Polygnathus kockelianus-P. robusticostatus assemblage which contains, besides the index species, P. trigonicus Bischoff & Ziegler and P. eiflius Bischoff & Ziegler. This assemblage probably persists across the Eifelian/Givetian boundary and is equivalent to the combined interval covered by Wittekindt's kockelianus-, eiflius-, and robusticostatus-Zones. In Australia the ranges of P. kockelianus and P. trigonicus extend upward to near the first occurrence of Polygnathus varcus Stauffer which is generally considered to be of late Givetian age. Thus the Moore Creek Limestone, in the Tamworth area, New South Wales, which contains a similar fauna, could range in age from late Eifelian to mid-Givetian. Philip (1966a), considering European conodont ranges, had concluded that it was late Eifelian; the corals suggest that Philip's view is substantially correct (Pedder, Jackson & Ellenor, 1970).

The uppermost conodont assemblage is that of Polygnathus varcus Stauffer of late Givetian age. The fauna includes Spathognathodus brevis Bischoff & Ziegler and other long-ranging forms; in one section in the Timor Limestone Ancyrognathus walliseri 'may indicate correlation with the walliseri horizon of the middle varcus-Zone' (Pedder et al, op. cit. 1970).

Polygnathus varcus Stauffer has been reported from the Canning Basin (Glenister & Klapper, 1966) where the initial Devonian transgression is considered to have taken place in the late Middle Devonian (Playford & Lowry, 1966). However, Seddon (1970) considers that the specimens should be more correctly included in Polygnathus xylus Stauffer and that P. varcus is confined to the Middle Devonian. The presence of the brachiopod Stringocephalus in the Home Range in the Canning Basin suggests the presence of the Givetian. I have collected from this outcrop and have found no Polygnathus varcus, but abundant icriodids, P. decorosus Stauffer, and P. xylus Stauffer. This tends to support my suggestion (Druce, in press) that the Schmidtognathus hermanni-Polygnathus cristatus Zone may be represented by a Biofacies II fauna (Druce, 1973) indistinguishable from that of the early Frasnian.

Similarly the fauna described by Seddon (1969) from the Gneudna Formation of the Carnarvon Basin, Western Australia is of Biofacies II aspect and could be either latest Givetian or earliest Frasnian (Seddon, 1969, p. 25); it is very similar to faunas associated with Stringocephalus in the Canning Basin.

UPPER DEVONIAN

The Upper Devonian rocks of the Canning Basin have yielded conodont faunas which virtually reproduce the conodont zones erected in the classic German sequence (Ziegler, 1962; Glenister & Klapper, 1966; Seddon, 1970; Druce, in press).

Frasnian

The problems associated with recognizing the upper boundary of the Givetian have been discussed above. The early Frasnian is, however, easily recognized; the Polygnathus asymmetricus Zone includes ancyrodellids (especially A. rotundiloba (Bryant)), polygnathids (P. asymmetricus Bischoff & Ziegler) and palmatolepids (P. punctata (Hinde), P. transitans Müller, P. hassi Müller & Müller, and P. proversa Ziegler). This zone is recognised within the Gogo Formation (inter-reef), Sadler Limestone (fore-reef), Virgin Hills Formation (fore- and inter-reef), and in subsurface dolomite penetrated in Matches Springs No. 1 well (McTavish fide Roberts et al. 1972).

The Ancyrognathus triangularis Zone is present in the Virgin Hills Formation and, at one locality, the Sadler Limestone; it is characterized by the presence of ancyrodellids (especially A. nodosa Ulrich & Bassler) and palmatolepids (P. hassi Müller & Müller, P. punctata (Hinde) and P. unicornis Miller & Youngquist).

The early Frasnian is represented in Australia by one other fauna from Mount Morgan, Queensland (Druce, 1970b). Originally I considered the fauna to be probably Upper Frasnian because of the presence of Ancyrognathus asymmetricus (Ulrich & Bassler). However, two indeterminate fragments appear to belong to Palmatolepis punctata (Hinde), which suggests early Frasnian. Recently Mouravieff (pers. comm.) has found a new species of Ancyrognathus of early Frasnian age to which he would refer my specimens of A. asymmetricus; furthermore, the polygnathids, which I left in open nomenclature, appear to belong to a new species described from the early Frasnian of the Canning Basin (Druce, in press).

