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North-Eastern Molong Arch and Adjacent Hill End Trough (Eastern Australia): Mid-Palaeozoic Conodont Data and Implications

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7 Text-Figures (one in pocket), 14 Tables and 13 Plates

Australia
New South Wales
Silurian
Devonian
Lochkovian
Pragian
Emsian
Debris flows
Megabreccias
Carbonate fans
Olistoliths
Conodonts
Hill End Trough
Molong Arch
Capertee Arch

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Der nordöstliche Molong Arch und der benachbarte Hill-End-Trog (Ost-Australien): Mittelpaläozoische Conodonten-Daten und ihre Interpretation

Zusammenfassung

Conodontendaten werden vorgelegt aus Einzelproben eines Dutzends stratigraphischer Profile durch Einheiten mit silurischen und unterdevonischen Kalken des Dripstone-Mumbil-Euchareena-Gebietes auf der Westflanke des Hill-End-Troges, sowie von Limekilns weiter östlich innerhalb des Hill-End-Troges im ost-zentralen Teil von New South Wales.

Diese Einheiten repräsentieren drei weitgehend unterschiedliche karbonatische Sedimentationsbedingungen:

1) Vorfeld des Plattformrandes mit generell gradiertem, zeitweise vom Molong Arch (Tolga-Member der Cunningham-Formation) eingeschwemmtem Kalkdetritus;
2) Channel-Ablagerungen, Einschwemmungen von beckenwärts transportierten Karbonatmaterialien, die in tieferen Wasserbereichen ausfächern;
3) zwischenzeitliche, großformatige Plattformrand-Kollapsabsätze (Nubrigyn-Member der Cunningham-Formation) mit Megabreccien und häufig grob gradierten detritischen Kalken, im typischen Fall rhythmisch sedimentiert als Ausdruck der Diskontinuität des auslösenden Mechanismus.

Die Altersangaben nach Conodonten für die jeweiligen Materialien, die diese Sedimenteinheiten zusammensetzen, sind folgende: Kalk-Fan- oder Channel-Ablagerungen im Wallace Shale: frühes Wenlock (offensichtlich vom Nandillyan-Limestone ableitbar); Tolga-Member der Cunningham-Formation: späte *delta*-/frühe *pesavis*-Zone (spätes Lochkovium) und bis in die *sulcatus*-Zone hineinreichend; Red-Hill-Limestone-Member: *pireneae*-Zone bis in die *dehiscens*-Zone reichend; Nubrigyn-Member: *pesavis*-Zone bis *inversus*-Zone; obere Cunningham-Formation: wenigstens bis zur *serotinus*-Zone reichend; Jesse-Limestone-Member der Limekilns-Formation: *dehiscens*- bis *serotinus*-Zonen (angehäuft während der *serotinus*-Zone). Klasten und/oder debris-flow-Kalke von hoch aus dem Nubrigyn-Member und der oberen Cunningham-Formation kommen von Karbonatkörpern, die bis zu 3 Conodontenzonen jünger sind als die Karbonatvorkommen, die auf der Molong-Plattform erhalten sind; sie implizieren das Andauern einer oder mehrerer ehemaliger Folgen von Flachwasser-Karbonatsedimentation auf der Plattform während eines großen Teils oder des gesamten Emsiums. Im weiteren Sinne entsprechen die Daten vom Hill-End-Trog dem Bild einer reziproken Sedimentation: die Bildung von Karbonatfächern im Hill-End-Trog ist zu korrelieren mit regressiven Ereignissen auf der anliegenden Karbonat-Plattform. Diese hinterlassen dort Spuren in Form von massiven oder kaum gebankten Kalkeinheiten, die in Schwellenmilieus gebildet wurden; andere mit Fensterstrukturen deuten auf Sabkha-artige Sedimentation. Die Sedimentation des Nubrigyn-Members dürfte primär tektonisch kontrolliert worden sein, wobei ihr rhythmischer Charakter zwischenzeitliche Bewegung auf einer nach W vorwandernden Deformationsfront widerspiegelt.

Abstract

Conodont data are presented from spot samples and a dozen stratigraphic sections from Silurian and Early Devonian limestone-bearing units from the Dripstone-Mumbil-Euchareena area on the western flank of the Hill End Trough, and from Limekilns farther east within the Hill End Trough of east-central New South Wales. These represent three broadly contrasting environments of carbonate sedimentation:

1) Platform margin apron of generally graded limestone detritus swept intermittently from the Molong Arch (Tolga Member of the Cunningham Formation).
2) Channel deposits, delineating chutes down which carbonate materials were transported, fanning out in deeper water contexts.
3) Intermittent grand-scale platform-margin collapse deposits (Nubrigyn Member of the Cunningham Formation) with megabreccias and often coarsely graded detrital limestones, typically rhythmically emplaced, implying intermittency of the triggering mechanism.

Ages indicated by conodont data for materials making up these sedimentary packages are: Limestone fan or channel-deposit in the Wallace Shale: early Wenlock (apparently derived from Nandillyan Limestone); Tolga Member of Cunningham Formation: late *delta*/early *pesavis* Zone (late Lochkovian) extending into the *sulcatus* Zone; Red Hill Limestone Member: *pireneae* Zone extending into the *dehiscens* Zone; Nubrigyn Member: *pesavis* Zone through to *inversus* Zone; upper Cunningham Formation: extending through to at least *serotinus* Zone; Jesse Limestone Member of Limekilns Formation: materials of *dehiscens* to *serotinus* Zones (accumulated during the *serotinus* Zone). Clasts and/or debris-flow limestones from high in the Nubrigyn Member and upper Cunningham Formation were derived from carbonate bodies post-dating the carbonate record preserved on the Molong Arch by as much as 3 conodont zones; they imply persistence of a former tract or tracts of shallow water carbonate sedimentation on the platform through much or all of Emsian time. In a broad way, data from the Hill End Trough are consistent with a pattern of reciprocal sedimentation: development of carbonate fans within the Hill End Trough correlating with erosional/regressive events on the adjacent carbonate platform. The Nubrigyn Member sedimentation may have been primarily tectonically driven, its rhythmic character reflecting intermittent movement on fault systems (?an advancing deformation front) to the west.

1. Introduction

Devonian, especially Pragian to Givetian, limestones are widespread in eastern Australia. In recent papers attention has been directed to mid-Palaeozoic sequences with allochthonous limestones (Text-Fig. 1): the Walhalla Synclinorium of eastern Victoria (MAWSON & TALENT, 1994), the Tamworth Belt of northern New South Wales (FUREY-GREIG, 1995, and this volume; MAWSON et al., 1997), the Broken River and Camel Creek regions of northern Queensland (SLOAN et al., 1995; SIMPSON, this volume) and, herein, a series of mid-Palaeozoic (predominantly Early Devonian) limestones, mostly along the western margin of the Hill End Trough of New South Wales.

For much of Late Ordovician through Silurian into Early Devonian times, large areas of the northern Molong Arch (also referred to as Molong High and Molong Platform) intermittently accumulated shallow water carbonates and predominantly andesitic volcanics. These (Table 1) tend to occur in meridionally-aligned outcrop-tracts (Text-Fig. 2), often delineated by major meridional faults (Text-Fig. 3), many of the latter problematic as to precise age. A similar intricate pattern may have extended eastwards into the portion of the Hill End Trough considered in this report but, because of the thick cover of predominantly Early Devonian basinal sediments, little is known about mid-Silurian and older sequences in the Trough. A "window" of Late Silurian and Lochkovian volcanics and clastics, identified as consisting largely of Cuga Burga Volcanics and Wallace Shale (= Barnby Hills Shale) by COLQUHOUN et al. (1997), has nevertheless been brought up through the Early Devonian sedimentary cover in a tectonically complex

Text-Fig. 1.
Mid-Palaeozoic sequences of eastern Australia having substantial intervals of allochthonous limestones occurring in debris flows (including megabreccias) or as olistoliths – with references to conodont faunas and showing location of study areas.

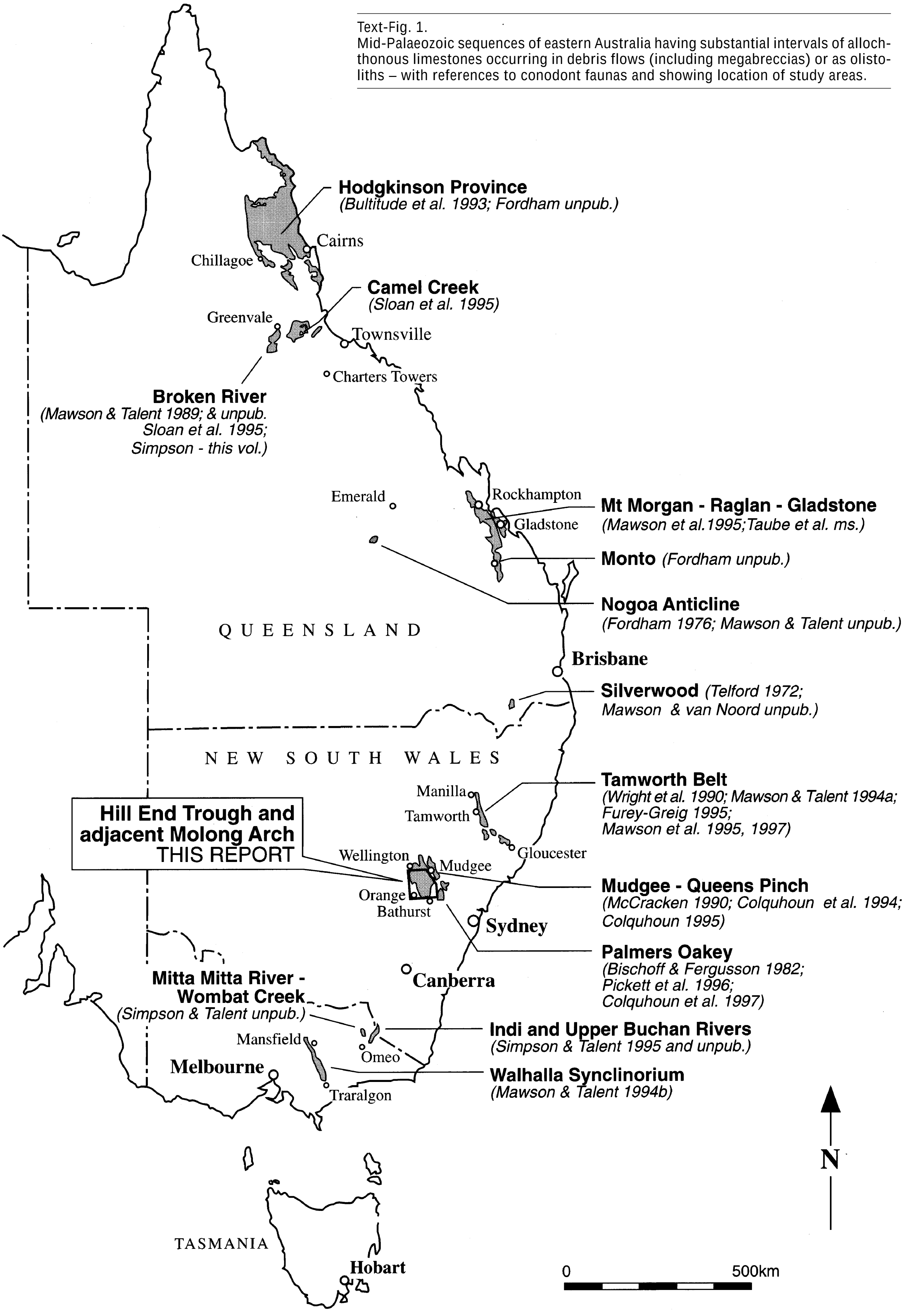


Table 1.
Characteristics of Late Ordovician, Silurian and Early Devonian stratigraphic units (oldest below) of the north-eastern Molong Platform (potential sources of limestone and volcanic clasts in the Cunningham Formation and the Wallace Shale) and the limestone-bearing units of the adjoining region of the Hill End Trough.

I. Molong Arch
(north-eastern part)

Garra Limestone: >1060 m; predominantly richly fossiliferous shoalwater limestones; diachronous, commencing in delta Zone in S, e.g. at Eurimbla and The Gap, and pesavis Zone in north, e.g. at Wellington; extending into at least *pireneae* Zone and, by inference, *dehiscens* Zone in N; formerly extending into late Emsian *serotinus* Zone (see this paper); Johnson (1975), Mawson et al. (1988), Sorentino (1989), Wilson (1989), Farrell (1992, and in Talent, 1995), see Strusz (1967) for older sources.

Mungallala Member (formerly Formation): max. c. 100 m; polymict conglomerates derived principally from Cuga Burga Volcanics with richly fossiliferous calcareous horizons at top; early in *pesavis* Zone but possibly late in *delta* Zone; largely a product of erosional interval between Cuga Burga Volcanics and Garra Limestone; inferred disconformable with underlying Cuga Burga Volcanics and conformable with overlying Garra Limestone; outcrops poorly south of the Wellington Caves area; Wilson (1989), Pogson & Watkins (1998).

Cuga Burga Volcanics: Thickness max. ?>1300 m; andesitic pillow lavas and pillow lava breccias overlain by subaqueously deposited volcanic breccias, arenites and lutites, overlain in turn by subaerial lava flows, tuffs and breccias; broadly *eurekaensis* Zone inferred from ages of overlying Garra Limestone and underlying Camelford Limestone; grain size, bedding thickness and ratio of volcanics to clastics decease eastwards suggesting submarine slope in that direction; sparse limestone occurrences are of problematic origin, ? from underlying limestone units (Narragal and/or Camelford); presence of indubitable carbonate aprons surrounding volcanic pedestals has been hypothesized but not been demonstrated; Morton (1974).

Mumbil Group

Camelford Limestone: max. ?>620 m; predominantly poorly bedded shoalwater limestones with rudites common in first 385 m of section; early Lochkovian (*woschmidti* Zone); earlier report of Pridoli (in Chatterton et al., 1979) has not been substantiated; conformably overlying or transitional from Wallace Shale but, viewed regionally, may also be in facies relationship with upper Wallace Shale; Johnson (1975), Farrell (in Talent, 1995)

Wallace Shale: 100–600 m; shales, siltstones and greywackes with, locally, debris flows and limestone olistoliths; graptolites suggest presence of late Ludlow, Pridoli and even Early Devonian horizons but Early Devonian reports have yet to be documented; Byrnes (1982, p. 154, Figs. 18, 19) suggested Wallace Shale to be mainly younger than ***Barnby Hills Shale*** whose age is constrained by early Lochkovian age of conformably overlying Camelford Limestone; suggested here that diachronism may be involved between typical Wallace Shale (north-west of Orange) and Barnby Hills Shale proposed subsequently for outcrop-tracts farther north in the Molong-Wellington-Mumbil area; the latter is therefore regarded herein as basically a junior synonym of the former; Stevens & Packham (1953), Strusz (1960), Sherwin (1971), Vandyke & Byrnes (1976), Byrnes (in Pickett, 1982), Rickards & Wright (1997), Pogson & Watkins (1998), Cockle (herein), E. Morgan (in prep.)

Narragal Limestone: 150–350 (? 550) m; grey biomicrites and yellow-brown dolomitic limestones with rarer pelsparites and bioclastic rudites; broadly Ludlow possibly extending as young as *crispus* Conodont Zone, but poorly constrained chronologically; disconformable on Catombal Park Formation, overlain conformably or gradationally by Wallace (= Barnby Hills) Shale; Vandyke & Byrnes (1976), Byrnes in Pickett (1982, p. 148–152), Percival (1997, 1998b).

Nandillyan Limestone: max. 320 m; lithologically closely resembles the Narragal Limestone (see above); early and ?late Wenlock; formerly thought to be possibly a synonym of the Narragal Limestone (Pickett, 1982, p. 149) but recent conodont data are consistent with much or all of it being older, spanning much or all of the Wenlock, though gross regional diachronism may be involved; it has been retained for major limestone outcrop-tracts south-west of the area considered in this report; Percival (1997, 1998b), Pogson & Watkins (1998).

