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Preliminary report on the biostratigraphy of new placoderm discoveries in the Hervey Group (Upper Devonian) of central New South Wales

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Abstract – Re-mapping during 1994–96 of the Upper Devonian on the Parkes and Grenfell 1:100,000 map sheets was the first systematic field examination of this area by an experienced vertebrate palaeontologist. This resulted in the discovery of some 40 new fossil localities (mostly fish) at various horizons within the Hervey Group. Two new fish occurrences, in sediments associated with the underlying Dulladerry Volcanics, require an age revision from Early to late Middle Devonian for the termination of Devonian volcanism in central New South Wales. The age of the Canowindra fossil fish fauna is uncertain, but may be as old as late Frasnian, rather than Famennian as was previously assumed. Correlations across the Lachlan River are clarified, and a new locality for the sinolepid antiarch *Grenfellaspis* is reported from near the top of the Bumberry Formation. A fish fauna from higher in the sequence includes an antiarch with an armour 1–2 m long, of comparable size to similar material from South China, which supports a latest Devonian Asian connection with East Gondwana. Preliminary analysis of faunal content is used to propose a provisional succession of six faunal zones, to improve the resolution on the Late Devonian part of the macrovertebrate zonation for East Gondwana.

INTRODUCTION

Fossil fish remains were first reported from the Hervey Group of central N.S.W. over 60 years ago (Hills 1932), but systematic studies of the fish faunas have only recently gained momentum. Hills (1932, 1936) recorded isolated plates and spines including placoderm remains (fragments of a phyllolepid; antiarchs *Bothriolepis* and *Remigolepis*) from the Hervey Range, southeast of Peak Hill (locality 2, Figure 1B), and a "large bothriolepid plate" from the Jemalong Range, west of Forbes. He did not formally describe any of the material as existing or new species. The first species described was the 'crossopterygian' (tetrapodomorph sarcopterygian) fish *Canowindra grossi* published by Thomson (1973), based on a single specimen from a remarkable sandstone slab covered in fossil fish impressions discovered near Canowindra over 50 years ago (Fletcher 1956; locality 5, Figure 1B). Much additional material has recently been obtained from a new (1993) excavation of this site (Cribb 1996). Several new sarcopterygians have been described (Ahlberg and Johanson 1997; Johanson and Ahlberg 1997, 1998), and Johanson (1995, 1997a) has described the antiarch *Remigolepis* from the Canowindra fauna.

In the last 20 years two other significant fossil fish localities were found in the region, at Redcliff Mountain about 15 km northeast of Grenfell, and at Jemalong Gap, about 32 km southwest of Forbes. These are respectively 35 km southwest and 80 km west of the Canowindra locality (Figure 1). The Grenfell locality (8, Figure 1B) was first reported to contain the arthrodire *Groenlandaspis* (Ritchie 1975), but is now known to have a diverse fossil fish fauna. From this locality Ritchie *et al.* (1992) monographed a remarkable antiarch, *Grenfellaspis branagani*, belonging to the endemic Chinese family Sinolepidae, and Johanson (1997b) has recently described new species of the antiarchs *Bothriolepis* and *Remigolepis*. Various acanthodian and rhipidistian remains also occur in the fauna. Sinolepid antiarchs are a major placoderm fish group otherwise only known from the South and North China blocks, so this occurrence in the Lachlan Fold Belt of eastern Australia has biogeographic significance (Young 1990; Rich and Young 1996; Young and Janvier in press). The Forbes locality (3, Figure 1B) has produced the lungfish *Soederbergia*, and a lower jaw of an early amphibian (tetrapod), *Metaxygnathus*, (Campbell and Bell 1977, 1982), plus undescribed remains of the placoderms *Bothriolepis*, *Remigolepis*, *Groenlandaspis* and *Phyllolepis* (the lungfish *Soederbergia* has also recently been found in the Canowindra fauna; Z. Johanson, pers. comm. 1997).

Until recently, geologic knowledge of the Upper Devonian sediments of central N.S.W. was based on field mapping undertaken over 30 years ago by J. Conolly, who noted the occurrence of "fish plates" at various horizons, but based correlations between different outcrops primarily on lithology

(Conolly 1965; Conolly *et al.* 1969). He referred the Canowindra fish site to the Mandagery Sandstone within the Hervey Group, but many of his other 'fish plate' occurrences are doubtful. In 1989 the author and Dr Zhang Guorui, a fossil fish expert from the Institute of Vertebrate Palaeontology and Palaeoanthropology (Beijing, China), visited a number of Conolly's putative localities but no fossil fish remains were found. Apart from fish, the lycopod plant *Leptophloeum australe*, and one marine invertebrate locality (Etheridge 1901) were the only fossils recorded from the Hervey Group at that time. Williams (1977) reported a new marine invertebrate locality with lingulid brachiopods and bivalves (associated with 'fish plates') in the southern part of the Parkes Syncline, and Pickett (1993a) described a single specimen of a horseshoe crab *Kasibelinurus* from the Bumberry Syncline east of Parkes (M,K, Figure 1B).

Campbell and Bell (1977) were the first to compare the fossil fish assemblages at different localities in an attempt to integrate biostratigraphic evidence with the lithological correlations previously used (Table 1). They disagreed with Conolly's (1965) correlation of the Weddin Sandstone in the west with the Mandagery Sandstone further east. More recently, Ritchie *et al.* (1992) noted the significant differences in the content of the Grenfell fish fauna, and suggested that it was also considerably younger than indicated by lithological correlation. The earlier correlations of Conolly (1965) placed the Grenfell fauna at the top of his Hunter Siltstone, and stratigraphically below bluff-forming sandstones identified as the Mandagery Sandstone, the same formation that contains the Canowindra fish site. In a recent discussion of problems in correlation raised by the age assessment of Ritchie *et al.* (1992), Pickett (1993a: 282) concluded that "there can be no doubt of the Famennian age of the Mandagery Sst and at least some of its overlying formations". At the same time, Young (1993) presented an analysis of the macrovertebrate fish faunas of East Gondwana, and attempted a preliminary faunal zonation which recognized 15 distinct assemblages through the Devonian, with the Grenfell fish fauna representing the youngest known Devonian macrovertebrate assemblage from the non-marine sequences of eastern Australia.