Jenkins (in Roberts et al, 1972) points out that the basal part of a sequence of interbedded volcanics and sediments in the Keepit Inlier, New South Wales, have yielded a conodont fauna which may belong to the A. triangularis Zone although no diagnostic forms have been recovered.

Upper Frasnian faunas in Australia are referable to the Palmatolepis gigas and part of the Palmatolepis triangularis Zones. In the Canning Basin these zones are found in the Virgin Hills and Napier Formations. Characteristic species include Ancyrognathus asymmetricus (Ulrich & Bassler), A. altus Müller & Müller, A. irregularis, Branson & Mehl, Palmatolepis gigas Miller & Youngquist, P. foliacea Youngquist, and P. linguiformis Müller in the P. gigas Zone.

Conodont faunas of this age are also known from the Bonaparte Gulf Basin where they have been found in the Westwood Member of the Cockatoo Formation (Druce, 1969). Other members, the Kununurra, Hargreaves, and Jeremiah, yielded non-diagnostic conodonts but they are considered to be generally of Frasnian age (Druce, op. cit.).

Recently two faunas of this age were reported from New South Wales; Jenkins (in Roberts et al., 1972) records conodonts diagnostic of the P. gigas Zone from the Keepit Inlier and Pickett (1972a) has also recorded a fauna from Ettrema, New South Wales which he refers to the Palmatolepis gigas Zone. This fauna contains abundant polygnathids but only a single palmatolepid; however, the presence of Ancyrognathus asymmetricus (Ulrich & Bassler) indicates the P. gigas Zone.

In the Canning Basin it is possible to recognize all the European Frasnian conodont zones above the hermanni-cristatus Zone; these zones are present in the fore- and inter-reef sediments but cannot be recognized in the reef and back-reef sediments. Seddon (1970) recognizes two distinct biofacies, the Palmatolepis sequence (Biofacies III) and the Icriodus sequence (Biofacies II). In an attempt to elucidate the relationship of these two distinct sequences he set up a series of zones based on icriodid species. Seddon's zonation covers most of the Frasnian and consists of three zones (I. symmetricus, I. curvatus, and I. alternatus). The I. symmetricus Zone is approximately equivalent to the Lower Polygnathus asymmetricus Zone; the I. curvatus Zone is equivalent to the Middle and Upper Polygnathus asymmetricus and the Ancyrognathus triangularis Zones; and the I. alternatus Zone is approximately equivalent to the Lower Palmatolepis gigas Zone. The fauna from the Westwood Member of the Cockatoo Formation in the Bonaparte Gulf Basin is probably referable to the I. alternatus Zone as is the fauna from Ettrema.

The conodont fauna from the Gneudna Formation of the Carnarvon Basin (Seddon, 1969) is possibly referable to the _I. symmetricus_ Zone.

Frasnian/Famennian Boundary

Bouckaert & Ziegler (1965) have shown that the oldest beds of the Famennian in the Senzeille Section can be referred to the Middle _Palmatolepis triangularis_ Zone. The Senzeille Section is the only section where the Frasnian/Famennian boundary is exposed; unfortunately no conodont faunas are known from the latest Frasnian 'Schistes de Metagne'.

In the Canning Basin the boundary between the Lower and Middle _Palmatolepis triangularis_ Zone is taken at the first occurrence of _Palmatolepis delicatula_ Branson & Mehl; _Palmatolepis gigas_ Youngquist has a last occurrence within the zone. _Palmatolepis subrecta_ Miller & Youngquist occurs in both zones; its extinction marks the top of the Middle _Palmatolepis triangularis_ Zone. No other area in Australia has yielded faunas indicative of the Frasnian/Famennian boundary; it is probably represented in the Cockatoo-Ningbing sequence in the Bonaparte Gulf Basin, but diagnostic conodonts have not been recovered from the upper part of the Cockatoo Formation (Druce, 1969).

Famennian

Famennian conodont faunas have been recorded from the Canning and Bonaparte Gulf Basins of Western Australia and from the Tamworth area of New South Wales.