Molong Limestone: 1200 m max.; massive or thick-bedded, relatively fossiliferous, shoalwater limestones; Wenlock–Ludlow (sparse biochronologic data); laterally equivalent to part of the Wallace Shale, and to some or all of Nandillyan and Narragal Limestones to the north-east; Adrian (1971), Pickett (1982), Pogson & Watkins (1998).

– – – – – – – – Disconformity – – – – – – – –

Dripstone Formation: originally proposed as Group; Vandyke & Byrnes (1976); three members.

Bell River Member (= Catombal Park Member): up to 120 m; acid volcanics and limestones; broadly Wenlock; Vandyke & Byrnes (1976).

Warderie Volcanic Member: 200–400 m; intermediate volcanics, conglomerates and breccias; ?Wenlock; Vandyke & Byrnes (1976).

Wylinga Member: max. 25 m; ?acid volcanics with richly fossiliferous limestone lenses; ?Wenlock; Vandyke & Byrnes (1976).

Mullions Range Volcanics: 500–2000 m; rhyolitic and dacitic volcanics with siltstones, sandstones, tuffs and rare ?allochthonous limestones; mid Ludlow; interpreted as southwards equivalent of Dripstone Formation; Packham (1968), Hilyard (1981), Pickett (1982, p. 144).

– – – – – – – – Unconformity – – – – – – – –

Cabonne Group

Oakdale Formation: originally proposed as a Group; Vandyke & Byrnes (1976); two members.

Mona Vale Siltstone Member: Thickness: ?200 m max.; banded carbonaceous siltstones, minor lenses of ferruginous dolomite and minor volcanics; Late Ordovician.

Cypress Hills Volcanics Member: >250 m; andesite, spilite, volcanic sandstone and siltstone with rare carbonates (e.g. ferruginous dolomite); Late Ordovician.

II. Hill End Trough
(north-western flank)
Limestone-bearing
units only

Cunningham Formation (sensu lato): 850 m to ?3700 m; mudstones with subordinate siltstones, greywackes, and generally rare conglomerates (generally distal debris flows); volcanic intercalations are not known; occurrences with prominence of allodapic limestones, megabreccias and limestone-filled channels have been discriminated as three members; *pesavis* Zone to at least *serotinus* Zone, but conceivably extending into the Eifelian; Packham (1968a), Pogson & Watkins (1998), Talent & Mawson (herein).

Tolga Member: up to 118 m; flaggy limestones (typically calcarenites) interleaved with non-calcareous mudstones; conformable or disconformable with underlying Cuga Burga Volcanics, passing laterally and up-sequence into Cunningham Formation sensu stricto; Crook & Powell (1976), Clark (1976), Talent & Mawson (herein).

Nubrigyn Member: approx. 1600 m in "Canobla"-"Merrimount" area in the north to approx. 2500 m in "Nubrigyn" area in the south; mudstones, allodapic limestones, megabreccias and isolated olistoliths (predominantly limestones) interfingering laterally and eastwards with the flyschoid greywacke-mudstone sequence of the Cunningham Formation sensu stricto; strata enclosing the megabreccias and isolated olistoliths are often graded and, typically with abundance of andesite fragments, presumably derived from the voluminous Ordovician andesites of the Molong Platform to the west; late Lochkovian (*pesavis* Zone) to late Emsian (*serotinus* Zone); Wolf (1963, 1965), Conaghan et al. (1976), Talent & Mawson (herein).

Red Hill Limestone Member: 85 m; lenses of rubbly calcarenites and calcirudites separated by and enclosed in fine Cunningham Formation clastics and interpreted as a carbonate fan or major, persisting channel fills of re-sedimented limestone debris, typically sand-sized and coarser derived from the Garra Limestone on the Molong Platform; Clark (1976), Talent & Mawson (herein).

Cuga Burga Volcanics: see column 1

Wallace Shale: see column 1

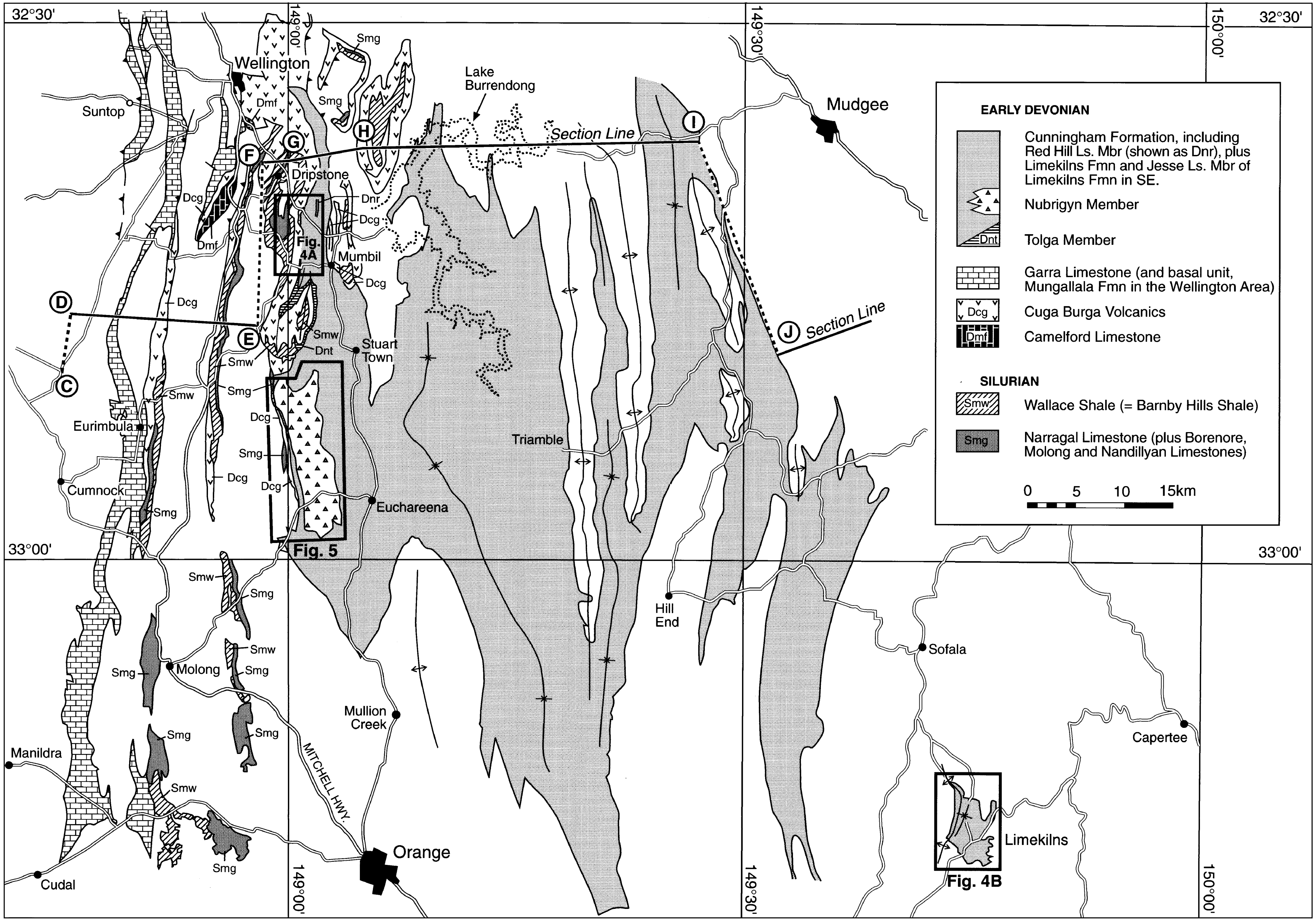
III. Hill End Trough
(?south-eastern flank)
Only units
discussed in text

Limekilns Formation: ca. 750 m; shales and lenticular limestone bodies referred to as the Jesse Limestone Member; laterally equivalent to the Cunningham Formation; late Pragian–late Emsian and ?Eifelian; Packham (1968).

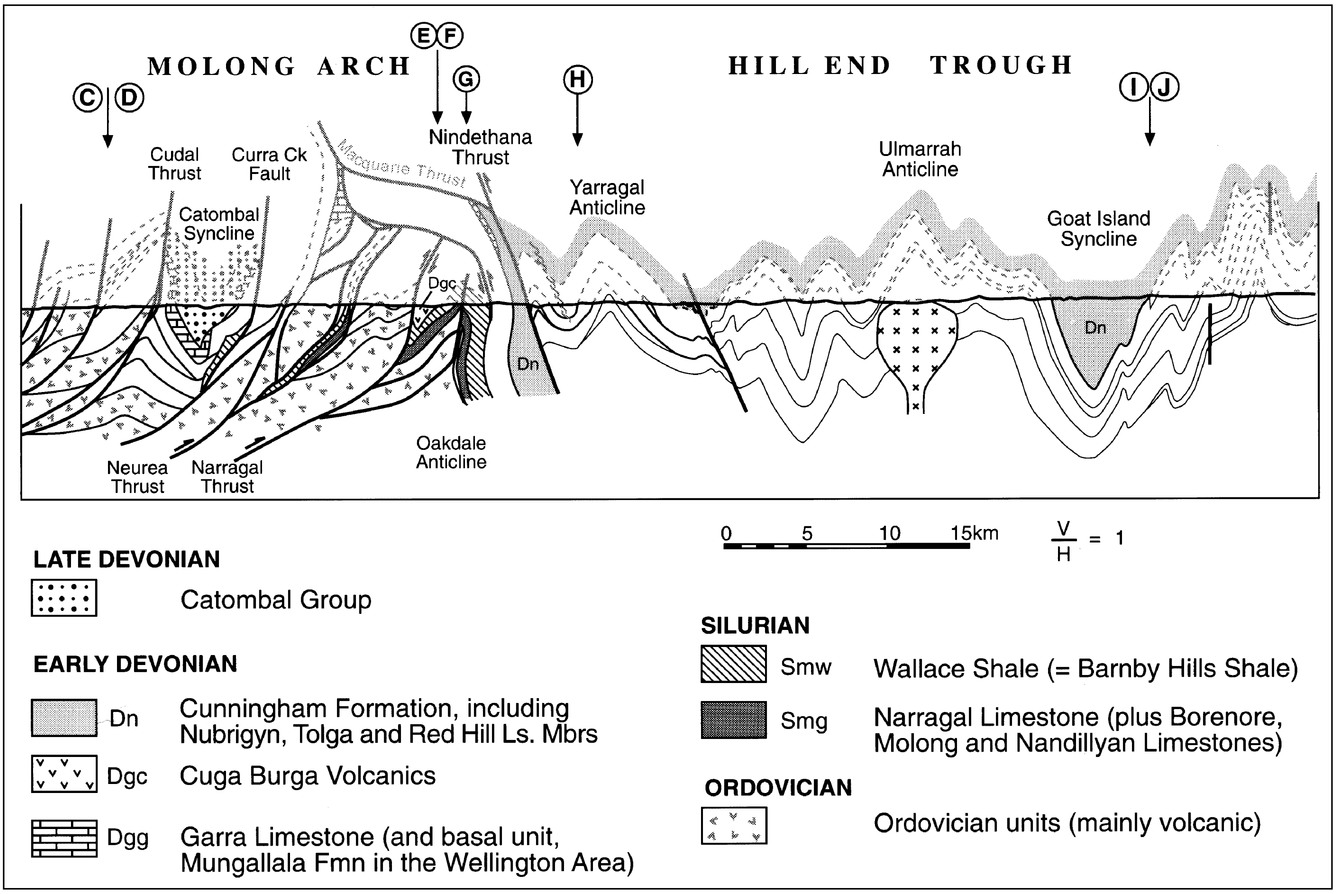
Jesse Limestone Member: max. 60 m; highly fossiliferous limestones with occasional prominent clasts of contrasting limestone lithologies, especially near the base; late Emsian (*serotinus* Zone) with older clasts; Packham (1968), Webby & Zhen (1993), Colquhoun et al. (1997), Pogson & Watkins (1998), Talent & Mawson (herein).

Tanwarra Shale: 275–375 m; shales, lithic sandstones, impure limestones, conglomerates (matrix-supported) and acid tuffs; limestone olistoliths abundant in the Palmers Oakey area; late Wenlock–earliest Ludlow (*lundgreni-testis* to *nilssoni* Zones); disconformably overlies Pipers Flat Formation; Packham (1968a), Bradley (in Pickett et al., 1982), Pickett et al. (1997), Pogson & Watkins (1998).

Pipers Flat Formation: 375 m or more; shales with at least one paraconglomerate (matrix-supported slump unit); unconformable/disconformable on Sofala Volcanics, overlain disconformably by Tanwarra Shale; late Llandovery *turriculatus* to *crispus* graptolite zones; Pickett et al. (1997), Pogson & Watkins (1998).



Text-Fig. 2.
Simplified geology of northern part of the Molong Arch and adjacent western flank of the Hill End Trough showing distribution of Silurian and Early Devonian stratigraphic units referred to in the text.
Based on Bathurst and Dubbo 1 : 250,000 geological maps, 2nd edition (COLQUHOUN et al., 1997; RAYMOND, POGSON et al., 1998), with omission of Ordovician, Late Devonian, and younger units, and omission of pre-Cunningham Formation units from the Hill End Trough.



Text-Fig. 3.
Cross-section in the north of Text-Fig. 2, based on section on the Dubbo 1 : 250,000 geological map, 2nd edition (COLQUHOUN et al., 1997).

area north and east of Mumbil (Text-Fig. 4A). The Wallace Shale in this "window", and in the area immediately west of the outcrop-tract of Nubrigyn Member of the Cunningham Formation (Text-Fig. 5, in pocket) has limestone olistoliths and ?channel/fan deposits charged with limestone clasts, evidence that the rapid Early Devonian sedimentation (Cunningham Formation) in the western Hill End Trough had antecedents extending back well into the Silurian.

During Early Devonian times the largely mudrock sequence along the western flank of the Hill End Trough received immense inputs of sediments; these include debris-flow intervals often copiously charged with limestone clasts and, in the area west of Stuart Town and Euchareena, large limestone olistoliths. The most important interval with such allochthonous limestones, here referred to as the Nubrigyn Member of the Cunningham Formation (formerly referred to as the Nubrigyn Formation, e.g. CONAGHAN et al. [1976]), passes laterally and up-sequence into the aerially extensive Cunningham Formation sensu stricto. Other significant units with allochthonous limestones occur in the Dripstone-Euchareena and Limekilns areas: the Red Hill and Tolga Members of the Cunningham Formation and the Jesse Limestone Member of the Limekilns Formation.