In 1994 the Australian Geological Survey Organisation collaborated with the N.S.W. Geological Survey under the National Geoscience Mapping Accord, to initiate a field mapping program to revise the Forbes 1:250,000 geological map, the first edition of which was published in 1972. This map sheet includes the Grenfell and Forbes fossil fish localities, with the Canowindra site just off its eastern margin on the adjacent Bathurst 1:250,000 sheet (Figure 1A). During 1994–96 the author was responsible for re-mapping of Conolly's (1965) Upper Devonian stratigraphy of the Hervey Group on two of the six 1:100,000 map sheets (Parkes and Grenfell) covering this area. This was the first systematic field examination by an experienced vertebrate palaeontologist of these Upper Devonian strata. The Parkes sheet includes type sections for Hervey Group formations (e.g. Mandagery Sandstone of the Canowindra fauna), and the locality for Pickett's (1993a) horseshoe crab *Kasibelinurus* (T,K, Figure 1B). The Grenfell sheet, with over 400 km^2 of Hervey Group exposure, had yielded the sinolepid *Grenfellaspis* fish fauna, as mentioned above.

As a result of the 1994–96 field survey some 40 new fossil localities were discovered at various horizons within the Hervey Group. Most of these contain fossil fish, in some cases associated with plant remains, and at four localities (at least two different horizons) fish occur with linguloid brachiopods, and other invertebrates including bivalve molluscs, suggesting a marine influence. A few other localities yielded only plants or invertebrates. In addition many examples of fossil tracks and trails were recorded, and other evidence of biological activity is often seen at certain horizons in the Hervey Group (e.g. abundant burrowing and bioturbation of many fine-grained horizons).

This large collection of new fossil material has not yet been studied in detail. Material from most localities has been curated, and some has been prepared and briefly studied. However a preliminary assessment of faunal content, based on observations in the field, and/or during preliminary curation, has implications for the stratigraphy and correlation of the Hervey Group, and for macrovertebrate biostratigraphy and zonation as previously outlined (Young 1993, 1995; Young and Laurie 1996). The biostratigraphic information from these new fossil localities will provide a completely independent dataset with which to test previous lithological correlations of sequences in different areas, and in this paper I summarize some preliminary results. It is stressed that the mapping programme is not yet completed, and all biostratigraphic conclusions are provisional, requiring support from detailed taxonomic study of the new fossil assemblages.

Three aspects of Hervey Group stratigraphy on which the new fossil fish discoveries have had a major impact are briefly summarized below: (a) the previously assumed Middle Devonian hiatus, the age of underlying volcanics, and the termination of volcanism in central N.S.W.; (b) the age of the Canowindra fish site; and (c) correlations across the Lachlan River, and the age of the Grenfell fish fauna. The new biostratigraphic information is then summarized in a series of five provisional faunal zones which are related to an update of the