In the Canning Basin the European Zones can be recognized (especially the early Famennian) in the Virgin Hills and Napier Formations.

The Palmatolepis triangularis Zone (middle and upper parts) is characterized by the presence of Palmatolepis triangularis (Sannemann) and P. delicatula Branson & Mehl. The Palmatolepis crepida Zone yields a fauna which includes Palmatolepis minuta loba Helms, P. quadrantinodosolobata Sannemann, P. cf. P. regularis Cooper, P. subperlobata Branson & Mehl, P. tenuipunctata Sannermann and Polygnathus glaber s.s. Ulrich & Bassler.

The first occurrence of P. glabra pectinata Ziegler, P. quadrantinodosa inflexoidea Ziegler, P. quadrantinodosa marginifera Helms, and Polygnathis triphyllatus (Ziegler) marks the base of the Palmatolepis rhomboidea Zone. No zones have been erected based on Biofacies II faunas, but Druce (in press) has suggested that Icriodus arkonensis Stauffer and Polygnathus cf. P. pennatus are Biofacies II species which are virtually restricted to the early Famennian.

The Palmatolepis quadrantinodosa Zone is present in the Canning Basin in the Virgin Hills and Napier Formations and the Bugle Gap Limestone. Key species include Palmatolepis distorta Branson & Mehl, P. glabra acuta Helms, and subspecies of P. quadrantinodosa and P. rugosa. In the Bonaparte Gulf Basin the Ningbing Limestone probably includes this zone. The fauna contains a preponderance of subspecies of Palmatolepis glabra, and Polylophondonta confluencs (Ulrich & Bassler); Roberts et al (1967) and Druce (1969) consider that the Ningbing Limestone has a probable range of toIIβ - toVI: the latter horizons are characterized by Palmatolepis gracilis sigmoidalis Ziegler, Polygnathus hassi Helms, and Spathognathodus aculeatus (Branson & Mehl). It may, however, extend into the Tournaisian (see below).

A fauna from the base of the Baldwin Formation of the Tamworth area of New South Wales is referable to either the P. rhomboidea or Lower P. quadrantinodosa Zone (Philip fide McKelvey in Roberts et al, 1972).

The late Famennian in the Canning Basin is characterized by faunas which do not allow the fine zonation erected in Europe to be used. The Scaphignathus veliferus Zone is recognizable, but not the subzones; the Polygnathus styriacus Zone is present but lacks the index species and palmatolepids are rare. The S. veliferus Zone is present in the Virgin Hills and Piker Hills Formations and the Bugle Gap Limestone. Characteristic species include Scaphignathus veliferus Ziegler, subspecies of Palmatolepis glabra and P. minuta, Polygnathus perplexus Thomas and P. znepolensis Spasov.

The Polygnathus styriacus Zone yields a fauna which includes Polygnathus collinsoni Druce, P. irregularis Thomas, P. subserratus Branson & Mehl (= Scaphignathus subserratus of some authors) and Spathognathodus bohlenanus Helms. This zone is found in the highest beds of the reef complex in the Canning Basin, the Bugle Gap Limestone, and the Piker Hills Formation.

The reef complex is succeeded by a late Devonian and early Carboniferous platform carbonate; the name Fairfield Beds has been applied to the Devonian part and Laurel Formation to the Carboniferous part. Recently, Playford & Lowry (1966) have changed the concept of Fairfield to include both the Fairfield Beds and the Laurel Formation.

The Fairfield Beds (sensu Guppy et al, 1958) yield a fauna including Polygnathus collinsoni Druce, abundant pelekysgnathids, Spathognathodus crassidentatus (Branson & Mehl), and icriodids. The early fauna is similar to that in the Piker Hills Formation; the later fauna includes Spathognathodus spinulicostatus (E.R. Branson). This fauna together with Palmatolepis gracilis sigmoidalis Ziegler has been recovered from rocks between 3850 m and 4572 m in Yulleroo No. 1 Well (Bischoff fide Roberts et al., 1972).