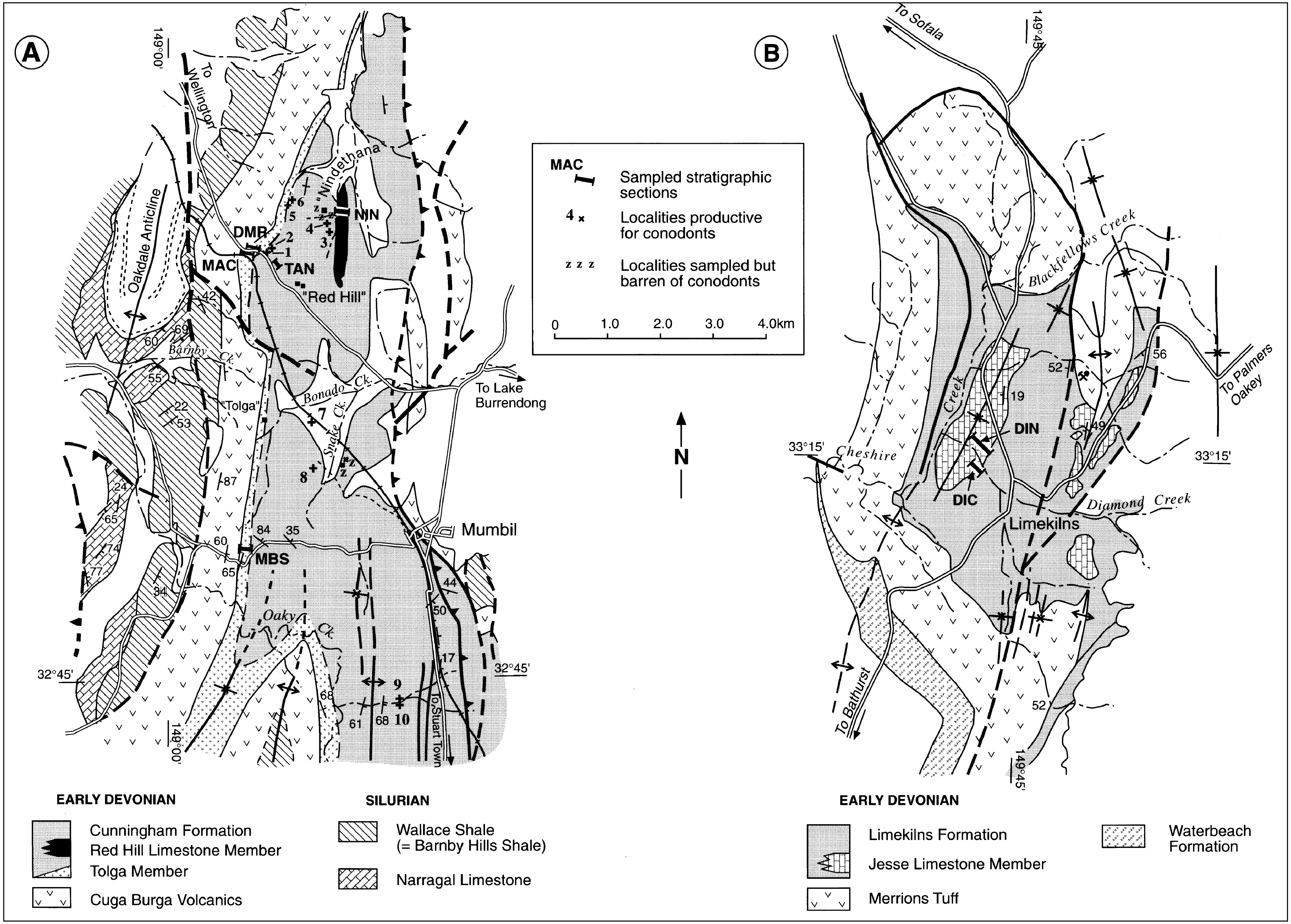
1.1. Scope of Present Report

Very little was known regarding the age-spectrum of limestone clasts and other limestone intervals involved in the above sedimentary units, nor how events in the Hill End Trough might align with sedimentary events, especially in carbonate sequences, on the adjoining Molong Arch. We have broached this problem by undertaking re-mapping of the outcrop-tract of Nubrigyn Member of the Cunningham Formation (Text-Fig. 5) and adjacent areas, giving special attention to location and sampling of olistoliths and limestone-rich intervals. Also undertaken was sampling of the Tolga and Red Hill Members of the Cunningham Formation (Text-Fig. 4A) and the Jesse Limestone Member of the Limekilns Formation (Text-Fig. 4B), 75 km south-east of Euchareena. A total of 534 limestone samples were acid-leached in pursuit of conodont data. Location of the stratigraphic sections sampled and the spot localities proved productive of conodonts are shown on Text-Figs. 4A, 4B and 5. It should be noted that wherever the word zone is used in the following text without specifying a particular fossil group, we imply the current conodont-based zonal schemes for the Silurian and Devonian.

2. Stratigraphic Context

2.1. Autochthonous/Primarily Autochthonous Silurian–Early Devonian Sequences on the Eastern Side of the Molong Arch

Re-mapping the Bathurst and Dubbo 1 : 250,000 map areas (cf. Text-Fig. 2) by the New South Wales Department of Mineral Resources has been bringing about important advances in structural knowledge, changes in mapped boundaries, and modifications of stratigraphic nomenclature (COLQUHOUN et al., 1997; RAYMOND et al., 1998); comprehensive bulletins on this work have just appeared (POGSON & WATKINS, 1998) or are in preparation (MEAKIN & MORGAN, in prep.). Because of this, and because the Late



Text-Fig. 4.
Location in relation to geology of sampled stratigraphic sections and spot localities proved productive for conodonts.
A. In the Dripstone-Mumbil area. Geology from CLARK (1976), VANDYKE & BYRNES (1976) and Dubbo 1 : 250,000 geological map (COLQUHOUN et al., 1997).
B. In the vicinity of Limekilns. Based on part of the Bathurst 1 : 250,000 geological map, 2nd edition (RAYMOND, POGSON et al., 1997).

Ordovician–Early Devonian stratigraphic units of the Molong Arch have not been the prime focus of the present investigation, we present no more than a summary, based primarily on previously published observations and interpretations (Table 1). These units constitute the source rocks for the megabreccias and isolated olistoliths in the adjacent Hill End Trough, the primary focus of this investigation.

2.2. Units with Allochthonous Silurian–Early Devonian Carbonates on the Western Flank of the Hill End Trough

2.2.1. Wallace Shale

The Wallace Shale (Table 1), based on outcrops ca. 50 km south-west of the mapped area, i.e. 20–38 km west-northwest of Orange, is regarded by us as being essentially a senior synonym of the Barnby Hills Shale of STRUSZ (1960), minor divergences in age-spectrum being attributable to the uneven nature of the presently available palaeontologic database. Inception of Wallace Shale sedimentation in that area occurred at or close to the Wenlock-Ludlow boundary and, on the basis of conodonts from a clast, persisted through into at least the late Ludlow (COCKLE, this volume). BYRNES (1976a, and in PICKETT, 1982, p. 154, Figs. 18, 19) suggested the Wallace Shale sensu stricto to have accumulated in a ?south-westerly directed feature, the Mirrabooka Submarine Valley.

In the Dripstone-Euchareena area, this unit (Table 1) consists of shales, siltstones and greywackes conformably overlying and seemingly gradational from the underlying Nandillyan and Narragal Limestones. It includes limestone lenses immediately west of the outcrop-tract of Nubrigyn Member of the Cunningham Formation. The two northerly of these, west and south-west of “Canobla” (Text-Fig. 5), are interpreted as limestone fans or channel fills of re-sedimented limestone debris – sand-sized and coarser. Lithologically, they recall the late Pragian Red Hill Limestone Member of the Cunningham Formation (see below) and, like the latter, are presumed to have received shallow water limestone debris from one or more of the pre-Devonian limestone units on the Molong Arch to the west. We have attempted to determine the age and thereby the source of these materials. As with the Red Hill Member, we suggest that these influxes of limestones may reflect a period or periods of low-stand on the platform, followed by reversion to “normal” (more distal) turbidite sedimentation. The southernmost occurrences in the mapped area (Text-Fig. 5) extending southwards from loc. 21 appear to be olistoliths of massive or poorly bedded pale grey shoal-water limestones. According to BYRNES (1976a, and in PICKETT, 1982, p. 154), such allochthonous limestones, noted in the Barnby Hills/Wallace Shale in other areas as being “calcarenites containing derived fossils“, would have been transported down an early stage of his hypothesised Nubrigyn Submarine Valley.

2.2.2. Cunningham Formation

The autochthonous platform carbonates on the Molong Arch – Nandillyan, Molong, Narragal, Camelford, Garra and less prominent limestone-bearing units (Table 1) – contrast lithologically with the limestone-bearing intervals on the western flank of the Hill End Trough. We have adopted a nomenclatorially conservative stance with regard to the latter, suggesting they might best be regarded as members of one, all-embracing flyschoid greywacke-mudstone assemblage, the Cunningham Formation. The principal intervals are:

1) The basal Tolga Member, formerly referred to as the Tolga “Calcarenite”; this unit fades out by decrease of limestone north from our DMR section and south from our MBS section (Text-Fig. 4A).
2) A significant but unnamed interval with allodapic or hemipelagic limestones disappearing north and south from our TAN section (Text-Fig. 4A).
3) The clearly defined lenticular Red Hill Limestone Member, typified by our section NIN.
4) The extensive Nubrigyn Member, formerly referred to as the Nubrigyn Formation, discriminated from the Cunningham Formation sensu stricto by the salient first and last occurrences of debris flows with allochthonous limestone blocks.

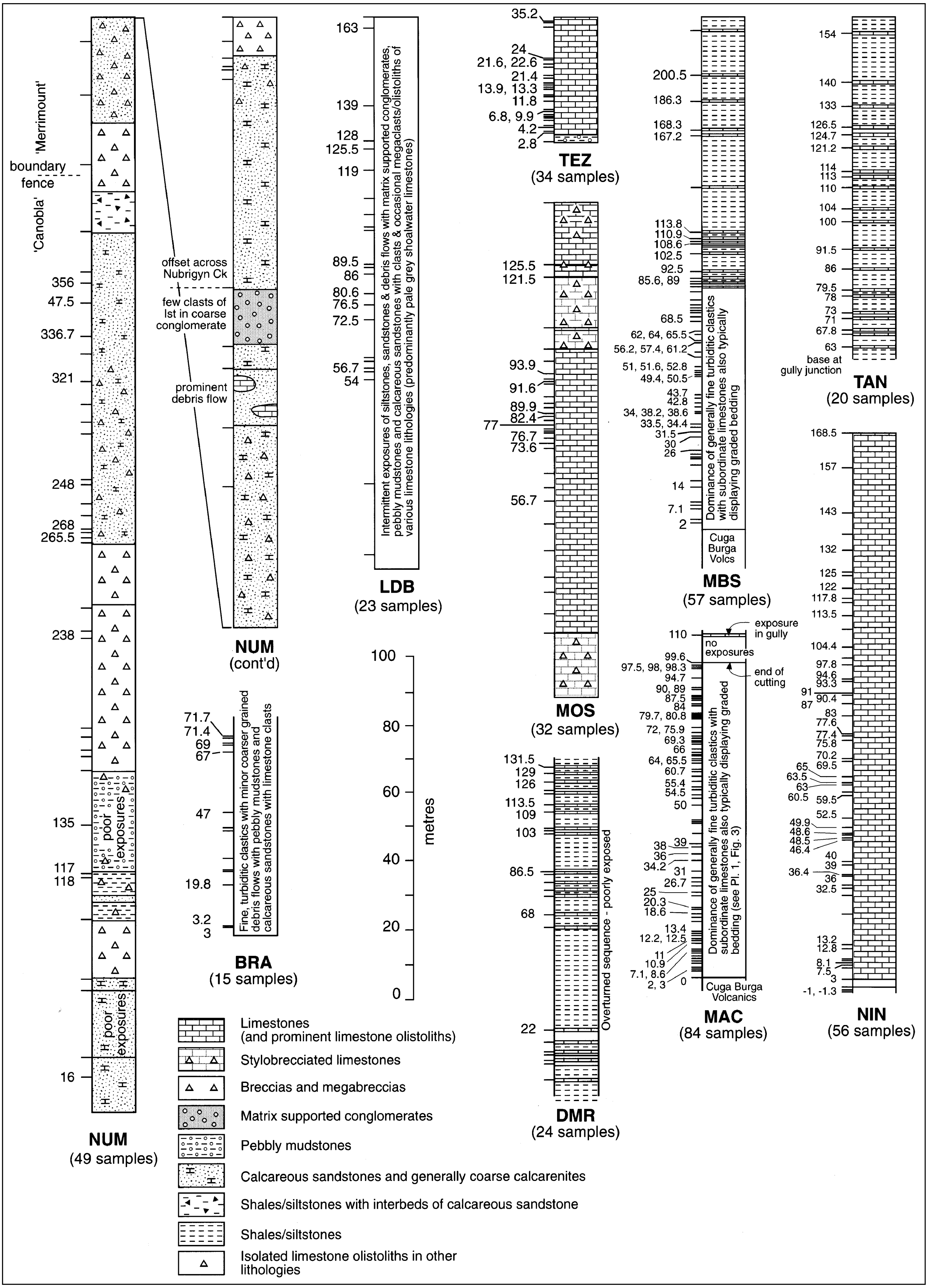
The Cunningham Formation sensu stricto (i.e. exclusive of the above members with prominence of limestone) consists of at least 850 m and perhaps as much as 3700 m of mudstones with subordinate siltstones and greywackes. Conglomerates (generally distal debris flows) are rare; volcanic intercalations are not known. Occurrences with allodapic limestones have been referred to one or other member of the Cunningham Formation. A salient exception is an interval (our section TAN) with allodapic/hemipelagic limestones north-west of “Red Hill” (Text-Fig. 4A). Lenses of coarse grained limestone outcropping poorly between the Red Hill Member and the village of Mumbil are interpreted by us (see below) as possible minor “distributary” lobes of the Red Hill limestone fan. An area of outcrop with several stratigraphically younger allodapic limestones but consisting overwhelmingly of mudstones ca. 2 km south of Mumbil produced chronologically useful conodonts (localities 9, 10; Table 14) indicating horizons younger than encountered in the Nubrigyn Member.

2.2.2.1. Tolga Member

This unit (Table 1) of non-calcareous mudstones with subordinate flaggy limestones (typically graded-bedded calcarenites) rests conformably on the Cuga Burga Volcanics. This relationship is well displayed in the type section (section MAC; Plate 1, Figs. 2 and 3): the long railway cutting on the Sydney–Dubbo railway between the “Mack Station” and “Tolga” properties where it is overfolded. It passes laterally and up-sequence into Cunningham Formation sensu stricto; the up-sequence gradation by decrease in beds of limestone is readily appreciated on our sampled section MBS adjacent to the Mumbil–Bakers Swamp road. The Tolga Member disappears rapidly northwards from the vicinity of its type section MAC and the nearby DMR section on the Wellington–Stuart Town road.

2.2.2.2. Red Hill Limestone Member

This unit consists of rubbly calcarenites and calcirudites separated by and enclosed within fine Cunningham Formation clastics on the “Red Hill” and “Nindethana” properties. Maximum thickness appears to be about 85 m in the vicinity of our section NIN. We concur with CLARK’s (1976) interpretation of these lenses as re-sedimented limestone debris, sand-sized and coarser. Blocks of limestone up to 2 m across, lithified prior to transport and incorporation in the limestone fan (or persistent limestone-charged channel), occur in the basal few metres. Boulder beds with limestone cobbles in otherwise normal turbi-



Text-Fig. 6.
Stratigraphic sections along the west flank of the Hill End Trough and at Limekilns, New South Wales, showing limestone horizons, clasts and olistoliths sampled and leached for acid-insoluble biota.
Horizons producing identifiable conodonts are indicated by a number corresponding to the distance along a metric tape; horizons shown without measurements failed to produce identifiable conodonts.

ditic Cunningham Formation outcrop in watercourses to the west of (stratigraphically below) the Red Hill Member; these too are interpreted as having been channelised.

2.2.2.3. Nubrigyn Member

This major sequence of mudstones, allodapic limestones, megabreccias and isolated olistoliths (predominantly limestones) interfingers laterally and eastwards with the flyschoid greywacke-mudstone sequence of the Cunningham Formation sensu stricto. The most striking feature of the Nubrigyn Member is the extraordinary size of the olistoliths/olistostromes, and the predominance among them of poorly bedded, pale grey limestones occurring as isolated olistoliths or making up virtually all clasts in the megabreccias. Volcanic clasts are absent or rare low in the sequence, but seem to become more prominent higher up, e.g. west and south-west of the junction of Boduldura and Nubrigyn Creeks. Clast types and lithologies, enclosed in flysch and hemipelagic mudstones, range widely from abundant shoal-water limestones (up to 1 km across) to minor volcanics, including one salient interval with abundant acid volcanics. The sedimentology of the Nubrigyn Member of the"Canobla"-"Merrimount" area has been discussed by CONAGHAN et al. (1976, q.v. for earlier contributions), especially as regards orientations and lithologies of clasts and their relationship to enclosing sediments.