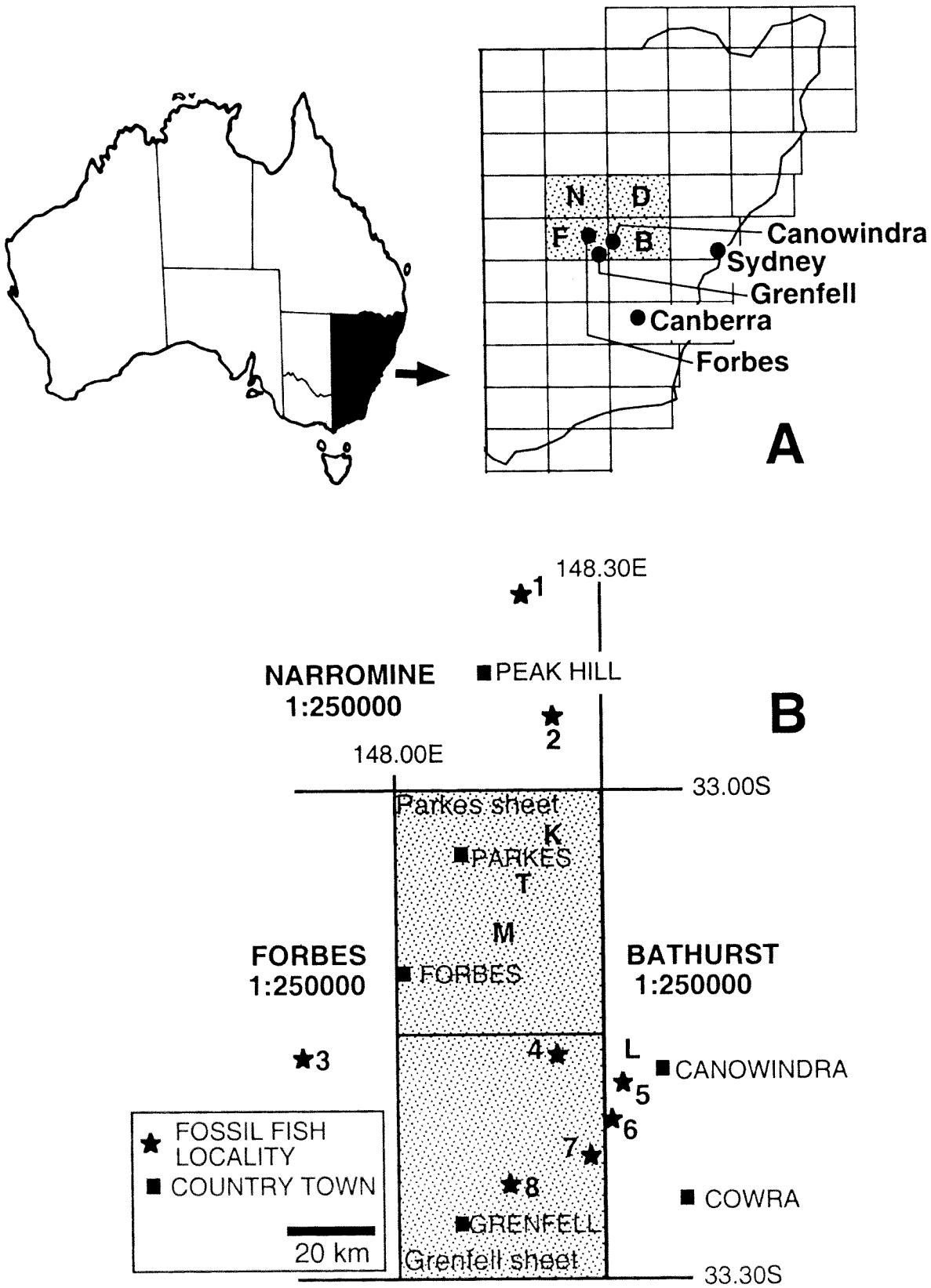

Figure 1 A. Region of central N.S.W. including fossil localities mentioned in the text, shown against the 1:250,000 map sheet grid. The four relevant geological maps are Narromine (N), Dubbo (D), Bathurst (B), and Forbes (F). B. Parkes and Grenfell 1:100,000 map sheets (eastern third of the Forbes 1:250,000 sheet) showing important fish fossil (numbered) and other localities in the Hervey Group. 1, Tomingley; 2, Gingham Gap, Hervey Range; 3, Jemalong Gap, Jemalong Range; 4, Nanami Road; 5, Canowindra fish site; 6, Merriganowry quarry; 7, Fragar's property; 8, Redcliff Mountain; K, *Kasibelinurus* locality of Pickett (1993a), Bumberry Syncline; T, Mandagery-Bumberry-Eurow Formation type sections, Parkes Syncline; M, marine lingulid locality, southern Parkes Syncline (Williams 1977); L, lingulid locality at Nyrang Creek (Etheridge 1901).

Table 1 Stratigraphic nomenclature for the Hervey Group, after Conolly (1965).

	HERVEY SYNCLINE	PARKES SHEET	GRENFELL SHEET
COOKAMIDGERA SUBGROUP	Burrill Fm	undiff.	undiff.
		Eurow Fm *	
NANGAR SUBGROUP	Caloma Sst.	Bumberry Fm *	Bumberry Fm
	Pipe Fm	Pipe Fm	
	Mandagery Sst.	Mandagery Sst.*	Mandagery Sst.
BEARGAMIL SUBGROUP	Kadina Fm	Kadina Fm	Hunter Slst.
	Clagger Sst.		Peaks Sst.

* type section in the Parkes Syncline, Parkes Sheet

macrovertebrate zonation previously published (Young 1993, 1995). The following stratigraphic subdivisions of the Hervey Group (oldest to youngest) are used in the text, as defined or recognized through the type sections in the Parkes Syncline by Conolly (1965): Kadina Formation, Mandagery Sandstone, Pipe Formation, Bumberry Formation, Eurow Formation. Existing stratigraphic nomenclature is summarized in Table 1.

Conolly (1965) mapped the Hervey Group largely by recognizing as formations the prominent strike ridges of sandstone separated by valleys of recessive finer-grained units. However, as pointed out by Sherwin (1973, figure 7), the prominence of such features depends largely on overall relief, and is often an unreliable basis for correlation. A good example is seen in the western limb of the Bumberry Syncline east of Parkes, on the main road to Molong, where high relief has obscured the normally recessive Pipe Formation. This is the important fossil locality (K, Figure 1B) which yielded the lycopod *Leptophloeum australe*, and the single specimen of the horseshoe crab *Kasibelinurus* (Pickett 1993a). According to existing geological maps this locality lies well within the 'Mandagery Sandstone' of Conolly (1965). New detailed field work, supported by airborne geophysical surveys, shows that lithological correlation failed over a distance less than 20 km from the type section in the Parkes Syncline. In the Bumberry Syncline the Pipe Formation is clearly recognized on radiometrics and lithology, and the Mandagery Formation is much less extensive than mapped by Conolly (1965). Much of the 'Mandagery' of previous maps is in fact the Bumberry Formation, including the sandstones beneath the dam wall of Lake Endeavour, which were illustrated by Conolly (1965, plates 2–3) as sedimentary structures from the Mandagery Formation.

NEW RESULTS

Middle Devonian hiatus and termination of volcanism in central N.S.W.

Two new fossil fish occurrences associated with volcanics underlying the Hervey Group have changed the accepted view of Devonian sedimentation and volcanism in central N.S.W. Previously, the Upper Devonian was assumed to unconformably overlie volcanics and sediments of Silurian-Early Devonian age, with the Middle Devonian represented by a hiatus in sedimentation (Conolly 1965; Packham 1969; Figure 2A). Webby's (1972, table 2) synthesis of the stratigraphy of the Lachlan Fold Belt showed the Middle Devonian as a time of "major orogenesis with main folding, uplift and granite emplacement", with volcanism terminating in the Lochkovian ('Gedinnian') on the Parkes Platform to the west, and as young as Eifelian (Winburn Tuff) on the Capertee Rise to the east. An unconformable relationship between the Hervey Group and underlying Early Devonian sediments and volcanics is established in some sections (Webby 1972; Powell *et al.* 1980).

A major underlying volcanic unit in the mapped region, the Dulladerry Volcanics, outcrops over a large area at the intersection of four 1:250,000 sheets (Narromine, Dubbo, Forbes, and Bathurst; Figure 1A), and has yielded a single fish plate, associated with plant remains (O'Sullivan 1992). The type area for the Dulladerry Volcanics (first description by Savage 1968) is the large outcrop on the northwestern corner of the Bathurst sheet, which