Elsewhere the late Famennian is represented by a fauna from the Bonaparte Beds in Kulshill No. 1 Well (3820-3823 m) (Druce in Roberts et al, 1967) which is possible referable to either the Scaphignathus veliferus or the Polygnathus styriacus Zone. In New South Wales, Philip & Jackson (1971) have found a fauna indicating the Spathognathodus costatus Zone (sensu Ziegler) in the Luton Formation; important species include Palmatolepis gracilis Ziegler, Polygnathus vogesi Ziegler and Pseudopolygnathus trigonicus Ziegler.

DEVONIAN/CARBONIFEROUS BOUNDARY

In the deeper parts of both the Bonaparte Gulf Basin and the Canning Basin there is probably a continuous sequence of strata across the Devonian/Carboniferous boundary. At the margins of both basins, however, there are probably local disconformities.

Bonaparte Gulf Basin

Devonian/Carboniferous sediments occur in different settings: the platform carbonate province and the basinal shale province. In the basinal shale province conodonts are rare; isolated horizons are referable to the Visean (Mestognathus) (Druce, 1969) and Famennian (Palmatolepis minuta). Although the basinal shale sequence (mainly Bonaparte Beds) ranges from Famennian (at least) to Visean, micropalaeontological evidence for the position of the Devonian/Carboniferous boundary is very poor.

The platform carbonate province is divided into two depositional areas; a reef complex on the western margin and an alternating sequence of limestone and sandstone on the southeastern margin. Within the reef complex only the back-reef is well exposed; it is Famennian. The poorly exposed fore-reef has, however, yielded Famennian and Tournaisian conodonts, but the outcrop is not good enough to pinpoint the boundary.

In the southeast the sequence is Buttons Beds (Famennian), Burt Range Limestone, Enga Sandstone, and Septimus Limestone (all Tournaisian); no structural break is visible (Veevers & Roberts, 1968). The age of the Buttons Beds at this locality is taken to be early Famennian; ostracod evidence shows that this section can be correlated with the type section, which is considered to be early Famennian on the presence of Polylophondonta sp. A (Druce, 1969, pl. 34, fig. 4). No conodonts were recovered in this section.

The Burt Range Limestone yielded conodonts but they are mainly spathognathodids and represent Biofacies II, which makes dating difficult. Siphonodella praesulcata Sandberg has been recovered from the basal beds of the unit; it is considered to range from latest Famennian to earliest Tournaisian. There is a strong possibility that the Devonian-Carboniferous boundary occurs within this sequence but the microfossil evidence, at present, is weak.

Canning Basin

The basinal shale facies of the Fitzroy Trough has been penetrated by one well, Yulleroo No. 1 (Bischoff, 1968, unpubl.). The sequence ranges in age from latest Famennian (*Spathognathodus costatus* Zone *sensu* Ziegler) to late Visean or earliest Namurian. Conodonts have been recovered from isolated horizons within the 3950 m of sediments and, although the temporal extent can be deduced, the position of the Devonian/Carboniferous boundary cannot be determined accurately and the nature of the faunas at this horizon is unknown.

The shelf carbonate sequence comprises the Fairfield Beds (Guppy et al, 1958) and the Laurel Formation (Thomas, 1959); these have been united as the Fairfield Formation (Playford & Lowry, 1966) but other workers (Roberts, 1971; Roberts et al, 1972; Jones et al, in press) reject this view. Currently work is in progress on the palaeontology, petrology, and geochemistry of this sequence. Roberts et al (1972) discuss the palaeontological evidence which suggests a stratigraphic break at, or about, the Devonian/Carboniferous boundary; Playford & Lowry (1966) on the other hand consider that the evidence for an unconformity is not conclusive. Further mapping has shown that the critical interval is poorly exposed but that there is some section between the previously described youngest Fairfield Beds and the oldest Laurel Formation.

Thus, although there are several sequences in Australia which cross the Devonian/Carbinferous boundary, the conodont information is still poor.

LOWER CARBONIFEROUS

Tournaisian

(a) Bonaparte Gulf Basin

The thickest, continually exposed, Tournaisian conodont-bearing sequence in Australia is in the Bonaparte Gulf Basin.