Previous discussion of the sedimentology of the Nubrigyn Member was based on exposures along Nubrigyn and Boduldura Creeks on "Canobla" and "Merrimount" properties (WOLF, 1965; CONAGHAN et al., 1976). In these accounts a sequence of 13 sedimentary intervals were recognized, grouped as 5 "members" or formations, the oldest, regarded as a tongue of Tolga "Calcarenite", was viewed as being overlain in the north of the "Canobla"-"Merrimount" area by 4 "members" of the Nubrigyn Formation discriminated on the basis of differing proportions of allodapic limestone, fine rudite, megabreccia, or by having matrix with little or no carbonate. We have reservations regarding the tract identified by earlier workers as Tolga "Calcarenite", preferring to regard the appearance of limestones in that interval as defining the onset of "Nubrigyn" sedimentation. We have reservations too regarding discrimination of the 4 "members" of the Nubrigyn Member in most of the "Merrimount"/Boduldura Creek portion of the "Canobla"-"Merrimount" area; we have not been able to discriminate them southwards towards "Nubrigyn" and Euchareena, largely because of poor outcrops. We have therefore not attempted to indicate members/sub-members on the accompanying map (Text-Fig. 5) of limestone bodies in the Nubrigyn Member as a whole.

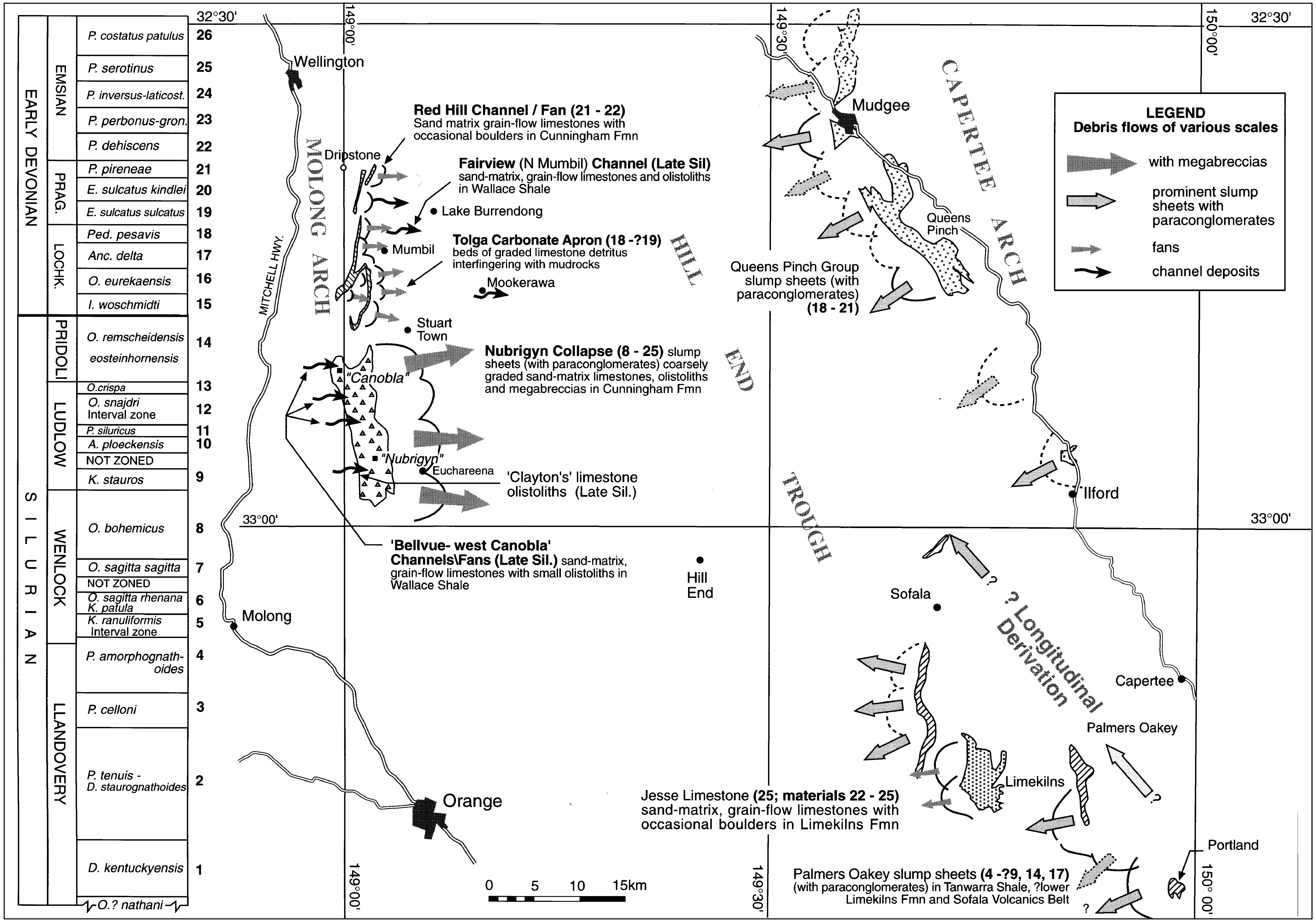
Strata enclosing the megabreccias in the "Canobla"-"Merrimount" area are often graded and consist of andesite fragments, presumably derived from the voluminous Ordovician andesites of the Molong Arch to the west, detrital quartz and pebbles of basalt, dolerite, rhyolite, quartzite and granite (WOLF, 1965). The allodapic limestones of the Nubrigyn Member are well-bedded (0.3–1.0 m), laterally persistent, almost invariably graded, grainstone and packstone calcarenites with grain size ranging from fine sand- to granule-size (CONAGHAN et al., 1976). Load casts and basal scour-and-fill structures occur. The rhythmic sedimentation of the allodapic limestones and fine rudites are especially well displayed about the junction of Boduldura and Nubrigyn Creeks (Pl. 1, Fig. 2) and on the hillsides north and east of "Canobla". Lens-like occurrences of rudites, are predominantly matrix-supported, occur in the latter area and in the vicinity of "Old Nubrigyn"; they are assumed to represent channel deposits. The distribution of some of the megabreccias in the"Canobla"-"Merrimount" area was indicated by CONAGHAN et al. (1976, Text-Fig. 3), but these are inferred to have been much more widespread. They are often recessive, masked by soil and vegetation away from the principal outcrop areas along watercourses and on the walls of steeper valleys. The megabreccias typically grade upwards, over a few metres, through fine rudites to allodapic limestones containing sporadic limestone blocks.

The limestone olistoliths are overwhelmingly massive, poorly fossiliferous, pale grey to mid-grey limestone (mudstone, wackestone and packstone), some with stromatactis, or are poorly bedded algal-stromatoporoid-boundstones with occasional tabulate corals, e.g. *Favosites*, *Cladopora* and, less frequently, heliolitids. All of these represent very shallow shelf or shelf-edge environments; they proved consistently disappointing as regards conodonts (see below). They nevertheless match well with prominent lithologic types in the Garra Limestone. Rarer olistolith lithologies include bedded limestone, dark argillaceous ?basinal mudstone and shale, observed only on pavements along watercourses (e.g. CONAGHAN et al., 1976, Text-Fig. 8), andesite, quartzite, rhyolite and plutonic rocks. A major lens approximately 1 km in length, between 2 and 3 km south of "Canobla", has such an abundance of rhyolite clasts that it was formerly mapped as a rhyolite flow (BYRNES, 1976b) but close examination of the principal pavement areas showed it to include limestone boulders, sometimes in abundance, representing a wide range of lithologies.

There are several instances in which discordance in stratigraphic orientation have been demonstrated between olistoliths and matrix (CONAGHAN et al., 1976, p. 524). The olistoliths are generally larger and much more abundant than the largest olistoliths in the otherwise similar mid-Palaeozoic debris flows recently described from the Walhalla Synclinorium of east-central Victoria (MAWSON & TALENT, 1994), the eastern flank of the Capertee High (MCCRACKEN, 1990), the Broken River-Camel Creek region of north-east Queensland (SLOAN et al., 1995) and the Tamworth Belt of north-east New South Wales (FUREY-GRIEG, 1995; MAWSON et al., 1997). CONAGHAN et al. (1976, p. 522) also reported olistoliths that have lost their integrity, having been turned into autoclastic breccias generated, apparently, "by injection of argillaceous matrix into the fractured surfaces or walls of blocks, with consequent dilation and eventual dispersion of angular limestone fragments into the surrounding host sediment".

2.2.2.4. Isolated Olistoliths

Though olistoliths, mostly of limestone and forming part of olistostromes or other mass movement deposits, occur in great abundance and are characteristic of the Nubrigyn Member, there are also isolated olistoliths (slide blocks) not apparently associated with debris flow intervals. Such isolated olistoliths may be exemplified by two colossal blocks exceeding 100 m in length occurring in turbidites in the Finch's Caves area north-west of Euchareena (Text-Fig. 5). In both cases, boundaries between olistolith and the enclosing basinal sequence cannot be deciphered because of soil and alluvial cover. One of these olistoliths, immediately south of the abandoned Thompson homestead, consists of weakly bedded blue-grey



Text-Fig. 7.
Cartoon showing distribution of Silurian and Early Devonian sequences with prominent allochthonous limestones – megabreccias, slump sheets (with paraconglomerates), olistoliths, channel deposits, and often coarsely graded detrital limestones – around the flanks of the Hill End Trough.
Postulated directions of transport and age-spectrum for each major occurrence are indicated, the age spectrum being based on conodont data presented here for limestone-bearing units in the Mumbil-Stuart Town area – Wallace Shale, and Tolga, Nubrigyn and Red Hill Limestone Members of the Cunningham Formation – and for the Jesse Limestone Member of the Limekilns area. Data for the Tanwarra Shale and Queens Pinch Group of the eastern flank of the Hill End Trough (= western flank of the Capertee Arch) are from BISCHOFF & FERGUSSON (1982), MCCRACKEN (1990), PICKETT et al. (1996), MAWSON & TALENT (unpub.) and COLQUHOUN (1995); the last has provided a useful synthesis of conodont data for the Capertee Arch.

limestone, with areas of brecciation (stylobreccias) and occasionally with dolomitic mottling. It is richly fossiliferous with tabulate corals (*Favosites*, *Heliolites*, *Cladopora*), stromatoporoids, algae, and rugose corals, especially *Tryplasma*. The other large olistolith, about 200 m east of the abandoned Thompson homestead, has the Finch's Caves system located within it. The cave system appears to connect with Coopers Creek, suggesting a north–south length of more than 200 m. It consists of massive pale grey limestone, some of it with fenestral fabric, with occasional algae, stromatoporoids and tabulate corals (*Favosites*, *Heliolites*, *Cladopora*). Lithologic similarity to massive shoal water limestones of the Garra Limestone farther west are striking; the macrofauna appears to be consistent with a broad mid-Early Devonian age.

2.3. Units with Allochthonous Silurian–Early Devonian Carbonates on the Eastern Flank of the Hill End Trough

2.3.1. Tanwarra Shale

Among the many occurrences of mid-Palaeozoic sedimentary sequences within and/or occurring on the eastern flank of the Hill End Trough is a largish area in the Palmers Oakey district about 12 km east and north-east of Limekilns. It is not our intention to review these occurrences nor enter into discussion of stratigraphic and palaeogeographic problems in that region, but we have included it in our palaeogeographic reconstruction (Text-Fig. 6). BISCHOFF (in BISCHOFF & FERGUSSON, 1982) listed conodonts from various localities in the vicinity of Palmers Oakey, but their stratigraphic position in relation to the stratigraphic nomenclature for the Hill End Trough (PACKHAM, 1968a, 1968b, 1969) remained problematic. PICKETT et al. (1996) have concluded that the conodont-bearing localities are from tracts of Tanwarra Shale, Limekilns Formation, and from limestone blocks (thought to be coeval with the Tanwarra Shale) in the Sofala Volcanics outcrop-belt.

2.3.2. Jesse Limestone Member of the Limekilns Formation

The principal occurrence of Jesse Limestone Member of the Limekilns Formation is a richly fossiliferous limestone body (PACKHAM, 1968a) interpreted as a fan of limestone detritus with prominent limestone clasts (particularly prominent in its basal 1 to 2 m) occurring in the Limekilns area 25 km north-east of Bathurst (Text-Figs. 2, 4B). The name has also been applied to other limestone occurrences (cf. Text-Fig. 4B) within the Limekilns Formation (COLQUHOUN et al., 1997). Some of these may be distributary channels from the main limestone fan system, but not all of them were necessarily contemporaneous with development of the main Jesse Limestone fan; some may be older.

Our attention was directed towards the Limekilns Formation and specifically its Jesse Limestone Member by a conodont fauna with *Polygnathus pireneae* and *P. dehiscens* brought to our attention by Dr A.J. WRIGHT in the 1980s. This association implied an age early in the *dehiscens* Zone. In the hope that close sampling might provide useful data in relation to the Pragian/Emsian boundary and perhaps even provide a candidate section for the global stratotype for that boundary, then a focus of activity by the Subcommission on Devonian Stratigraphy (cf. YOLKIN et al., 1997), we copiously sampled the principal outcrop-tract referred to the Jesse Limestone Member (our section DIN and the short complementary section DIC) on either side of Diamond Ck at Limekilns (Text-Fig. 4B). It was immediately apparent that the sequence included limestone clasts to 0.5 m across, especially in the basal 1 or 2 m where the clasts display a broad spectrum of lithologies. Clasts were sampled separately (especially low in the sequence where they are larger and more abundant) from the characteristically granular matrix with clasts so small that they could not be sampled separately from the matrix. The Jesse Limestone Member is noteworthy for the excellence of preservation of its stromatoporoids (WEBBY & ZHEN, 1993), silicified trilobites (WRIGHT & CHATTERTON, 1988; WRIGHT & HAAS, 1990), rugosan and tabulate corals, fish micro-remains and other groups. We present our conodont data in extenso because, inevitably, questions will be asked regarding the precise age to be attached to such well preserved materials.

3. Conodont Data: Age Implications

Emphasis in sampling was on stratigraphic sections, supplemented by numerous spot samples (Appendix A). A low proportion of samples when acid-leached produced useful conodonts, presumably because the clasts at all scales, including the largest olistoliths, consist overwhelmingly of massive, pale grey shoal-water limestones, environments which rarely yield conodonts or, at best, produce very rare coniforms of little chronological value. The conodont faunas, on which our conclusions rest, are tabulated (Tables 2–14) and illustrated (Plates 3–13) so that subsequent workers can evaluate our conclusions. Because of small numbers of taxa from most of the productive samples, and presumed difficulty in obtaining identical (or nearly identical results) in sampling debris-flow contexts, formal taxonomy has been sidestepped. Discussion (Section 5) has been limited to 13 salient forms.

In the commentary which follows, we have taken it to be axiomatic that fossils from indubitably autochthonous carbonate intervals, derived from previously unlithified carbonates, are the best possible guides to age of enclosing sediments. In dealing with obviously allochthonous limestones of the Hill End Trough and other areas in eastern Australia we have employed two working principles, and have used these with great caution:

1) Limestone clasts and olistoliths occurring in abundance, and evidently derived from limestones lithified prior to incorporation in the sedimentary succession under investigation, may be used (exercising caution) to provide a close approximation to the age of the enclosing rock. This model assumes a dynamic situation with more or less continuous inpouring of allochthonous materials, derived from lithified and/or unlithified carbonates up-slope, into the sedimentary succession down-slope. In this situation, the allochthonous materials would be expected to become gradually younger up-sequence. This applies – in a general way – to the Nubrigyn Member of the Cunningham Formation.
2) Where, however, carbonate sedimentation has ceased up-slope and the carbonate platform is undergoing erosion, one would assume that increasing incision into the platform would produce, up-sequence, an increasing proportion of remanié materials from older horizons. This is not apparent for sequences with allochthonous limestones in the present area of investigation. It is exemplified, however, by the increasing

proportion of Late Ordovician conodonts relative to Llandovery conodonts up-sequence in the Perry Creek Formation of north-east Queensland (SLOAN et al., 1995).

3.1. Silurian Units

3.1.1. Wallace Shale

TEZ Section (Table 2)

The presence of *Distomodus staurognathoides* with *Kockelella ranuliformis* to 13.3 m above the base of the section accords with interpreting the lower part of the lens as being made up of materials derived from a limestone unit including a substantial interval broadly referrable to the early Wenlock *procerus* Zone of JEPPSSON (1997) and/or Lower *ranuliformis* Zone of BARRICK & KLAPPER (1976). The lowest horizons sampled come from conglomeratic mudstone testifying to the debris-flow origin of this unit. Samples from 21.4 m above the base of the section have produced *Ozarkodina excavata*, a form occurring frequently in the Upper *granuliformis* Zone on Gotland (L. JEPPSSON, pers. comm.) together with *Panderodus greenlandensis*. The age indicated falls within the age-spectrum indicated for the Nandillyan Limestone, a unit known from several outcrop-tracts south-west of the area mapped for Text-Fig. 5, and believed to have accumulated through most if not all of the Wenlock, including the earliest Wenlock *procerus* Zone (PERCIVAL, 1997, 1998b).