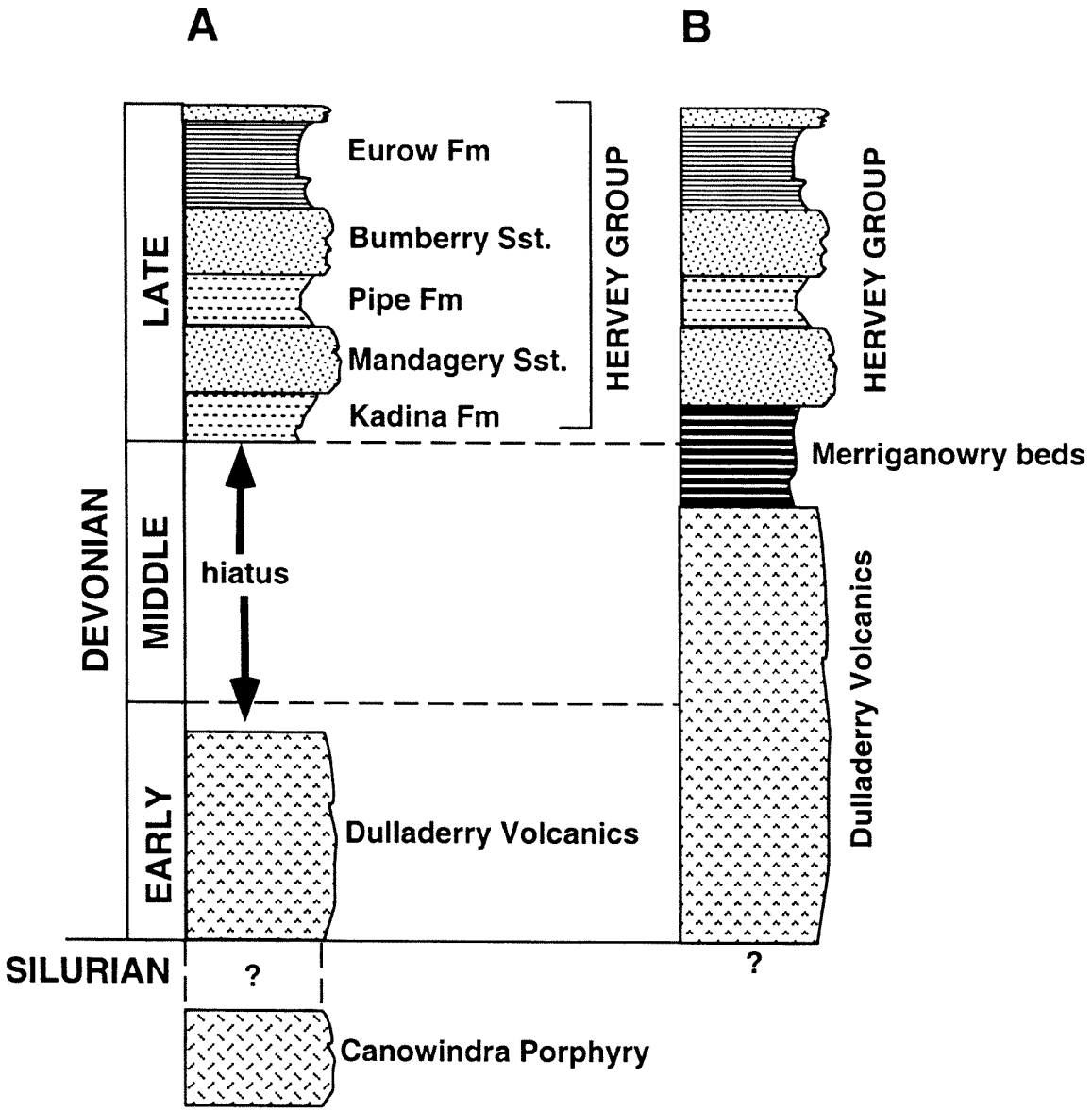

Figure 2 Previous (A) and revised (B) stratigraphy resulting from the discovery of a fish/plant assemblage of probable Givetian/Frasnian age in sediments associated with the Dulladerry Volcanics.

extends onto the southeastern part of the Narromine sheet, where it underlies the Hervey Group on the western limb of the Hervey Syncline (Sherwin 1996). At the northern end of the Hervey Range, near Tomingley (1, Figure 1B), an epithermal system within the Dulladerry Volcanics (Geopeko's Glen-Isla prospect) was studied by O'Sullivan (1992), who recorded a "plate fragment from the trunk shield of an unidentified Devonian arthrodire" from a sedimentary interbed of mudstone, conglomerate and chert (sinter) enclosed within coarsely phyric and flow-banded rhyolites. The associated plant remains were provisionally identified by Pickett (1993b) as *'Protolepidodendron' yalwalense*, a form previously recorded from southeastern New South Wales (e.g. Fergusson *et al.* 1979).

Upon examination in Canberra, it was clear that the fish specimen found by O'Sullivan was in fact a dermal bone impression of a phyllolepid placoderm, a group first recorded from southeastern Australia by Hills (1929), and subsequently found there at many localities (Young, in Fergusson *et al.* 1979; Long 1984, 1989; Ritchie 1984), as well as in Queensland, the Georgina and Amadeus Basins of central Australia and in southern Victoria Land, Antarctica (Young 1985, 1988a 1988b, 1989). This placoderm indicates an age of late Middle Devonian or younger (Young 1993).

In early 1993 another new Devonian fish locality was discovered by Dr A. Ritchie in a quarry at Merriganowry, about 120 km southeast of Tomingley (6, Figure 1B). This outcrop, previously