Druce (1969) recognized a sequence of eight conodont zones in the Burt Range Formation, Enga Sandstone, and Septimus Limestone. They are based on the occurrence of Biofacies II faunas, and Jones et al (in press) have pointed out that some of the zones may be equivalent to some of the siphonodellid zones rather than younger as was suggested by Druce (1969). Although Druce (1973) suggested that the biofacies picture was relatively simple, it may be complicated. For example the *Clydagnathus nodosus* Zone may represent the intercalation of a shallower fauna; in a sequence deposited in deeper water it may not be represented. On the other hand, relative shallowing of the sea may introduce the *Clydagnathus nodosus* fauna at other horizons.

The earliest fauna recognized is in the lowest 16 m of the Burt Range Formation; it contains *Spathognathodus* cf. *S. tridentatus* (Branson & Mehl) and *Siphonodella praesulcata* Sandberg, and is either latest Famennian or earliest Tournaisian.

The lowest zone recognized is the *Spathognathodus plumulus* Assemblage Zone, which is overlain by the *Siphonodella sulcata*-*Polygnathus parapetus* and the *Siphonodella isosticha*-*P. inornatus nodulatus* Assemblage Zones and which is equivalent to the cuI zone of Germany and the Tn1b of the standard Belgian sequence (Jones et al in press).Siphonodellids (including

S. sulcata (Huddle) and S. isosticha (Cooper) are rare, and the common species are subspecies of Spathognathodus plumulus Rhodes, Austin & Druce, Polygnathus parapetus Druce, P. communis dentatus Druce, and clydagnathids.

Jones et al (op. cit.), following Matthews (1970a, b) recognize a gap in the goniatite sequence between cuI and cuII, which they consider to be equivalent to the Tn2 and early Tn3 of the Belgian sequence. The remaining conodont zones fit within this interval according to Jones et al (op. cit.); they are the Siphonodella quadruplicata-S. cooperi, Clydagnathus nodosus, Spathognathodus tridentatus, S. costatus (sensu Druce), and Pseudopolygnathus nodomarginatus Assemblage Zones.

The lower part of this sequence is characterized by rare siphonodellids, subspecies of Polygnathus inornatus, P. elongonodosus Druce, Clydagnathus darensis Rhodes, Austin & Druce, and "Gnathodus" burtensis Druce (?an aberrant Polygnathus communis). The upper part of the sequence is characterized by laterally nodose spathognathodids of the S. tridentatus gens, Pseudopolygnathus nodomarginatus (F.R. Branson) and Clydagnathus darensis Rhodes, Austin & Druce.

One sample from reef limestone in the Bonaparte Gulf Basin, 7/1, poses problems; it contains good zonal conodont species, Siphonodella quadruplicata (Branson & Mehl), S. cooperi Hass, Polygnathus communis carinus Hass, and Pseudopolygnathus triangulus triangulus Voges. Druce (1969) correlated this fauna with the Siphonodella quadruplicata-S. cooperi Zone in the Burt Range Formation, probably equivalent to early Tn2. This correlation was strengthened by the discovery of the brachiopod Acanthocosta teicherti Roberts, the index species for the A. teicherti Zone, at both the 7/1 locality and in the interval 470-720' (142-218 m) in the Burt Range Formation (an interval which includes the S. quadruplicata-S. cooperi Zone).

However, recent studies in Belgium (Groessens, 1971) suggest that the fauna may be younger, and perhaps mixed. Groessens records the last occurrence of Siphonodella at the Tn2c/Tn3a boundary; Polygnathus communis carinus Hass has a first occurrence in Tn3a and Pseudopolygnathus triangulus pinnatus Voges (= P. triangularis s.s. Voges, (Druce, 1969, pl. 37, fig. 2)) appears in Tn3b.

The problems of correlating the 7/1 locality can be summarized as follows:

1. The siphonodellids in the Burt Range Formation do not represent the total range of the genus; the fauna at 7/1 is of Tn3a age and is equivalent to the overlying spathognathodid zones in the Burt Range Formation or younger. When considering the Belgian ranges the following solutions are possible:
2. Polygnathus communis carinus Hass and Pseudopolygnathus triangularis pinnatus Voges occur earlier in Australia.
3. Siphonodella occurs later at the 7/1 locality than in Belgium, and far later than in the southeast platform area of the Bonaparte Gulf Basin.
4. The 7/1 locality contains either a condensed or admixed fauna including early Tn2, Tn3a, and Tn3b, and perhaps, latest Tournaisian faunas.