Table 2.
Conodont data from sampled stratigraphic section TEZ (location: Text-Fig. 5) through Nandillyan Limestone-derived carbonate lens in the Wallace Shale west of "Canobla".

Metres above base		2.8	4.2	6.8	7.9	9.0	11.8	13.3	13.9	21.4	21.6	22.6	24.0	35.1	40.0	67.8
TEZ Sample number		2.8	4.2	6.8	7.9	9.0	11.8	13.3	13.9	21.4	21.6	22.6	24.0	35.1	40.0	67.8
Distomodus staurognathoides	Pa	1		2	1	3		2	2							
cf. ***Panderodus*** sp.			1					1			1					
Kockelella ranuliformis	Pa			1						1						1
Ozarkodina sp.	Pa			1												
Panderodus cf. ***equicostatus***				1											1	
cf. ***Ozarkodina*** sp.	Pa				1											1
Panderodus greenlandensis						1						2	4		1	
Panderodus unicostatus							1							1		
Ozarkodina cf. ***confluens***	Pa						1	1								
Ozarkodina excavata excavata	Pa									1	1		1			
	Pb								1							
	M									1	1					
	Sa													1		
Panderodus cf. ***unicostatus***										1						
Panderodus n.sp.													3	1		
Oulodus sp.	Pa													1		
cf. ***Kockelella*** sp.	Pa															1

Other presumably Silurian limestone tracts, south-east and south-southeast of "Bellvue" (Text-Fig. 5), representing carbonate fans or limestone-filled channel deposits, were cursorily sampled for conodonts without success.

3.1.2. Large Olistolith (MOS) in Nubrigyn Member of Cunningham Formation

MOS Section (Table 3)

The small conodont faunas obtained from the MOS section, sampled through a large olistolith (Text-Figs. 5 and 6) rather high in the Nubrigyn Member of the Cunningham Formation, are difficult to date with accuracy.

Entry of elements of the *Ozarkodina remscheidensis* group having denticles alternating in size suggests that this olistolith-megaclast is no older than *crispa* Zone (late Ludlow); co-occurrence with *Coryssognathus dubius* accords with an age close to the Ludlow-Pridoli boundary.

Interestingly, this age falls within a time-slice for which there are no known outcrops of autochthonous limestones on the Molong Arch to the west. It substantially postdates the Nandillyan and Molong Limestones and seemingly the Narragal Limestone as well; it seems to be somewhat older than the Camelford Limestone (Table 1).

The MOS olistolith may thus have originated from a now "lost" latest Ludlow/earliest Pridoli carbonate interval on the Molong Arch. Alternatively, limestones of that age may have escaped recognition among the many limestone tracts in that region.

Table 3.
Conodont data from section through a large Silurian limestone olistolith MOS (location: Text-Fig. 5) in the Nubrigyn Member of the Cunningham Formation.

Metres above base		56.9	73.7	76.5	77.0	77.4	78.8	80.1	80.5	81.1	82.6	90.2	92.5	119.7	123.6
MOS Sample number		56.9	73.7	76.5	77.0	77.4	78.8	80.1	80.5	82.4	83.9	91.6	93.9	121.5	125.5
Oulodus sp.	Pa	1			1					1		1	1		1
Ozarkodina "remscheidensis" group	Pa		1							2					
	Sb									1					
Panderodus sp.				1					1	1				1	
Panderodus equicostatus						1					1				
Coryssognathus dubius	Pa							1		2					1
Ozarkodina excavata excavata	Pa										1				
Ozarkodina sp.	Pa														1

3.2. Devonian Units

3.2.1. Tolga Member

The "Tolga" carbonate apron is noteworthy for low yields (typically a conodont per kg or less), a general decrease in productivity up-sequence, and a noticeably high proportion of broken material. This is consistent with appreciable transport, and/or a conspicuously turbulent environment. We therefore suggest the Tolga Member to represent carbonate debris swept intermittently eastwards from the adjacent Molong carbonate platform to produce beds of limestone interfingering with intervals of basinal shales and turbidites.

MAC Section
(Table 4)

The type section for the Tolga Member of the Cunningham Formation, in railway cutting behind "Mack" Station (cf. Plate 1, Figs. 2 & 3) was subjected to bed-by-bed sampling. Although *Pandorinellina optima* is shown to occur in the *delta* Zone in Nevada (KLAPPER & MURPHY, 1975), it occurs more commonly in faunas of the *pesavis* and *sulcatus* Zones. Its co-occurrence with forms such as *Ozarkodina remscheidensis repetitor* and *O. r. remscheidensis* to 28.5 m above the base of the section is consistent with allocating the lower part of the section to the *pesavis* Zone. Occurrence of *Pand. exigua philipi* 43.3 m above the base of the section is evidence for *sulcatus* Zone for that level and above. Conodonts from the above three sampled sections

Table 4.
Distribution of conodont elements in section MAC (location: Text-Fig. 4A) through the Tolga Member of the Cunningham Formation in cutting on the north-eastern side of the Orange-Dubbo railway cutting.

Metres above base		1.8	2.1	2.8	7.9	10.0	10.1	11.2	11.5	12.3	17.1	18.6	23.0	24.6	28.5	31.5	35.0	35.9	43.3	46.3	46.9	50.4	53.1	54.4	54.8	57.5	59.3	62.2	65.4	66.3	68.8	71.5	72.7	73.4	77.0	79.1	79.5	79.7	80.7	88.5
MAC Sample number		2.0	2.3	3.0	8.6	10.9	11.0	12.2	12.5	13.4	18.6	20.3	25.0	26.7	31.0	34.2	38.0	39.0	50.0	54.5	55.4	60.7	64.0	65.5	66.0	69.3	72.0	75.7	79.7	80.8	84.0	87.5	89.0	90.0	94.7	97.5	98.0	98.3	99.6	110.0
Oulodus sp.	Pb	1																																						
	Sa																	1																		1	1			
	Sc	2								1																							2				1			
Ozarkodina excavata excavata	Pa			1									1																										1	
	Pb	1																																						
	Sb	1																																						
Ozarkodina spp.	Pa	2									1						1																							
Pandorinellina optima	Pa	4	1																1						1															
Panderodus unicostatus		1	1	2										1	1							1														2				
Ancyrodelloides omus	Pa			1											1																									
Ozarkodina r. remscheidensis	Pa			1							1				1										1															1
Ozarkodina r. repetitor	Pa					1		1			1				1																									
Panderodus sp.									1																															
Amydrotaxis sp.	Sa														1		1	1																						
Pandorinellina exigua philipi	Pa																		1																					
Belodella sp.																												1												
Icriodus steinachensis eta morph	I																															1								
Indeterminate elements	Pa	3	1		2					1	2	1	2		1	1		3		1	1	1						1						1				1		1
	Pb	2		3																								1					1							
	Sb	2				1											1						1	1				1	1	1						1				1
	Sc	2	2		1		1				1				1			2	1							1	1	1		1	1				1					1

therefore indicate that the Tolga Member of the Cunningham Formation extends from very close to the *delta-pesavis* boundary through into the *sulcatus* Zone.

DARGAN (1996) has reported tabulate corals and rugosans from two localities at the base, and just above the base, respectively, of the Cunningham Formation in the Sofala area, outside of the area investigated by us. At the former locality, the rugosans *Xystriphyllum* and two species of *Tryplasma* are reported in association with *Thamnopora alterivalis*, *Cladopora gippslandica*, *Squameofavosites bryani*, and *Parastriatopora* sp. The occurrence with this macrofauna of *Ozarkodina pandora* accordes with allocation to the late Lochkovian *pesavis* Zone, but allocation to early in the Pragian is possible. The age DARGAN has suggested accords nicely with the age indicated here for the base of the Tolga Member (= the base of the Cunningham Formation) on the western flank of the Hill End Trough.

MBS section
(Table 5)

Although *Amydrotaxis johnsoni* alpha morph has been reported from the *delta* Zone (KLAPPER, 1969; KLAPPER & JOHNSON, 1980), it is known to extend into the lowermost *pesavis* Zone (KLAPPER & MURPHY, 1980). In the MBS section *A. johnsoni* alpha morph overlaps for nearly 30 m of section with *Oulodus aclys*, a form recovered high in the

Table 5.
Distribution of conodont elements in section MBS (location: Text-Fig. 4A) through the Tolga Member of the Cunningham Formation on the south side of the Mumbil-Bakers Swamp road.

Metres above base		6.4	12.7	23.6	28.5	30.4	31.2	34.6	35.0	39.0	39.8	45.2	45.9	46.6	47.1	48.1	50.9	51.9	55.1	55.7	57.4	58.6	61.1	63.4	63.6	64.2	66.1	72.0	73.8	75.6	80.9	83.2	84.2	85.0	115.2	115.8	125.3	132.9
MBS Sample number		7.1	14.0	26.0	31.5	33.5	34.4	38.2	38.6	42.8	43.7	49.4	50.1	51.0	51.6	52.8	56.2	57.4	61.2	62.0	64.0	65.5	68.5	71.2	71.5	72.2	74.5	85.6	89.0	92.5	102.5	106.8	108.6	110.9	167.2	168.3	186.3	200.5
Panderodus unicostatus					1		1			1	1			1	1		1	2		2	1	2		1		1				2			4	1			1	
Belodella devonica						1																																
Ozarkodina excavata excavata	Pa						1																						1		1		2					
Ozarkodina r. repetitor	Pa						1		1									1		2				2								1	2	1				
Ancryodelloides omus	Pa											1																										
Oulodus aclys	M																															1						
	Sb																															1						
	Sc																		1													1	1					
Ozarkodina r. remscheidensis	Pa											1										1									1							
Amydrotaxis johnsoni alpha morph	Pa																			1							1						2		1			
	Pb																					1				1		1							1			
	Sa																									2				1			1					
	Sb																																1					
	Sc																							1									2					
Oulodus sp.	Pb																														1	1					1	
Pseudooneotodus beckmanni																																						1
Indeterminate elements	Pa							1			1		1		4			2				1		3		1						1	1	1		1		
	Pb		1												1					1											2	1				1		2
	M																												1	1					1			
	Sa																																2				1	
	Sb						1								2					1		2		2	1	1				1	1		4					
	Sc	1		2	1		1		1				1	1	3	3			1	1			1			2					1	1	3	1				1

section at Windellama in south-east New South Wales where *O. aclys* and *A. johnsoni* alpha morph likewise co-occur and where allocation to the *pesavis* Zone has been advocated (MAWSON, 1986). It is suggested, therefore, that the MBS section commences late in the *delta* Zone or early in the *pesavis* Zone, possibly in the latter, unless there is diachronism between the DMR and MBS sections. Data from the last 50+ metres of section are poor, so there is no certainty that the *sulcatus-pesavis* zonal boundary occurs within that interval as one might anticipate from data from the MAC section (below).

DMR Section (Table 6)

The road cutting on the Dripstone–Mumbil road just north of the MAC section (below) has generally poor outcrops and therefore was more cursorily sampled than either the MBS or MAC sections. However, the occurrence of lowermost *pesavis* Zone is suggested by the co-occurrence of *Amydrotaxis johnsoni* alpha morph and *Icriodus steinachensis* eta morph as the ranges of these two forms, according to available data (e.g. KLAPPER & MURPHY, 1980), overlap slightly above the *delta-pesavis* boundary.

Table 6.
Distribution of conodont elements in section DMR (location: Text-Fig. 4A) through the Tolga Member of the Cunningham Formation in road cutting beside the Dripstone–Mumbil road.

Metres above base		5.0	16.1	48.9	74.1	78.4	81.6	88.5	90.6	92.4
DMR Sample number		6.8	22.0	68.0	103.0	109.0	113.5	126.0	129.0	131.5
Ozarkodina r. remscheidensis	Pa	2							1	
Panderodus unicostatus			1	1	2					
Amtydrotaxis johnsoni alpha morph	Pa				1					
	Sa			1						
	Sc						1			
Icriodus steinachensis eta morph	I					1				
Indeterminate elements	Pa	1	1							1
	Pb						1			
	Sc						1	1		

3.2.2. Lower Cunningham Formation

TAN Section (Table 7)

Conodonts from this sequence of fine-grained ?hemipelagic limestones interbedded with shales, stratigraphically intermediate between the Tolga and Red Hill Members (Text-Fig. 3), display a conspicuously lower level of breakage than conodonts from the Tolga, Red Hill and Nubrigyn Members of the Cunningham Formation, indicating considerably less transport. On the basis of co-occurrence of *Pandorinellina steinhornensis miae*, *Pand. optima* and *Amydrotaxis druceana* throughout the section, with occasional occurrences of *Icriodus steinachensis* eta morph and *Pedavis mariannae*, the section is inferred to be most likely early *kindlei* Zone.

A sample from along strike southwards from our TAN section at grid reference 902_0 378_7, is approximately the same level stratigraphically as our locality 8 (Text-Fig. 4A; Table 14). It has been reported (PERCIVAL, 1998a) to have produced a small conodont fauna indicative of the *kindlei* Zone associated with the stromatoporoids *Gerronostroma vergens* and *Actinostroma*? sp., the tabulate corals *Squameofavosites bryani*, *Favosites* sp. and *Cladopora* sp., and the rugosans *Pseudochonophyllum pseudohelianthoides* and *Tryplasma*? sp.

Conodonts from clasts occurring stratigraphically between our TAN and NIN sections (spot samples 3 and 4) and from clasts at the base of the Red Hill Member on our NIN section have produced, inter alia, specimens of *Polygnathus pireneae*. This form ranges into the *dehiscens* interval, but allocation to the *pireneae* Zone, conceivably low in the zone, is constrained by conodont data from the overlying Red Hill Limestone Member (see immediately below).

3.2.3. Red Hill Limestone Member

NIN Section (Table 8)

Occurrence of the very earliest polygnathids *Polygnathus trilinearis* and *P. zeravshanicus* (MAWSON & TALENT, 1994b; MAWSON, 1995; 1998) in the first 38 m of section through this generally coarse-grained limestone unit, interpreted by us as a carbonate fan, accords with allocation to the *pireneae* Zone. It is not until 152 m above the base of our NIN section that *P. dehiscens* enters the record. As only a single specimen of *P. dehiscens* was obtained, this horizon could be appreciably above the *pireneae-dehiscens* boundary. A similar age is indicated for a small bioclastic limestone lense at locality 8 where the occurrence of *Pand. exigua exigua* implies an age in the interval spanned by the *pireneae* and *dehiscens* Zones. Other small limestone occurrences in the same area may have represented smaller distributaries away from the main Red Hill limestone fan.

3.2.4. Nubrigyn Member

Despite close search during our mapping of the Nubrigyn Member outcrop-tract, we have been unable to specify horizons which are indubitably autochthonous. All calcareous units from sheet-like megabreccias to allodapic limestones (whether calcisiltites or calcareous arenites) appear to be allochthonous; the clasts at all scales occurring in finer matrix indicating mixing with various amounts of basinal mud and silt and transport en masse to their present positions. All data therefore from our sampling of limestones from the Nubrigyn Member represent, in our view, maximum ages for the specific horizon and, at that, ages of accumulation upslope in the source area. In most cases, however, the age in the source area could be appreciably (in terms of conodont zonation) than the age of dislodgement and re-deposition in the Nubrigyn sequence.

NUM Section (Table 9)

Only 13 of the 49 horizons sampled along section NUM, the type section for the Nubrigyn Member, yielded identifiable conodonts.

Locality 11, about 50 m above the base of the Nubrigyn Member, produced *Kimognathus alexeii* indicative of the late Lochkovian *pesavis* Zone. A sample from 113 m above the base of section NUM has co-occurring *Eognathodus sulcatus* iota morph, *Polygnathus zeravshanicus*, *Pandorinellina exigua philipi* and *Pand. steinhornensis miae* indicating allocation to the *kindlei* or *pireneae* Zones.