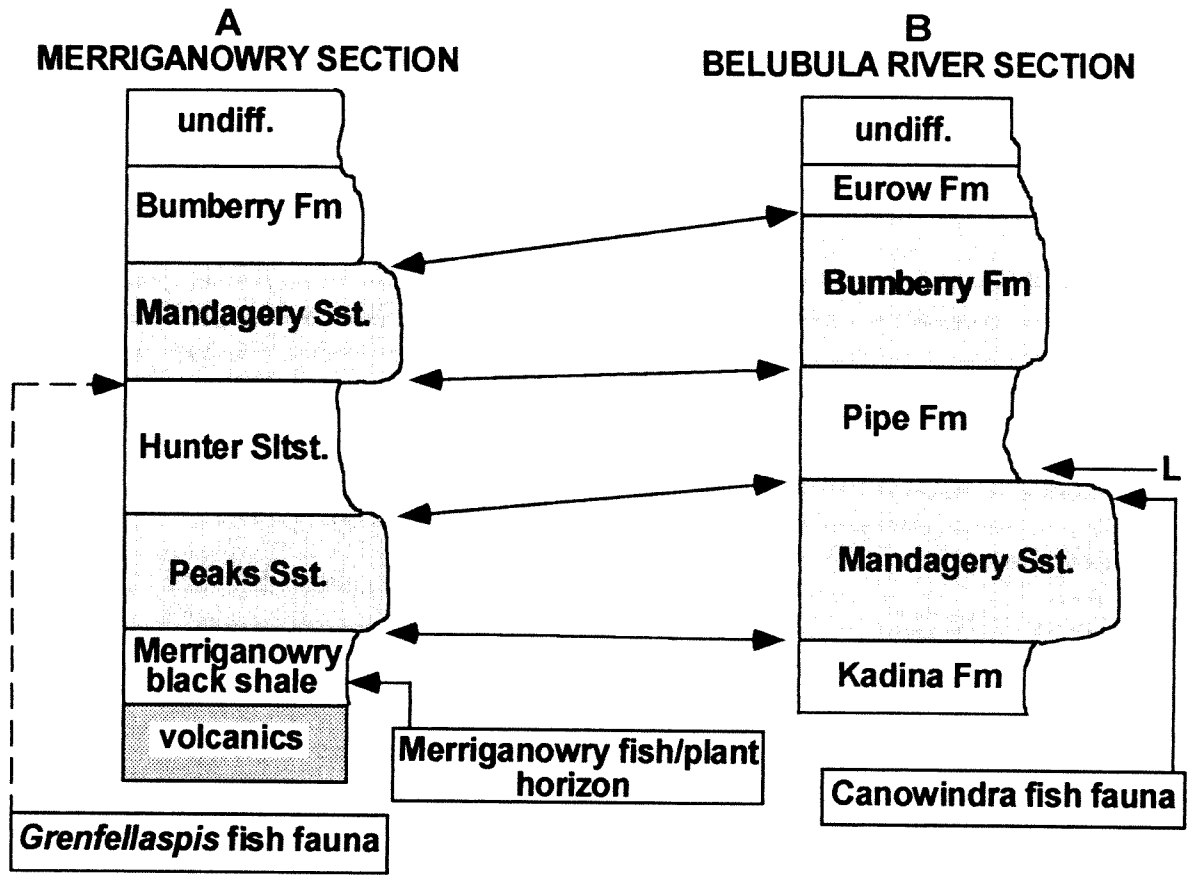

Figure 3 Comparisons of two sections through the M-U Devonian Hervey Group, with suggested correlations across the Lachlan River. Formation names are those used by Conolly (1965), and indicate his correlations. A, Merriganowry section, south of the Lachlan River; B, Belubula River section, including the Canowindra fossil fish site. The *Grenfellaspis* fish fauna has not been located in the Merriganowry section. L, assumed approximate stratigraphic horizon of the lingulid locality at Nyrang Creek, 8 km along strike to the north of the Canowindra fish site (L, Figure 1B).

mapped as Canowindra Volcanics (Silurian), also contains abundant remains of a new phyllolepid, associated with similar lycopod stems of *Protolepidodendron* type, and branching stems like those referred to *Praeramunculus alternatiramus* by McLoughlin and Long (1994). This association indicates a comparable age to the Tomingley occurrence. The locality is a black shale deposit closely associated with underlying volcaniclastics including rhyolite blocks and possible flows. The shale includes slumped beds and graded interbeds of rhyolitic sand up to about 30 cm thick, suggesting deposition in a lake of sufficient size and depth for turbidity currents to be generated, with water depths of tens to hundreds of metres, perhaps an elongate deep lake such as are associated with strike-slip faulting (P. O'Brien, pers. comm. 1994). The flow-banded rhyolites in the underlying volcanics at this locality are typical lithologies for the Dulladerry Volcanics (O. Raymond, pers. comm. 1995).

On the western limb of the Hervey Syncline the contact between volcanics and the overlying Hervey Group is often faulted, so it is not clear from field evidence whether there was a depositional break, but if so, it was probably of short duration (L. Sherwin, pers. comm.). At Merriganowry, field mapping in the surrounding area has shown the sandstone ridges about 1 km to the northwest to have the same dip and strike as the black shale in the quarry, and there is evidently a conformable sequence from the underlying volcanics and Merriganowry Beds in continuous section to the west, where they underlie strata mapped as Peaks Sandstone (Table 1).

Previously the Dulladerry Volcanics was dated as no younger than Early Devonian, based on conodonts from near Murga (Molong 1:100,000 sheet) on the eastern limb of the Eugowra syncline, which were determined by Pickett (1979) to indicate a late Lochkovian age. The conodont sample and age assessment were updated by Pickett (1993b) to the slightly younger early Pragian *sulcatus* Conodont Zone. The field relationship of this conodont locality is now suspect, being interpreted as a possible faulted block of older sediments (?Garra Formation) within the rhyolite, whilst a

provisional SHRIMP isotopic age determination of 376 ± 4 Myr from the middle flow-banded rhyolite unit of the Dulladerry Volcanics in the northwest corner of the Bathurst sheet (O. Raymond pers. comm. 1994) is entirely consistent with the fish and plant evidence (Young 1993, 1995). The consistent evidence from two localities 120 km apart indicates that, at least in some localities, volcanism in central N.S.W. continued until the late Middle Devonian (Figure 2B), as is the case with the Middle Devonian Comerong Volcanics and Boyd Volcanic Complex in the eastern part of the Lachlan Fold Belt (Eden-Comerong-Yalwal volcanic zone; Fergusson *et al.* 1979).

Age of the Canowindra fish fauna

The Canowindra fish site occurs about 8 km along strike to the south of a locality from which Etheridge (1901) described the inarticulate brachiopod *Lingula gregaria*, recorded as "Nyrang Creek, about five miles west of Canowindra" (L, Figure 1). R.K. Jones (1982, and pers. comm.) found the same lingulids at another locality in the vicinity (the type locality is not precisely known), a creek bed from which the author has also collected fish remains (*Bothriolepis* sp., antiarch indet. (coarse ornament); ?phyllolepid fragments, probable osteichthyan cycloid scales). No section has been measured here, but it lies to the west (i.e. higher in the sequence) than the main strike ridge of the westerly-dipping Mandagery Sandstone, in interbedded fine-grained sandstones and red siltstones probably representing the transitional beds to the overlying Pipe Formation. The Canowindra fish site also lies on the western slope of the Mandagery strike ridge, but occurs in sandstones, and thus presumably represents the upper beds of the Mandagery Sandstone (Figure 3B).