Finally the original suggestion of Druce (1969), that the range of Siphonodella in the Burt Range Formation is equivalent to its total range may be correct; in this case the Enga Sandstone and Septimus Limestone are of late Tournaisian age (Tn3a-Tn3c). If this is true then the 7/1 locality is:

5. Late Tn2 and *Polygnathus communis carinus* Hass and *Pseudopolygnathus triangularis pinnatus* Voges occur slightly earlier in Australia than in Belgium.
6. The 7/1 sequence is condensed (possibly admixed) and includes late Tn2 and Tn3 elements.

If the 7/1 fauna is a mixture of elements of different ages then the presence of *Polygnathus bischoffi* Rhodes, Austin & Druce suggests a latest Tournaisian age and thus would be some of the youngest Tournaisian known in the basin.

(b) Canning Basin

The Lower Carboniferous conodonts from the Laurel Formation are being studied by McTavish (West Australian Petroleum Pty. Ltd) and Druce & Nicoll (Bureau of Mineral Resources). Roberts et al (1972) review the occurrence of Carboniferous conodonts in samples from the Fairfield Formation (*sensu* Playford & Lowry, 1966) (= Laurel Formation Thomas, 1959).

Jones (*in* Roberts et al, 1972) has recognized faunas indicating the presence of *Siphonodella sulcata*-*Polygnathus parapetus* and *Spathognathodus tridentatus* Assemblage Zones. Further work has shown that a majority of other zones recognized in the Bonaparte Gulf Basin are present in the Canning Basin, including the *Siphonodella praesulcata* fauna.

In the thick shale sequence in the trough Bischoff (*fide* Roberts et al 1972) has recognized in Yulleroo No. 1 Well a thick Tournaisian sequence overlying the late Devonian *Spathognathodus costatus* Zone (*sensu* Ziegler, 1962). A fauna from the interval 12042-12230' (3649-3706 m) contains *Siphonodella* cf. *S. quadruplicata* (Branson & Mehl),

S. obsoleta Hass, and Polygnathus communis carinus Hass. This suggests a correlation with the Siphonodella quadruplicata-S. cooperi Assemblage Zone of the Bonaparte Gulf Basin. At a higher interval 11 456' (=3472 m) two specimens of Spathognathous costatus sensu Rhodes, Austin & Druce suggest the presence of the Spathognathouds costatus Assemblage Zone sensu Druce.

(c) Eastern Australia

Published reports on Tournaisian faunas from Eastern Australia are few. Druce (1970c) described faunas from the Yarrol Basin, Queensland; they include an early Tournaisian fauna from the Gudman Oolite Member of the Malchi Formation which includes Siphonodella sp. and Polygnathus communis dentatus Druce, suggesting a correlatión with the lower half of the Burt Range Formation of the Bonaparte Gulf Basin (Tn1b).

A late Tournaisian fauna was recovered from an unnamed limestone bed within the Malchi Formation; it includes Gnathodus delicatus Branson & Mehl, Pseudopolygnathus nodomarginatus (Branson & Mehl), P. triangulus Voges, and a staurognathid-like form (= S. cruciformis Branson & Mehl of Druce, 1970c). This probably correlates with the Dollymae bouckaerti Assemblage Zone or perhaps the Doliognathus latus Subzone of Groessens (1971).

Branagan et al (1970) record a fauna from the Glenbawn area, New South Wales. The Brushy Hill Limestone contains Patrognathus sp. similar to P. andersoni Klapper (Jenkins, fide Jones et al, in press), which is probably of Tn2 age. Overlying this, within the Dangarfield Formation, Jenkins (op. cit.) has recovered a fauna with abundant pseudopolygnathids of late Tournaisian age.

The Rangari Limestone Member of the Tulcumba Sandstone in the Werri-Belvue area has yielded a fauna which is probably of late Tn2 age (this is in the mis-named 'Berwick Formation' of Rhodes, Austin & Druce, 1969, p.60) (see Jones et al, in press for details).