MAWSON & TALENT (1994b) noted that *Pand. s. miae*, originally described from *dehiscens* Zone horizons in the Sierra

Table 7.
Distribution of conodont elements in section TAN through an unnamed carbonate-bearing interval in the lower part of the Cunningham Formation.

Metres above base		63.0	67.8	71.0	73.0	78.0	79.5	86.0	91.5	100.0	104.0	110.0	113.0	114.0	121.2	124.7	126.5	133.0	140.0	154.0
TAN Sample number		63.0	67.8	71.0	73.0	78.0	79.5	86.0	91.5	100.0	104.0	110.0	113.0	114.0	121.2	124.7	126.5	133.0	140.0	154.0
Amydrotaxis druceana	Pa		1	2	1	2		1	3		1	2	1	2				1	2	1
	Pb	1	1	3	2					1				4		1	1			1
	M		1							1				1					1	1
	Sa							2	1	1								1		
	Sb	2		1	1	1		2	1											
	Sc	2			4	1		1	1					1						2
Ozarkodina excavata excavata	Pa	2	7	2	4	3		6			1	1	1	4	1	1	3	2	1	6
	Pb								1						1	1	1		2	3
	M							1		1			2			2		1	2	
	Sa			2		1		1	3			1	1			3	1		2	
	Sb							2					1		1	2				
	Sc											2								
Ozarkodina r. remscheidensis	Pa	3	3		4	11		5	5	4			2	2		1		3	10	9
	Pb					1														
	M					1														
	Sa					2		1												
	Sb					1														
	Sc					3			1	1										
Ozarkodina sp.	Pa	1	2		1			1								1				2
Panderodus unicostatus		3	6	4	24	18	14	4	3	4	3		16	46	25	12	8	1	16	9
Pandorinellina steinhornensis miae	Pa	2	2	5	4			2						3		1				2
Pseudooneotodus beckmanni		1	1	45	23	4	3	1					5	48	2	7	15		3	7
Oulodus n. sp. A	Pa			1	1											1				
	Pb		1	1	1								1							
	M		1																	
	Sa				1															
	Sb			2	1									1						
	Sc		2	2	1									2						
Panderodus spp.			1	1											1					
Pandorinellina optima	Pa		1			1				1						1				2
Ancyrodelloides omus	Pa			2	2	1													2	1
Coelocerodontus reduncus				2													1		1	
Dvorakia spp.				1	1											1				
Oulodus spicula	Pb												1						1	
	Sa			1												1	1			
	Sb			1																
	Sc			1	1									1						
Oulodus walliseri	Pa				1									1						
	Sa					1		1								1	1			
	Sb								1											
	Sc				1															
Panderodus recurvatus					1			1								1				
Oulodus greilingi hirpex	Pa					1							1	1						
	Pb						1													
	Sa																		1	
	Sc												1			1				
Icriodus steinachensis eta morph	I								1											
Pedavis mariannae	I								1											
	M2a																			1
	M2d																			1
Belodella devonica												1			3	1				
Oulodus aclys	Sc				1									1		1			2	
Indeterminate elements	Pa	1										2		2					4	2
	Pb	1	1	2	4	3	1	2		1	1	1	1	4		2	2	2	6	3
	M	1	1		4				1					4	1		1		3	2
	Sa			2	2	1						1		2						1
	Sb			10	3	1	1					1		8					1	1
	Sc	2	2	18	10							1	1	8	3			1	1	3

Table 8.
Distribution of conodont elements in section NIN (location: Text-Fig. 4A) through the Red Hill Limestone Member of the Cunningham Formation.

Metres above base		-1.2	-0.9	1.2	2.8	6.9	7.5	11.8	12.2	29.9	33.1	33.5	35.9	43.2	45.3	45.4	46.6	49.6	56.1	56.6	57.1	59.6	60.0	61.5	66.0	66.6	72.2	73.7	73.9	77.3	79.3	83.2	86.3	87.1	89.4	90.7	93.8	100.3	109.3	113.5	117.7	120.6	138.3	152.1	163.5
NIN Sample number		-1.3	-1.0	1.3	3.0	7.5	8.1	12.8	13.2	32.5	36.0	36.4	39.0	46.4	48.5	48.6	49.9	52.9	59.5	60.0	60.5	63.0	63.5	65.0	69.5	70.2	75.8	77.4	77.6	81.0	83.0	87.0	90.2	91.0	93.3	94.6	97.8	104.4	113.5	117.8	122.0	125.0	143.0	157.0	168.5
Amydrotaxis druceana	Pa	1				1															1			1			1										1							1	
	M					1																					1																		
	Sc					1		1		1					2	1																													
Ozarkodina cf. *prolata*	Pa	2		1	1																																								
Panderodus unicostatus	Pa	5			2			1	1	11	1	5	4		4	2								5	1									1											
Pandorinellina exigua exigua	Pa	3		1	2								1		1														1															1	
Pedavis sp.	I																			1																									
	S	1																																											
	M2d											1																																	
Oulodus walliseri	Pb																							6																					
	Sa			1																				1																					
	Sc					1				1										1																									
Ozarkodina pandora alpha morph	Pa			1															1	1																									
Ozarkodina r. remscheidensis	Pa			1						2		1					1			1								2																	
Pandorinellina optima	Pa			1																				3																					
Belodella triangularis					1							1						1																											
Ozarkodina excavata excavata	Pa				1					2					2		3		1	3				9				3									1								1
	Pb																		1																										
	Sa															1				1				1																					
	Sb																							1																					
Polygnathus trilinearis	Pa				1							1																																	
Coelocerodontus reduncus							1																					1		1					1			1							
Panderodus recurvatus										1							1																												
Belodella devonica												1																																	
Belodella resima												1												2																					
Polygnathus zeravshanicus	Pa				1																																								
Pseudooneotodus beckmanni								2		1								1																											
Ancyrodelloides omus	Pa														1	1								1														1							
Ancyrodelloides sp.	Pa																			1																									
Ozarkodina pseudomiae	Pa																							18				3																	
Ozarkodina sp.	Pa																																								1				
Polygnathus pireneae	Pa																																		1			2		1	1				
Pandorinellina steinhornensis miae	Pa																																									1			
Polygnathus dehiscens	Pa																																										1		
Indeterminate elements	Pa	1								1					1	1	1			1																								1	
	Pb	3	1	4	1					1					1	1	3	2			2			11		1		1																	
	M			2													1							4																					
	Sa									1					1									2																					
	Sb	1		2						2				1			1						1	13					1																
	Sc	2		2	1					2	1		1			1	3				1			25				1			1				1	1							1		

de Guadarrama, Spain (BULTYNCK, 1971), is frequently found in horizons of that age, e.g. in Morocco (BULTYNCK & HOLLARD, 1980), east-central Alaska (LANE & ORMISTON, 1979) and Central Asia (MASHKOVA, 1978). In the Tyers-Boola area of Australia, however, *Pand. s. miae* occurs in relatively high numbers in horizons of *sulcatus* and *kindlei* age. This accords with SCHÖNLAUB'S (1985) report that in his Oberbuchach II section in the Carnic Alps *Pand. s. miae* makes its appearance prior to the entry of *P. dehiscens*.

BRA Section (Table 10)

Sampling of this section demonstrated co-occurrence of *Polygnathus dehiscens*, *Panderodus exigua exigua*: *Oulodus murrindalensis* and *Ozarkodina prolata* indicating an age of *dehiscens* Zone for some or all of the allochthonous limestone materials in this part of the Nubrigyn Member.

Table 9.
Distribution of conodont elements in section NUM through the Nubrigyn Member of the Cunningham Formation (location: Text-Fig. 5).

Metres above base		2.4	9.6	68.0	70.4	81.2	143.2	165.3	167.4	180.5	210.8	223.6	232.5	239.5
NUM Sample number		4.0	16.0	113.0	117.0	135.0	238.0	265.5	268.0	284.0	321.0	336.7	347.5	356.0
Panderodus unicostatus		1		1		4							2	1
Eognathodus sulcatus iota morph	Pa			2										
Ozarkodina excavata excavata	Pa			2				1		1			2	
	Pb			1										
Pandorinellina exigua philipi	Pa			2										
Polygnathus zeravshanicus	Pa			1										
Pandorinellina steinhornensis miae	Pa				1		1							
Icriodus sp.	I					1								
Panderodus spp.						1						1		
Indeterminate elements	Pa		1											
	Pb			1									1	
	M										1			
	Sa			1										
	Sc		1	1		1	1		1				3	

Table 10.
Distribution of conodont elements in section BRA through portion of upper Nubrigyn Member of the Cunningham Formation (location: Text-Fig. 5).

Metres above base		2.2	2.3	14.4	34.4	54.8	56.9	57.2
BRA Sample number		3.0	3.2	19.8	47.0	69.0	71.4	71.7
Pandorinellina exigua exigua	Pa	1		3		2	2	3
Ozarkodina excavata excavata	Pa	1					1	
Panderodus unicostatus				1				2
Pandorinellina steinhornensis miae	Pa				1			
Ozarkodina sp.	Pa					1		
Oulodus murrindalensis	Sc						1	
Ozarkodina prolata	Pa						1	
Panderodus sp.							2	
Polygnathus dehiscens	Pa						1	1
Polygnathus sp.	Pa						1	
Indeterminate elements	Pb		1	1				
	Sb				1			
	Sc	1	1					

LDB Section (Table 11)

This sequence was sampled across a hill top through a succession of siltstones, arenites, matrix-supported conglomerates with clasts of limestone and other lithologies, and isolated limestone olistoliths; the section commenced about 1500 m (guesstimate) above the base of the Nubrigyn Member. At 68.1 m above the base of the sampled section, a single Pa element of *Polygnathus inversus* is indicative of the *inversus* Zone. It is not inconsistent with the occurrence of *P. nothoperbonus* farther up-section as these two species are known to co-occur in the *inversus* Zone in sections at Buchan, Victoria.

Spot samples

The most interesting Nubrigyn Member spot localities, as regards conodont data (Table 12), are localities 11, 12, 14, 17, 18, 20 and 23–29.

Locality 11 very low in the Nubrigyn Member is *pesavis* Zone and important for obtaining an impression of when the onset of Nubrigyn sedimentation may have occurred.

Locality 12, appreciably higher stratigraphically, produced *O. eleanorae* indicating that materials in that locality came from an older horizon, namely *delta* Zone, known from autochthonous Garra Limestone on the Molong Arch in the Wellington Caves area (WILSON, 1989) and The Gap (FARRELL, 1992, 1995).

Locality 17, stratigraphically intermediate between the last two localities, produced *I. steinachensis* eta morph indicating derivation of materials from a horizon referrable to the *sulcatus* or *kindlei* Zones.

Locality 18, one of the stratigraphically highest localities in the "Canobla" synclinal area produced co-occurring *Ozarkodina selfi* and *Pandorinellina optima* indicating derivation of materials from a horizon also referrable to the *sulcatus* or *kindlei* Zones.

Younger source materials – early Emsian *dehiscens* Zone indicated by the presence of *P. dehiscens* and *Pand. exigua philipi* – were obtained from locality 20, high in the Nubrigyn Member north-east of "Merrimount", and from clasts beside the "Merrimount" road at locality 28. The faunas from localities 23–27 and 29 have materials derived from somewhere in the interval *dehiscens* to *serotinus* Zones (but arguably as old as *pireneae* Zone).

The conodont data for the Nubrigyn Member from sampled sections and spot samples thus indicate an age-spectrum of *pesavis* to *inversus* Zones (and conceivably *serotinus* Zone) for its materials, with most intervening zones being represented in the source horizons. This age-spectrum is consistent with *serotinus* Zone allodapic limestones

Table 11.
Distribution of conodont elements in section LDB through portion of upper Nubrigyn Member of the Cunningham Formation (location: Text-Fig. 5).

Metres above base		50.7	53.3	63.9	68.1	71.9	80.8	84.1	98.7	111.8	117.9	120.3	130.6	153.2
LDB Sample number		54.0	56.7	68.0	72.5	76.5	86.0	89.5	105.0	119.0	125.5	128.0	139.0	163.0
Dvorakia sp.		1	1											
Ozarkodina excavata excavata	Pa	6	4											
Panderodus unicostatus		7	4			1		1				4	1	
Panderodus recurvatus		1												
Oulodus murrindalensis	Sa		1											
	Sc											2		
Pandorinellina steinhornensis miae	Pa		1											
Ozarkodina prolata	Pa			1							1			
Pandorinellina exigua exigua	Pa			1								7		1
Ozarkodina sp.	Pa				2									
Polygnathus inversus	Pa				1									
Belodella resima							1			1				
Panderodus sp.												1		
Polygnathus nothoperbonus	Pa													1
Indeterminate elements	Pa					1								
	Pb		4											
	M	1	1											
	Sb	1												
	Sc	6	1						1					

occurring at stratigraphically higher horizons (localities 9 and 10) in the Cunningham Formation south of Mumbil.

3.2.5. Upper Cunningham Formation

An area of outcrop with several stratigraphically younger allodapic limestones but consisting overwhelmingly of mudstones ca. 2 km south of Mumbil produced chronologically useful conodonts (localities 9, 10; Table 12) but the area is not sufficiently extensive to warrant discrimination as a discrete member within the Cunningham Formation.

One of these, locality 9, is no older than *serotinus* Zone because of the presence of *Polygnathus serotinus*. The presence of *Pandorinellina exigua exigua* and *Pand. e. philipi* at nearby locality 10 is evidence that the source materials for that horizon are from the interval bracketed by the *pireneae* to *perbonus* Zones.

From Grattai Creek, north of Hargraves, at grid reference 926_1382_1, outside of the area investigated by us, PERCIVAL (1998a) has reported *Polygnathus nothoperbonus*/*P. inversus*, *Pandorinellina exigua exigua* and *Ozarkodina linearis* associated with the tabulate corals *Squameofavosites bryani* and *Thamnopora* sp., and the rugosans *Phillipsastrea* sp. and *Xystriphyllum* sp.

Like all carbonates we have encountered in the Cunningham Formation, we assume the limestone from this locality to be allochthonous. Interestingly, it is approximately the same age as the limestones encountered on our section LDB high in the Nubrigyn Member of the Cunningham Formation.

These data, considered in conjunction with the data presented earlier for the Nubrigyn Member, accord with continuous carbonate sedimentation having taken place through all of Emsian time, with the exception of the *patulus* Zone, on the adjacent platform to the west.

3.2.6. Jesse Limestone Member of Limekilns Formation

Two sections (Text-Fig. 4B: DIN and a short section DIC which failed to produce useful conodont data) were sampled north and south of Diamond Creek at Limekilns, both on the east limb of the syncline (Text-Fig. 4B).

The sampling was so closely spaced through the relatively thin, gently dipping sequence that no stratigraphic column is presented for either sampled section.

The sample numbers along a metric tape (Table 13) provide an impression of sequence through the generally coarse calcarenites.

Larger limestone clasts (Table 14 – DIN clasts) are especially abundant in the basal 1–2 m of the sequence. These are up to 30 cms and more in diameter and consist of various lithologies, the most abundant being pale grey shoal-water limestones but with a few conspicuous, rather dark micritic limestones. These latter produced co-occurring *Polygnathus dehiscens* and *P. pireneae* in a sample collected by Dr A.J. WRIGHT indicating a horizon low in the *dehiscens* Zone.

There is no clear succession of conodont faunas from bottom to top of the Jesse Limestone Member. The zonal form, *Polygnathus perbonus* occurs from the base of the section to sample 67 (perhaps as little as 5.8 m above the base of the Jesse Limestone Member). Occurrences scattered through the section of *P. inversus*, *P.* ? *serotinus* and *P. pseudoserotinus* are indicative of the mixing of faunas that has taken place during accumulation of the Jesse Limestone Member.

We therefore conclude that the carbonate fan is best viewed as having been emplaced largely if not entirely during the *serotinus* Zone, with cannibalisation of previously lithified limestones ranging in age from early in the *dehiscens* Zone through to the *serotinus* Zone, with a tendency to preponderance of horizons referable to the *perbonus* Zone.