Young (1993: 216) argued that in the Hervey Group of central N.S.W. "there is no confirmed occurrence of fish remains older than the marine deposits forming the basal part of the sequence". This now seems incorrect if the lingulid horizon at Nyrang Creek is assumed to indicate brackish water conditions approximating stratigraphically the more extensive marine horizon farther east, which has been equated with the late Frasnian sea level high documented by conodonts etc. (Pickett 1972, 1993a). Jones, Turner and Fordham (in press) consider an alternative younger age (?Famennian) for a conodont assemblage from Gap Creek near Orange, but this seems unlikely for the Mandagery Sandstone, which is near the base of the Upper Devonian sequence in the Canowindra area. Other localities within the Pipe Formation support an older (?late Frasnian) age. Conolly (1965: 56) stated that lepidodendroid plant remains were the only fossils to be found in the Pipe Formation, but Williams (1975) reported abundant broken fish plates, and the new field work has confirmed abundant fish material in the valley south of the Mandagery railway section, in horizons in the lower part of the fine-grained recessive unit (Pipe Formation) overlying the type Mandagery Sandstone. The fauna includes the following: *Bothriolepis* sp., *Remigolepis* sp., *Groenlandaspis* sp., phyllolepid indet., osteolepid scales, and holoptychiid scales. The *Groenlandaspis* represents a different species from the one in the Grenfell assemblage at Redcliff Mountain, which is characterized by unornamented dermal bones (Ritchie *et al.* 1992). Detailed taxonomic work has not been undertaken, but it is predicted that these assemblages may include species in common with the Canowindra fish fauna, on the assumption that these faunas occupy a similar stratigraphic interval, representing the transitional beds between the upper Mandagery Sandstone and the lower Pipe Formation (Figure 3B). The change to fine-grained deposition may have been the lithological result of the marine flooding event, which caused brackish water conditions and the lingulid assemblage at the Nyrang Creek locality. The fine-grained Gooloogong Beds on the Grenfell sheet also contain lingulid brachiopods and placoderm plates (Colwell 1974; M. Jones 1984), suggesting correlation either with the Pipe Formation, or with the Kadina Formation in the Hervey Syncline, from which Sherwin (1996) has also recorded crinoid ossicles which indicate marine conditions.

The above discussion implies that the Canowindra fish fauna is likely to be late Frasnian in age, rather than Famennian as previously suggested (e.g. Young 1993, 1995). At several of the new fossil localities fish remains are also associated with lingulid brachiopods, indicating brackish water conditions. Their complete absence from other horizons with similar lithologies suggests that fish occurrences may have been related to marine influence in an otherwise predominantly fluvial system, and more than one episode of marine influence seems likely through the sequence.

Correlations across the Lachlan River and age of the *Grenfellaspis* fish fauna

Problems in correlation of the Mandagery Sandstone raised by Ritchie *et al.*'s (1992) age assessment of the Grenfell fish fauna were discussed by Pickett (1993a), who accepted the lithological correlations of Conolly (1965) to conclude that the Mandagery was of Famennian age.

Conolly (1965: 61) identified the Mandagery Sandstone in the Gooloogong-Grenfell area as the "first thick white sandstone formation overlying the red beds of the Beargamil Sub-Group", which "can be traced along the strike along the eastern side of the Manildra region across the Lachlan River down