Visean

Visean conodont faunas have not been described in detail. All described faunas are from isolated outcrops in the Bonaparte Gulf and Canning Basins in Western Australia and in the Yarrol Basin of eastern Australia.

(a) Bonaparte Gulf Basin

Visean faunas are known from four different localities. The Utting Calcarenite yields the *Gnathodus texanus* fauna (Assemblage Zone of Druce, 1969, p. 38). This includes *Gnathodus texanus* Roundy, *Mestognathus beckmanni* Bischoff, *Spathognathodus coalescens* Rexroad & Collinson, and *S. scitulus* (Hinde), and indicates a correlation with the cuIIδ ammonite zone of Germany (Druce, 1969). Jones et al (in press) discuss the correlation with the Belgian standard succession and conclude that it is of V2-V3a age.

The Burvill Beds yield a poor fauna which includes *Gnathodus girtyi simplex* Dunn and *Cavusgnathus* sp.; this fauna is probably late Visean in age.

In the subsurface, the Bonaparte No. 1 and No. 2 Wells have yielded unidentified gnathodids and *Mestognathus beckmanni* Bischoff which are probably early Visean in age (Druce, 1969).

(b) Canning Basin

Visean conodonts are known only from the subsurface in the Fitzroy Trough. Bischoff (*fide* Jones et al, in press) reports *Cavusgnathus unicornis* Youngquist & Miller and *Spathognathodus scitulus* (Hinde) from the interval 2840-2890' (866-881 m) in Yulleroo No. 1 Well; this is probably early Visean. In Barlee No. 1 Well Bischoff (op. cit.) records latest Visean conodonts.

(c) Eastern Australia

A Visean fauna is known from rocks equivalent to the Little Larcomvale Formation, it includes *Gnathodus girtyi* Hass and *G. texanus* Roundy suggesting an early V3 age (Druce, 1970c). The extensive occurrence of *Taphrognathus capricornus* Druce was considered by Druce to indicate the Visean because of its occurrence in the Bonaparte Gulf Basin in the *Gnathodus texanus* fauna. *Taphrognathus capricornus* is now considered to be a separate species from that in the Bonaparte Gulf Basin; however, the unnamed species does occur in the Yarrol Basin. The only sample in which *T. capricornus* is not unique is from the Kolonga Creek Limestone Member of the Splinter Creek Formation, 3.2 km southwest of Kalpowar, in the Monto area, Central Queensland; a single specimen occurs with ten specimens of *Gnathodus antetexanus* Rexroad & Scott (= *G. texanus* Roundy of Druce, 1970a), and *G. cuneiformis* Mehl & Thomas. The presence of a broken mestognathid suggests that the fauna is close to the Tournaisian-Visean boundary, probably Tournaisian.

Finally a fauna from Murgon in southeast Queensland has yielded Upper Carboniferous conodonts (Palmieri, 1969). Palmieri concludes that some of the samples may be as old as late Mississippian (Chesterian), equivalent to a horizon near the Visean-Namurian boundary. However, the presence of the genus Idiognathoides suggests that they are probably Namurian; the remaining samples are of Westphalian age.

CONCLUSIONS

Conodonts have proved extremely useful in correlating Australian Devonian and Carboniferous faunas with the European standard successions.

In the Lower Devonian many European species are recognized and the correlation problems are mainly concerned with the relations between the Emsian and the Pragian. The isolated Middle Devonian limestones of the Lachlan geosyncline have yielded diagnostic conodonts; European index species are present but in some places appear to have slightly longer ranges.

Upper Devonian faunas have demonstrated the use of conodonts in international correlation. The European index species are abundant and the German zonation can be recognized in detail. The zonal application tends to break down in the late Famennian, where the European faunas are rare or absent; however, the Australian faunas are known from North America.

This dichotomy of faunas is also present in the Tournaisian, and firm recognition of the Devonian/Carboniferous boundary is not possible. However, the faunas do appear to be similar to Belgian faunas and correlation with the type Tournaisian is more confident than with the German cephalopod zones. The scanty information available on Visean faunas suggests that index European and American species are present.