It is thus apparent that there is a high possibility that even a collection of macrofauna or microfauna from a single bed may contain materials from any one (or more) of the Emsian conodont zones, with the possible exception of only one interval, the brief latest Emsian *patulus* Zone.

Table 12.
Conodont elements from productive spot localities from the western flank of the Hill End Trough (locations: Text-Figs. 4A and 5).

Spot localities		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	20	21	22	23	24	25	26	27	28	29
Amydrotaxis druceana	Pa				1										1														
	Pb	1	1	1	1																								
	Sb				1																								
	Sc														1														
Ancyrodelloides omus	Pa		3		1		1								1														
Ozarkodina linearis	Pa		2																										
Kimognathus alexeii	Pa				1							1																	
Oulodus walliseri	Pa				1																								
	Pb				2																								
	Sa				1																								
	Sc				2																								
Oulodus sp.	Pa						1																						
	Pb						1																						
	Sa														1														
	Sc				1								1						1										
Coelocerodontus reduncus					2			1																					
Flajsella streptostygia	Pa				1																								
Flajsella schulzei	Pa				1																								
Ozarkodina excavata excavata	Pa				14								2	2	1						3					1			
	Pb				2																1								
	M				1																								
	Sa				5																1								
	Sb				1																								
	Sc																				1								
Ozarkodina r. remscheidensis	Pa				2																	1							
	M													1															
	Sb													1															
Ozarkodina eleanori	Pa				4								1																
Ozarkodina r. repetitor	Pa				2														2										
Panderodus spp.					1											1		1	1										
Panderodus unicostatus	Pa				24		6			1	3		1	4	2	1	1		4		1			1		4		1	1
Pandorinellina steinhornensis miae	Pa				1						4																		
Pedavis sp.	M2a				1																								
Pseudooneotodus beckmanni					3								4		1		1												
Ozarkodina pseudomiae	Pa					1	2																						
Pandorinellina exigua exigua	Pa								1		8				2									1	2	7	6	2	8
Ozarkodina sp.	Pa									1					1	2						1							
Polygnathus serotinus	Pa									1																			
Belodella devonica											3																		
Ozarkodina prolata	Pa										4												3			1			1
Pandorinellina exigua philipi	Pa										1								6	1								4	
Pandorinellina optima	Pa											1	1																
Amydrotaxis sp.	Sc												1																
Icriodus steinachensis eta morph	I																	1											
Ozarkodina selfi	Pa																		1										
Polygnathus dehiscens	Pa																			1									
Belodella resima																								1					
Icriodus sp.																												1	
Indeterminate elements	Pa				1		2								2		1			2									
	Pb				14		1	2		1	3			1			1		1	1	1			1		1	1		
	M				9						1			1	1														
	Sa				2		1												1		1								
	Sb			1	2	1	1								3					2	1					1			
	Sc		1	1	16	1		1			4	2		2	1		4		3		2						1		1

Table 13.
Distribution of conodont elements in section DIN (location: Text-Fig. 4B).from the Jesse Limestone Member of the Limekilns Formation at Limekilns.

Metres above base		0.00	0.01	0.02	0.03	0.03	0.05	0.07	0.08	0.10	0.22	0.24	0.26	0.44	0.54	0.71	0.82	0.85	0.94	0.96	1.01	1.15	1.30	1.34	1.43	1.74	1.75	1.82	1.86	1.93	1.97	2.09	2.19	2.22	2.35	2.49	2.66	2.72	2.82	2.88	3.05	3.19	3.44	3.68	3.71	4.72	5.84	6.82	7.43	8.18	16.41	29.2	76.63
DIN Sample number		0.0	0.1	0.2	0.3	0.35	0.6	0.8	0.9	1.1	2.5	2.8	3.0	5.0	6.2	8.2	9.4	9.7	10.8	11.0	11.6	13.2	14.9	15.4	16.4	20.0	20.1	20.9	21.3	22.1	22.6	24.0	25.1	25.5	27.0	28.6	30.5	31.2	32.3	33.0	35.0	36.6	39.5	42.2	42.6	54.2	67.0	78.2	85.3	91.0	120.0	165.0	332.0
Polygnathus perbonus	Pa	3		2		3	5	2	8	1	3	9		1		4	1	1		1					4		2		2		1				5		7				3	1					1						
Ozarkodina excavata excavata	Pa		2		1			1																																													
Panderodus unicostatus			1						1	1											1					1			5						17		2	1	1							1	1		1			1	
Ozarkodina linearis	Pa			3			1	1	3	1		1				2													1			1	1				1				1			2			2						
	Pb																								1																												
Pandorinellina exigua exigua	Pa			3			6	5	4	2	1	3		1		3				1	1		1			1	3	4	2	1			1		6		11			1	1					2	7		8		2		1
Amydrotaxis druceana	Pa			1																																																	
Polygnathus sp.	Pa			1		1					2									1						2	4								2	1	1			1	1												
Coelocerodontus reduncus						1																																															
Ozarkodina prolata	Pa					1	1	1	1												1				1				1			1	1	1	2												1		2				
Polygnathus serotinus	Pa							1?		1?	1?						2				1?	1				8	7							1		1					1		3	2									
Polygnathus nothoperbonus	Pa											7				4										1			1			2	1	1	1		1																
Pandorinellina sp.	Pa												1			1	1																																				
Belodella resima														1							1									1					1														2				
Pandorinellina expansa	Pa																1							1																									1				
	Pb																						1												1																		
Ozarkodina sp.	Pa																				1																								1								
Drepanodus sp.																																			1																		
Belodella devonica																																			2														1				
Polygnathus inversus	Pa																																				1																
Oulodus murrindalensis	Sb																																							1													
Polygnathus pseudoserotinus	Pa																																							1													
Indeterminate elements	Pa				3	1		1																											1																		
	Pb					1	2	2							1		1		1									1				1			8		2			1		1							4			1	
	M																						1																	1													
	Sb																																				1																
	Sc						1							1							1								1						3																		

Table 11.
Distribution of conodont elements from 12 clasts from the basal 1 m of section DIN (location: Text-Fig. 4B) through the Jesse Limestone, Member of the Limekilns Formation at Limekilns.

DIN Clast		Corner clast - base	1	2	3	4	5	6	7	8	9	10	11
Oulodus murrindalensis	Pa											1	
	M	1									1		
	Sa						1		1				
	Sb		1	1									
Ozarkodina linearis	Pa	1	1	1			1			3	2		
	Pb			1									
Ozarkodina prolata	Pa	6	1	7	1	2	1	1			4	2	3
Polygnathus dehiscens	Pa	2		2				4		1			
Polygnathus perbonus	Pa	1		17			5	10	9	39		12	
Panderodus unicostatus		4		14	3	2	9	13	1	8	1	1	
Pandorinellina exigua exigua	Pa	17	2	36	1	3	28		2	25	26	12	
Drepanodus sp.		1						4	1			3	
Belodella devonica				1		2	1	4				2	
Belodella resima				2				2					3
Polygnathus nothoperbonus	Pa			2			1	2	1	3			
Belodella triangularis						1							1
Pandorinellina expansa	Pa						1						
	Pb						1						
Pandorinellina sp.	Pa						1						
Polygnathus n. sp. A	Pa							9			1		
Polygnathus sp.	Pa							1		3			
Polygnathus inversus	Pa									1			
Indeterminate elements	Pa	1										1	
	Pb		1	1		4	4	9	1		4	2	
	M	4		2							1	2	
	Sa	1		1				1					
	Sb	1						1					
	Sc	5	1	3		3	2	8	2		1		

4. Events Along and Adjacent to the Western Flank of the Hill End Trough

4.1. Late Silurian–Early Devonian Sedimentary Events on the Molong Arch

We suggest that a suite of events representing significant environmental change may be discerned in the Late Silurian to Early Devonian history of the portion of the Molong Arch adjoining the main focus of the present investigations, the Dripstone-Mumbil-Euchareena area. Some of these events have been alluded to elsewhere (TALENT & YOLKIN, 1987; TALENT, 1989). Many of these represent transgressive or regressive events identified by change between intervals with pelagic fauna, particularly graptolites and conodonts, and intervals identified as shallow water (or even emergent). For example, massive algal limestones and limestones with fenestral fabrics are accepted as indicators of particularly shallow or, in the case of the latter, even supratidal environments. The following scenario is suggested:

❶ A regression event (or expression of tectonic activity) indicated by the disconformable relation between the Narragal Limestone and older units.

❷ A regional transgressive event represented by the Narragal Limestone. This unit is noteworthy for relative abundance of dolomite often occurring interstitially as matrix between fossils and, occasionally, of fenestral fabrics, both phenomena being indicative of very shallow water.

❸ A major deepening event represented by the graptolitic Wallace Shale and, in various areas including the area west of "Canobla", carbonate fan or channel deposits derived from erosion of presumably orographically positive areas of outcrop of Nandillyan and Narragal Limestones.

❹ An early Lochkovian shallowing event indicated by the Camelford Limestone.

❺ A presumed complex of tectonic events associated with extrusion of the predominantly andesitic Cuga Burga Volcanics and, farther south, southeast of Manildra, its possibly coeval but more volcaniclastic Goonigal Group (formerly Fairhill Formation of SAVAGE [1969] not to be confused with Mandagery Formation of POGSON & WATKINS [1998]). These are inferred to be a product of events during the early Lochkovian (broadly *eurekaensis* Zone), with at least some of the volcanic activity having been submarine.

❻ Following cessation of the Cuga Burga volcanic episode, an erosional and transgressive event, expressed in the Wellington area by the Mungallalla Member – consisting of conglomerates (derived from Cuga Burga and older units) passing up into impure limestones. This event was followed by

❼ a further transgressive event represented by an interval of dark limestones (20–30 cm beds) on WILSON's (1989) MUNG section at Wellington; this event occurred within the *pesavis* Zone and was followed by

❽ a regressive event extending from apparently late in the *delta* Zone and extending through into the *pesavis* Zone. This is expressed by an extensive interval of massive and poorly bedded limestones at The Gap (FARRELL, 1992) and by massive poorly bedded limestones between WILSON's (1989) MUNG and GCR sections in the Wellington Caves area. This may be a local rather than regional or global event. It was followed by

❾ a transgression high in the *pesavis* Zone well expressed on WILSON's (1989) GCR section in the Wellington Caves area. The excellent Garra Limestone sequence at Wellington does not show evidence of significant regression through the *sulcatus-kindlei* interval, although soon after the first appearance of *P. pireneae* in WILSON's (1989) MVR section there was

❿ a major regression (Johnson's, 1975, units 12–17), expressed by the swift change from well-bedded, highly fossiliferous grainstones into massive limestones, often with fenestral fabrics testifying to occasional supratidal environments. Fossils are generally infrequent, consisting of rare, coarsely recrystallized trochiform gastropods, huge bivalves – sometimes demonstrably fossilized by leaching of shell carbonate followed by laminar sedimentation within the moulds – and a disheartening dearth of conodonts apart from rare, simple cones. We correlate this event, in the *pireneae* Zone, with increased erosion on the carbonate platform and generation of the Red Hill carbonate fan on the western flank of the Hill End Trough.

⓫ A deepening transgressive event high in the Garra Limestone sequence at Wellington characterised by return to highly fossiliferous limestones with corals, stromatoporoids, crinoids including calices, and brachiopods (Johnson's, 1975, unit 18), followed by

⓬ Another regressive event characterised again by massive and poorly bedded limestones with reduced faunal diversity (Johnson, 1975, units 19–20).

4.2. Sedimentary Events Along the Western Flank of the Hill End Trough

Though the former Devonian platform margins have not been preserved, we have concluded that the Tolga Member of the Cunningham Formation may be interpreted as a mid-ramp accumulation, primarily a product of intermittent carbonate turbidites (allodapic limestones) and grain-flow carbonates intercalated with intervals of shale and argillaceous mudstone identified, at least in part, as having been turbidite-emplaced (Pl. 2, Fig. 3). We interpret the Red Hill Limestone Member to represent a carbonate fan or major persisting channels in the Cunningham Formation receiving carbonate debris from the Garra Limestone on the Molong Arch. We have not identified change in sedimentary style up-sequence that might reflect progradation or regression, but suggest that the influx of "Red Hill" carbonates reflects a period of low-stand on the platform, followed, on termination of the "Red Hill" carbonate event, by reversion to "normal" distal turbidite sedimentation. We accept the contention by Conaghan et al. (1976) that the rhythmic character of the Nubrigyn sedimentation implies a periodic triggering mechanism (or mechanisms) causing "repeated dislodgement of carbonates and associated sedimentary and volcanic rocks" (see below). Evidence from the Hill End Trough sequence (discussed earlier) implies persistence of carbonate sedimentation and perhaps originally of an unbroken Garra Limestone sequence on the adjoining platform through most of the Emsian, until at least into the *serotinus* Zone.

Sedimentary events along the western side of the Hill End Trough, that seem to align chronologically with events on the adjacent platform, are as follows:

❶ The Wallace Shale sequence extends eastwards into the Hill End Trough (Text-Figs. 4A, 5) where it includes prominent limestone bodies interpreted as probably submarine fan or channel fills (see earlier) derived at least in part from Nandillyan Limestone. We are unable to determine whether or not these imply a regressive interval on the adjacent platform or if it is a reflection of tectonic activity.

❷ As suggested earlier, we interpret the Tolga Member as displaying rhythmic winnowing of limestone detritus, chronologically consistent with derivation from lower levels of the Garra Limestone, swept over the platform margin into the Hill End Trough, i.e. this sedimentary package may be an expression of the late *delta*–early *pesavis* Zone shallowing interval well expressed in the Garra Limestone on the adjacent platform.

❸ The Red Hill Limestone Member aligns well with the *pireneae* Zone event 11 on the platform. Its persistence into the *dehiscens* Zone suggests that transgression 12 (not well constrained by conodont data from the Molong Arch) took place within the *dehiscens* Zone.

❹ Large scale limestone-fan accumulation, lithologically very similar to that represented by the Red Hill Fan, occurred again in the Jesse Limestone Member at Limekilns, farther to the east in the Hill End Trough; it is believed to have been derived from easterly or southerly sources rather than from the Molong Arch. As noted above, a sampled sequence through this unit showed it to have been emplaced no earlier than late Emsian *serotinus* Zone, though including materials of the preceding 3 zones.

In summary, sedimentary events on the Molong Arch align chronologically in broad fashion with sedimentary events in the adjacent Hill End Trough. They may be interpreted as being consistent with a pattern of reciprocal sedimentation: development of carbonate fans within the Hill End Trough correlative "time-wise" with regressive events on the adjacent carbonate platform.

4.3. "Lost" Carbonate Platforms

❶ Conodonts from our MOS section through a large olistolith in the Nubrigyn Member indicate an age close to the Ludlow-Pridoli boundary, a time-slice for which there is no presently identifiable carbonate sequence on the adjoining platform. It apparently postdates the Narragal Limestone and predates the Camelford Limestone (see section 3.1.2; cf. Table 1).

❷ Conodonts from limestone clasts high in the Nubrigyn Member of the Cunningham Formation and from the Jesse Limestone (see section 3.2.6.) provide evidence for former platform limestone sequences – "lost" Emsian carbonate platforms. There are no identifiable potential source-intervals in the surviving tracts of autochthonous Devonian limestones The conodont data imply former existence up-slope of autochthonous limestone intervals with *dehiscens*, *perbonus*, *inversus* and *serotinus* Zones. The *dehiscens* Zone is nevertheless inferred by us to be represented in the Wellington sequence of the Garra Limestone but not in a polygnathid biofacies. In the case of the Jesse Limestone Member, there are no Emsian platform carbonate sequences east of it which could be remnants of a possible source sequence.

4.4. Possible Tectonic Triggering of Nubrigyn Member Sedimentation

Byrnes (1976, and in Pickett 1982) suggested that the debris flows and transport of Late Silurian and Early Devonian olistoliths occurred in submarine valleys heading back into the Molong Arch:

❶ The Mirrabooka Submarine Valley oriented south-west during accumulation of the Wallace Shale.

❷ The Nubrigyn Submarine Valley oriented north-east during accumulation of the Nubrigyn Member.