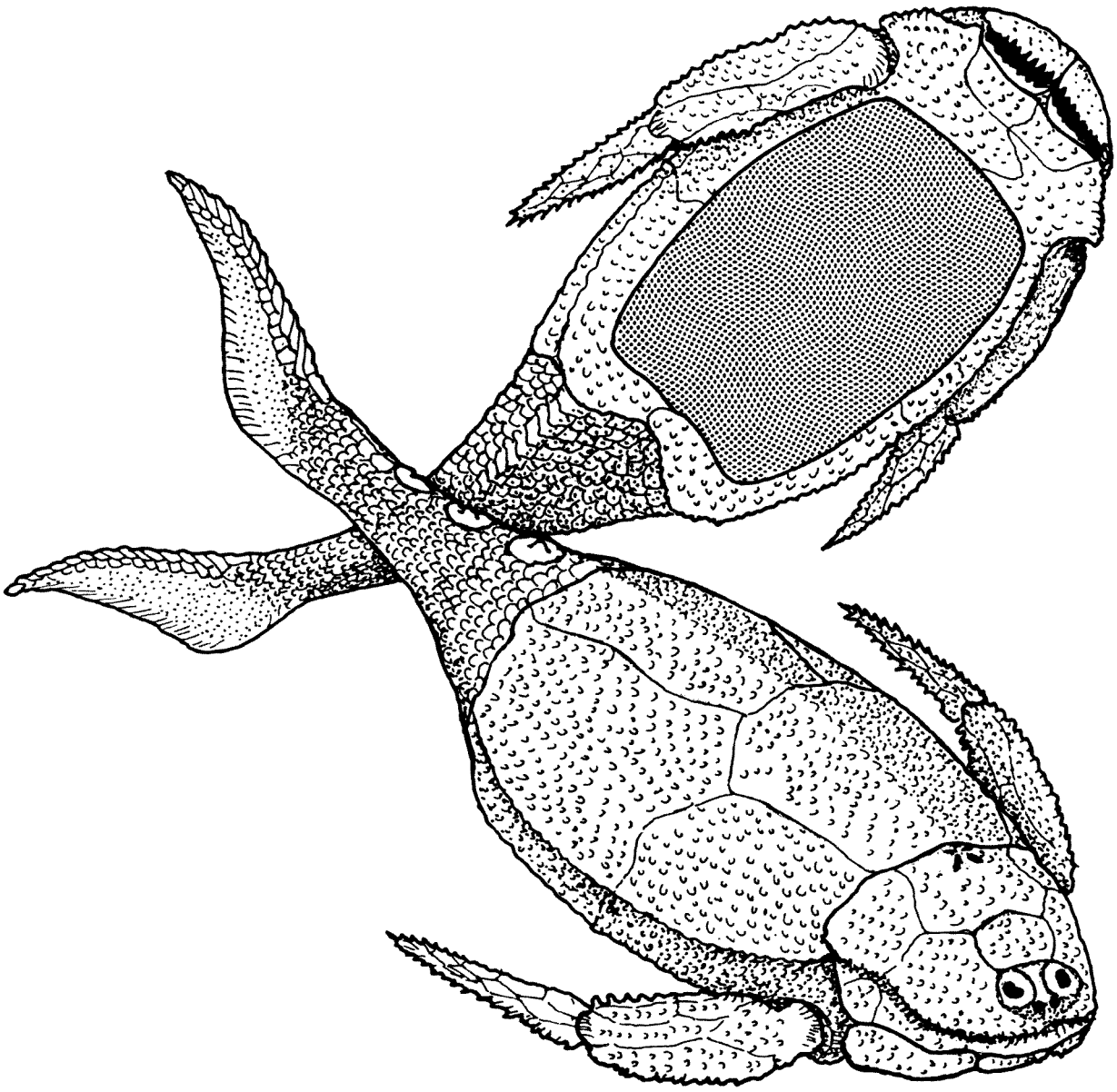

Figure 4 New reconstruction of *Grenfellaspis branagani* Ritchie *et al.*, 1992, based on the new articulated specimen from the Eugowra Syncline. Tail restoration based on study of specimens of the sinolepid *Liujiangolepis* described by Wang (1987).

the eastern side of the Grenfell-Gooloogong region". The northernmost outcrop south of the Lachlan River in this area is the Merriganowry section mentioned above (6, Figure 1B), where the sequence was given by Conolly (1965, figure 11) as: Peaks Sandstone, Hunter Siltstone, Mandagery Sandstone, and Bumberry Formation, overlain by undifferentiated Cookamidgera Sub-Group (Figure 3A). About 9 km to the north, across the river flats of the Lachlan and Belubula Rivers, is the most southerly outcrop of Hervey Group north of the Lachlan River. This sequence, which includes the Canowindra fish locality, is referred to here as the Belubula River section (Figure 3B). Comparing the two sections, a problem with previous stratigraphic nomenclature is evident, because the lowermost prominent sandstone ridge north of the Lachlan River was referred to the Mandagery Sandstone, and that south of the river was named the Peaks Sandstone. However, the type sections for the Peaks Sandstone (Peaks Creek, Redcliff Syncline) and overlying Hunter Siltstone (Hunter Gully Creek, Gooloogong Anticline) are some 20 km away, in the western part of the outcrop, and are not continuous along strike with the Merriganowry section. Like the Pipe Formation to the north, the Hunter Siltstone was identified by Conolly (1965: 61) as red siltstones and shales with some fine-grained red sandstones which "forms prominent valleys between the strike ridges of the Mandagery and Peaks Sandstones".