The interpretation of Australian stratigraphy in international terms has been greatly enhanced by conodont study.

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To accompany Record 1973/127

FIG I Correlation chart of Devonian and Carboniferous conodont sequences (stippled) and ranges of Key Species

M(S)272

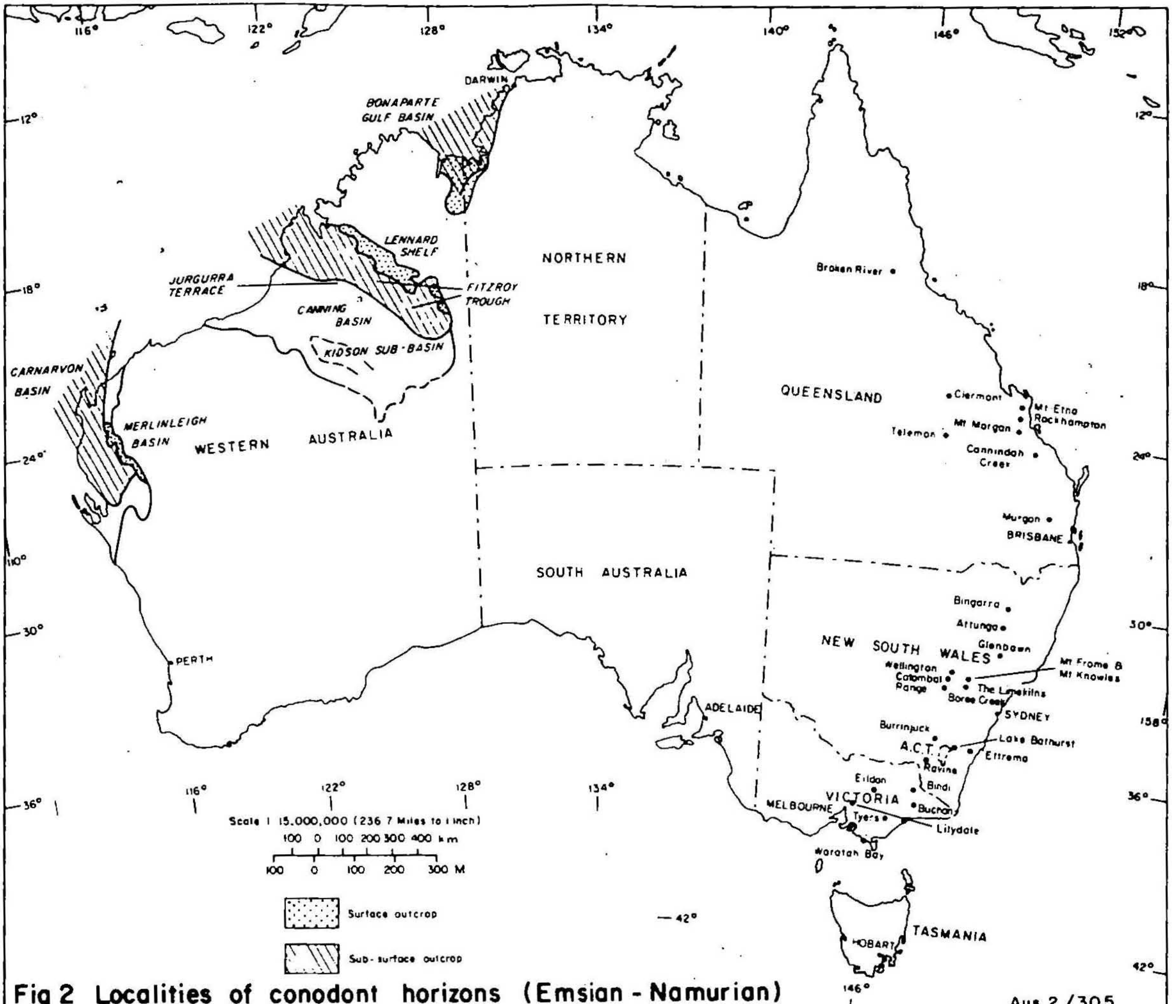

Fig 2 Localities of conodont horizons (Emsian - Namurian)

To accompany Record 1973/127