The *Grenfellaspis* fish fauna occurs just beneath the

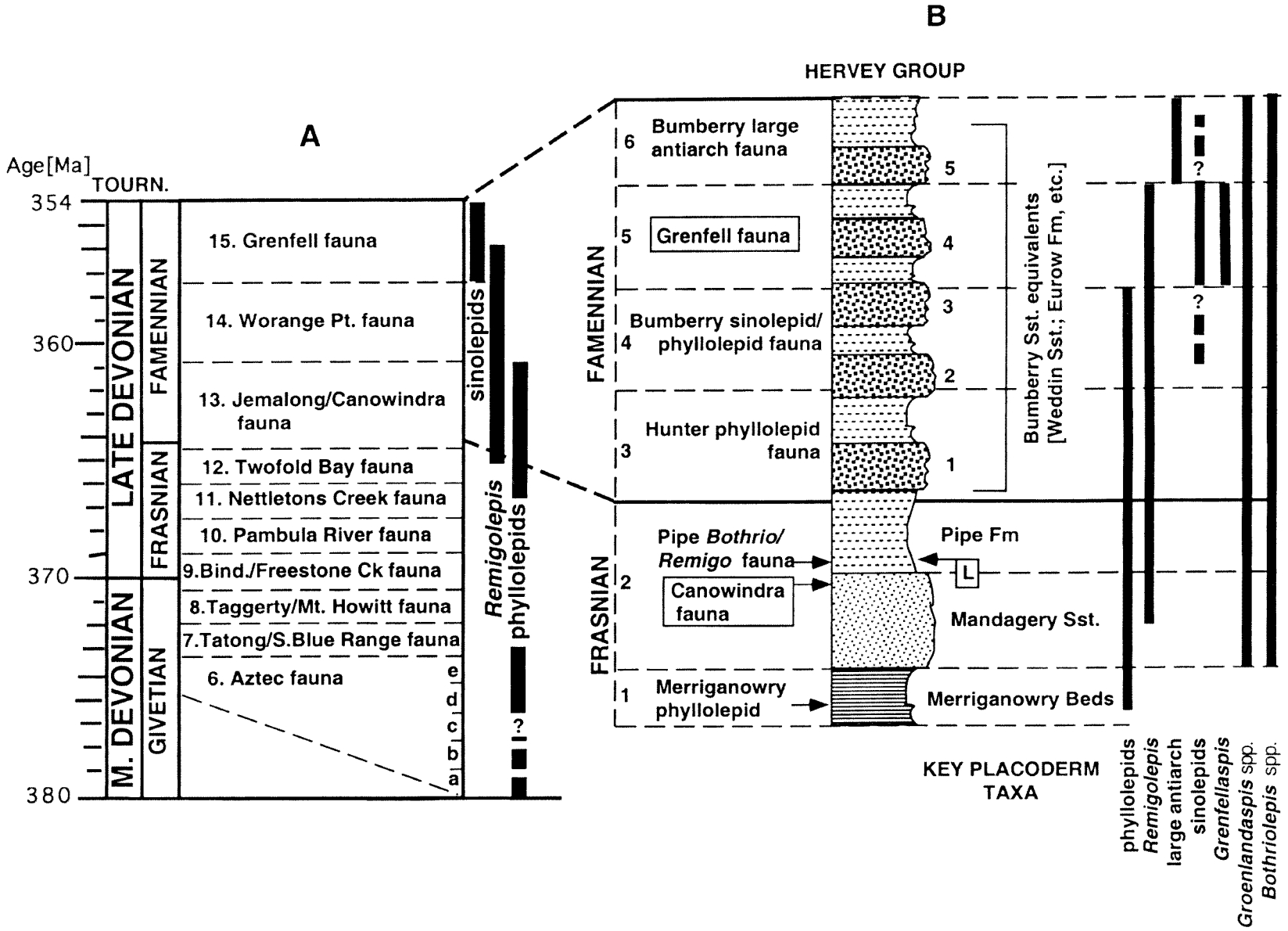

Figure 5 A. Alignments for Middle-Late Devonian macrovertebrate zones, modified from Young (1995), to incorporate new results from Hervey Group maping. B. Preliminary vertebrate faunal succession for the Hervey Group, with distribution of key placoderm taxa shown on the right. (L, assumed Nyrang Creek lingulid horizon; see Figures 1B, 3B).

base of sandstone ridges mapped by Conolly as Mandagery Sandstone, and alternative correlations (arrows in Figure 3) proposed by Ritchie *et al.* (1992) placed it at a higher level in the sequence than the Canowindra fish fauna. This interpretation is now supported by a new *Grenfellaspis* locality discovered in 1996, which is the first on the northern side of the Lachlan River, about 25 km downstream (northwest) of the Merriganowry section (4, Figure 1B). The locality is a gravel quarry on the western limb of the southern part of the Eugowra Syncline, in red mudstone forming an upper recessive unit near the top of the Bumberry Formation. This has yielded the only known articulated specimen of *Grenfellaspis branagani* (Figure 4). The Bumberry Formation is overlain by the recessive Eurow Formation, which forms the extensive alluvial valley in the core of this syncline, extending from Nanami in the south to Mount Taylor in the north (see Conolly 1965, figure 8). Whilst lithological boundaries over this distance are probably diachronous, general continuity of outcrop along strike leaves little doubt that this new fish horizon approximates to the upper Bumberry-lower Eurow interval in the type section in the Parkes Syncline.

MACROVERTEBRATE ZONATION

A generalized stratigraphic framework incorporating the issues just discussed is shown in Figure 5B. Black shales of the Merriganowry Beds form the base of the sequence overlying the volcanics. Above this, the first of alternating coarse and fine-grained units that characterize the Hervey Group is represented by the Mandagery Sandstone and overlying fine-grained Pipe Formation. A notional subdivision of five fining-upward cycles is shown for the upper part of the sequence. The Bumberry Formation in its type section (thickness 707 m), comprises four cycles, each with pebbly white sandstones at the base, interbedded red siltstones and white sandstones in the middle part, and fine red siltstones and shales at the top (Conolly 1965, figure 10). The overlying Eurow Formation was interpreted by Conolly as a fifth cycle in which fine-grained sediments predominated. This outcrop pattern can be traced south from the type section in the Parkes Syncline, and is also seen in the Eugowra Syncline, which includes the new *Grenfellaspis* locality. North of the Lachlan River the upper part of the sequence is predominantly fine-grained (Eurow Formation), but south of the Lachlan the upper part is predominantly coarse-grained (Weddin Sandstone), the latter formation being probably equivalent to one or more of the coarse-grained units within the Bumberry Formation to the north.

Distribution of key placoderm taxa (right side of Figure 5B), derived from a preliminary analysis of the new fossil localities, forms the basis for a provisional succession of new fossil faunas (left side, Figure 5B), with alignments to an updated macrovertebrate zonation shown in Figure 5A (see Young and Turner in press).

The oldest of six assemblages is the phyllolepid occurrence of the Merriganowry Beds. Fish remains in the upper Mandagery – lower Pipe interval probably include species in common with the Canowindra fish fauna, as discussed above. Several new localities in the middle part of the Hunter Siltstone northeast of Grenfell have yielded a phyllolepid assemblage (including *Bothriolepis*), which is distinguished from the Grenfell fauna (with *Grenfellaspis)* at the top of the Hunter Siltstone, which lacks phyllolepids. Detailed taxonomic comparisons are required to show whether this assemblage can be differentiated from the underlying *Bothriolepis/Remigolepis* assemblage. A noteworthy new faunal association is the possible stratigraphic overlap of phyllolepids and sinolepid antiarchs, based on a new assemblage from the Bumberry Syncline on the Parkes sheet. However, the putative sinolepid remains are fragmentary, so this association needs confirmation with better material. The Grenfell fauna, in its type locality occurring at the top of the Hunter Siltstone, is placed in the upper part of Bumberry Formation equivalents, as demonstrated by the new discovery north of the Lachlan River reported above.

The youngest assemblage is recorded from a number of localities in the Conimbla Syncline and adjacent areas of the eastern and northern parts of the Grenfell sheet. The original locality (7, Figure 1B), discovered in the early 1980's, was mentioned by Pickett (1993a: 282) as a "locality high in the Bumberry Fmn". No taxa have yet been described, but the assemblage is characterized by a large antiarch (new taxon) with an armour 1–2 m long, associated with *Bothriolepis* and *Groenlandaspis* remains, the latter distinguished from the smooth species in the *Grenfellaspis* fauna by their dermal ornament. Sinolepids are apparently absent, whilst the large antiarch may be compared with material of similar size from South China (Zhang Guorui pers. comm. 1989), perhaps additional evidence supporting a latest Devonian Asian connection with East Gondwana (Young 1990; Rich and Young 1996; Young and Janvier in press). At this stage, with detailed mapping of this area still incomplete, structural complexity permits only the general conclusion that the localities producing this uppermost fish assemblage occupy a high level within Bumberry/Eurow Formation equivalents.

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