CONAGHAN et al. (1976, p. 528) suggested (see earlier), with respect to the Nubrigyn Member, that dislodging the carbonates and associated sedimentary and volcanic rocks may have taken place from "slopes overloaded and oversteepened by outbuilding" of the host carbonate platform, and that collapse may have been triggered by tsunamis or earthquakes. We accept this as a competing hypothesis for triggering of the Nubrigyn Member cyclic sedimentation.

Triggering by tsunamis or earthquakes may explain some, perhaps all of the rhythmic sedimentation displayed by the Nubrigyn Member, but the thick spread of westerly-derived sediments, the abnormal range of clast sizes, and the broad spectrum of clast types – Silurian and Early Devonian olistrostromal limestones, and Silurian, Early Devonian and ?Ordovician andesitic and rhyolitic volcanics and olistoliths of presumed pre-Devonian non-carbonate clastics – testifies to the possibility of even more dramatic sedimentation processes connected with major slope-failure.

We suggest that the Nubrigyn Member materials may have been shed off an advancing deformation front with re-working of unlithified and lithified limestones and other materials down the western margin of the Hill End Trough, and that the rhythmic nature of the Nubrigyn Member, so easily appreciated in the field in the "Canobla"-"Merrimount" area (Pl. 2, Fig. 2) and elsewhere, may be eloquent testimony to the nature of the triggering tectonic activity. We suggest because of this pulsed character of sedimentation and especially because of the grand scale of many of the sedimentary packages – the major debris flows, the spectacular megabreccias, and the colossal scale of numerous olistoliths – that the Nubrigyn sedimentation may reflect the sequence and scale of movements on adjacent structures to the west: successive sizable movements triggering sloughing off of unlithified and lithified material from the deformation area, and transport of the dislodged materials eastwards into the deeper waters of the Hill End Trough.

A more subtle mechanism seems required for the finer rhythmic sedimentation displayed by the Tolga Member. The graded bedding of the carbonates may reflect the activity of tempests periodically sweeping detritus from the adjoining carbonate platform to the west, producing an apron of largely allodapic carbonates interleaved with mudstones, including shales and siltstones, to various degrees flyschoid.

5. Taxonomic Comment

As most forms identified in this study have been extensively documented in other publications, for example in the Catalogue of Conodonts (ZIEGLER, ed., 1973–1991), discussion is restricted to species that are new or of particular biostratigraphic interest. Other species have been identified (Tables 2–14) and are illustrated (Plates 3–13). We continue to use the four-fold zonation of the Lochkovian, including the *delta* and *pesavis* Zones, that has been in use for 19 years (e.g. KLAPPER & JOHNSON, 1980; KLAPPER & MURPHY, 1980), though a new approach to zonation of the middle Lochkovian, with focus on *Flajsella* and *Ancyrodelloides*, has been proposed recently (VALENZUELA-RÍOS & MURPHY, 1997). The classification used herein follows SWEET (1988). Figured specimens are housed in the collections of the Australian Museum, Sydney catalogued with the prefix AMF.

Genus: *Panderodus* ETHINGTON, 1959

Panderodus greenlandensis **ARMSTRONG, 1990**

(Pl. 3, Figs. 5, 16–19)

Remarks: For synonymy see ARMSTRONG (1990, p. 102). Specimens identified herein as *Panderodus greenlandensis* ARMSTRONG, conform with the diagnosis of the species (ARMSTRONG, 1990, p. 102) in all respects being "typically robust, broad" and in having "well developed, broadly rounded lateral costae and a deep lateral furrow". The zone of basal wrinkles commonly associated with the species is usually clearly developed on specimens from the TEZ section (e.g. Pl. 3, Figs. 5, 17, 18) but is less obvious on less well preserved specimens (e.g. Pl. 3, Figs. 16, 19, 20). Specimens identified herein as *Panderodus* n. sp. SIMPSON, that similarly have a broad base and a comparable basal ridge, may be derived from *P. greenlandensis*.

Panderodus **n. sp. SIMPSON, this volume**

(Pl. 3, Figs. 20–22)

Remarks: For synonymy see SIMPSON (this volume). This broad based panderodid has been described by SIMPSON (this volume) but not named because of lack of numbers. In the Nubrigyn area it appears first in TEZ 24 – in association with the *Ozarkodina excavata* group – above the last occurrence of *Distomodus staurognathoides* BARRICK & KLAPPER. The slightly inflated, rolled basal margin of the cones is remarkably similar to those of *P. greenlandensis* suggesting close relationship.

Genus: *Icriodus* BRANSON & MEHL, 1938

Icriodus steinachensis **AL-RAWI, 1977 eta morph**

(Pl. 4, Fig. 6; Pl. 7, Figs. 5, 6; Pl. 12, Fig. 17)

Remarks: For synonymy see MAWSON & TALENT (1994b, p. 47). Several poorly preserved icriodontans have been identified as *I. steinachensis* AL-RAWI eta morph on the basis of the widest part of the spindle being more or less central rather than at or near the posterior extremity, and having the angle of the posterior lateral process ranging from "less than 90 to 110 degrees". MURPHY & MATTI (1983) reported this morph to occur from the middle of the *delta* Zone through to the early *kindlei* Zone.

Genus: *Ancyrodelloides* BISCHOFF & SANNEMANN, 1958

Ancyrodelloides omus **MURPHY & MATTI, 1983**

(Pl. 5, Figs. 6–9; Pl. 7, Fig. 13; Pl. 8, Figs. 4, 11)

Remarks: For synonymy see KLAPPER (in ZIEGLER [ed.], 1991) and VALENZUELA-RÍOS (1994, p. 37, 38 and 49). In erecting a new species, *Ancyrodelloides omus* MURPHY & MATTI (1983) suggested that this species – with shouldered platform lobes – evolved from *Ozarkodina remscheidensis* and is the oldest representative of the genus *Ancyrodelloides*. They suggested that during the evolution of *Ancyrodelloides* the open basal cavity present in *Anc. omus* became gradually more restricted through time. Two morphs were designated: *Anc. omus* alpha morph in which the platform lobes are shouldered but smooth, and *Anc. omus* beta morph in which the shouldered platform nodes are surmounted by tubercles (MURPHY & MATTI, 1983, p. 17). They (MURPHY & MATTI, 1983, Fig. 4) indicated that *Anc. omus* alpha morph is restricted to the basal *delta* Zone and that *Anc. omus* beta morph makes its first appearance slightly above the base of the *delta* Zone, continuing through to horizons slightly above the last appearance of *Anc. omus* alpha morph. They occur together in the basal quarter of the *delta* Zone. Based on stratigraphic information provided by MURPHY & BERRY (1983, Fig. 2), KLAPPER (in ZIEGLER, 1991) gave the range of the species as highest *eurekaensis* Zone to *delta* Zone.

Subsequent to MURPHY & MATTI's 1983 publication, CHLUPÁC et al. (1985, Fig. 17) showed that in faunas from the Barrandian and Carnic Alps the first appearance of *Ancyrodelloides omus* was late in the early Lochkovian, and that it extended through until early in the late Pragian. KLAPPER (in ZIEGLER, ed., 1991) included material from Tyers, Australia, referred to *Spathognathodus steinhornensis* by PHILIP (1965), in the synonymy of *Anc. omus* specimens, noting that the stratigraphic position of the material was not known. MAWSON & TALENT (1994b) showed from abundant material that both morphs of *Anc. omus* occurred in their sections at Tyers (197 specimens) and nearly at Boola (272 specimens) in the *sulcatus* and *kindlei* Zones.

It is apparent, therefore, that *Anc. omus* is long ranging, extending from late in the *eurekaensis* Zone through into the *kindlei* Zone. We suggest that because of its wide, open ozarkodinan-type of basal cavity, this species might be better placed in *Ozarkodina*, though still recognised as the ancestral form of the *Ancyrodelloides* lineage.

In the area under study, *Anc. omus* occurs in horizons referred to the *pesavis* Zone in the MAC section, early *kindlei* Zone in the TAN section, and of *kindlei* into *pireneae* Zone in the NIN section.

Genus: *Flajsella*
VALENZUELA-RÍOS & MURPHY 1997

Remarks: *Flajsella* is discriminated from *Ozarkodina* on the basis of its large, posterior basal cavity, tiny posterior blade, and near-conical cusp (VALENZUELA-RÍOS & MURPHY, 1997, p. 135).

Flajsella schultzei (BARDASHEV, 1989)

(Pl. 11, Fig. 19)

Remarks: For synonymy see VALENZUELA-RÍOS & MURPHY (1997, p. 136). According to VALENZUELA-RÍOS & MURPHY (1997, p. 137 and Fig. 3), this species is restricted to the "upper half of the middle part of the middle Lochkovian (= *eleanorae-trigonicus* Zone)", equating with the middle of the *delta* Zone. The single occurrence of *Flajsella schulzei* in association with *F. streptostygia* in a spot sample suggests that, in Australia at least, this species may range into the *pesavis* Zone.

Flajsella streptostygia VALENZUELA-RÍOS & MURPHY, 1997

(Pl. 11, Fig. 20)

1979 *Ozarkodina stygia* (FLAJS) delta morph LANE & ORMISTON. – p. 57–58, Pl. 2, Figs. 23, 28.
1980 *Ozarkodina stygia* (FLAJS) gamma morph SCHÖNLAUB. – p. 38, Pl. 4, Figs. 21, 22; delta morph, SCHÖNLAUB. – Pl. 4, Fig. 26.
1983 *Ozarkodina stygia* (FLAJS). – MURPHY & MATTI, p. 10–12, Text-Fig. 2.
1988 *Ozarkodina stygia* (FLAJS). – MAWSON et al., 1988, Fig. 21.6.
1989 *Ozarkodina stygia* (FLAJS) delta morph LANE & ORMISTON. – WILSON, p. 138, Pl. 4, Figs. 22–28.
1997 *Flajsella streptostygia* VALENZUELA-RÍOS & MURPHY. – p. 140, Fig. 9: 1–4, ?13–16, ?19–25, 31–37.

Remarks: This form was first recognised by LANE & ORMISTON (1979, p. 57–59, Pl. 2, Figs. 23, 28) in a collection of over 460 specimens of "*Ozarkodina stygia*" from the *delta* and *pesavis* zones in the Salmontrout Limestone of Alaska. They believed this particular morph was restricted to the *pesavis* Zone and was therefore a good indicator for that zone. The holotype of *F. streptostygia* designated by VALENZUELA-RÍOS & MURPHY is, however, a specimen from Coal Canyon, northern Simpson Park Range, Nevada (VALENZUELA-RÍOS & MURPHY, 1997, Fig. 32, 33). However, it appears from VALENZUELA-RÍOS & MURPHY's comments that, in Nevada, the species occurs in older horizons, in the *delta* Zone. On the basis of presently available data for *Kimognathus alexeii*, we are inclined to regard the co-occurrence of *F. streptostygia* with *K. alexeii* in their samples SP-VII/15 and 15a to be evidence for allocation of that interval to the *pesavis* Zone. VALENZUELA-RÍOS & MURPHY (1997, p. 135) noted, in discussion of the genus *Flajsella*, that WILSON (1989) had documented LANE & ORMISTON's delta morph from the Garra Limestone in eastern Australia from horizons dated as *pesavis* Zone, but no comment was made regarding possible chronologic implications of WILSON's identification. Additional data are clearly needed on the origin and evolution of *Kimognathus*.

Genus: *Kimognathus* MASHKOVA, 1978

Kimognathus alexeii MASHKOVA, 1978

(Pl. 11, Fig. 11)

1971 gen. et sp. nov. DRUCE, p. 48, Pl. 9, Fig. 5.
1978 *Kimognathus alexeii* sp. nov. MASHKOVA, p. 94, 96, Plate 2, Figs. a–m.
1984 *Kimognathus alexeii* MASHKOVA. – SAVAGE & GEHRELS, p. 1423.
1984 *Kimognathus* n. sp. A. – SAVAGE & GEHRELS, p. 1423, Pl. 1, Figs. 27–30.
1984 *Kimognathus* n. sp. B. – SAVAGE & GEHRELS, p. 1423, Pl. 1, Figs. 31–34; Pl. 2, Figs. 27–30.
1988 *Kimognathus alexeii* MASHKOVA. – MAWSON et al., Fig. 21: 7–17.
1989 *Kimognathus alexeii* MASHKOVA. – SORENTINO, p. 92, Pl. 5, Figs. 1–12.
1989 *Kimognathus alexeii* MASHKOVA. – WILSON, p. 144, Pl. 5, Figs. 1–28; Pl. 6, Figs. 1–12.
1990 *Kimognathus alexeii* MASHKOVA. – BARDASHEV, p. 220–221, Pl. 109, Figs. 8–21.
1991 *Kimognathus alexeii* MASHKOVA. – BARDASHEV & ZIEGLER, Pl. 2, Figs. 21–24, 26–30.
1995 *Kimognathus alexeii* MASHKOVA. – SAPEL'NIKOV et al., Text-Fig. 2.

Remarks: The morphologically highly distinctive *Kimognathus alexeii* – with its lateral process in the form of an "outrigger" – has been reported from horizons referred to the *pesavis* Zone from several localities in Australia: from the Garra Limestone at Wellington, New South Wales (DRUCE, 1971; MAWSON et al., 1988; WILSON, 1989), The Gap (MAWSON et al., 1988), and Eurimbla (MAWSON et al., 1988; SORENTINO, 1989; BROCK, 1996, and in prep.); and from the Martins Well Limestone Member of the Shield Creek Formation of north-eastern Queensland (MAWSON et al., 1988). Its biogeographic significance is obvious. It has not been encountered in Europe or North America except for Prince of Wales Island in southeastern Alaska (SAVAGE & GEHRELS, 1984), but is known from the west flank of the Urals, and from central Asia from a region assumed to have once been part of the Gondwana continental margin (MASHKOVA, 1978; BARDASHEV, 1991).

Genus: *Eognathodus* PHILIP 1965

Eognathodus sulcatus PHILIP, 1965 iota morph

(Pl. 9, Figs. 20, 21)

Remarks: For synonymy and discussion of *E. sulcatus*, its morphs and subspecies, see MURPHY, MATTI & WALLISER (1981), MURPHY (1989), MAWSON & TALENT (1994b) and MAWSON (1998). In order to understand variation in this species and in order to allay concern regarding the relative stratigraphic position of the holotype of *E. sulcatus* and its paratypes expressed in recent years at meetings of the Subcommission on Devonian Stratigraphy and by individual researchers (e.g. MURPHY 1989), MAWSON & TALENT (1994b) undertook a study of conodont faunas from the Tyers-Boola area in eastern Victoria, including the long-abandoned Tyers Limestone Quarry, type locality of *E. sulcatus* (PHILIP 1965), and the nearby Boola Quarry. Despite the holotype of *E. sulcatus* being a large and obviously gerontic specimen compared to the designated paratypes illustrated by PHILIP (1965), workers globally, for more than 30 years, have been able to recognise *E. sulcatus* (See MAWSON, 1998, for cited literature). The boundary between the *sulcatus* and *kindlei* zones is readily discriminated in the sampled sections in both the Tyers and Boola quarries. The occurrence of *E. sulcatus* iota morph with *P. zeravshanicus* in NUM 113, in the type section for the Nubrigyn Member, suggests extension of its range from the *kindlei* Zone into the *pireneae* Zone.

Genus: *Polygnathus* HINDE, 1879

Polygnathus trilinearis (COOPER, 1973)

(Pl. 8, Figs. 18, 20)

Remarks: For synonymy see MAWSON et al. (1992, p. 51, Fig. 9A-G). That this species, described by COOPER (1973) as "*Spathognathodus*" *trilinearis*, should be recognised as one of the earliest polygnathids, has been discussed at length (MAWSON et al., 1992; MAWSON & TALENT, 1994b; MAWSON, 1995, 1998; WALL et al., 1995). It has been suggested (MAWSON, 1998) that a wide form of *Eognathodus sulcatus*, *E. sulcatus* secus, gave rise to the "*Polygnathus*" *trilinearis-hindei* lineage, one that, seemingly, did not evolve further. In the study area, *P. trilinearis* occurs with *P. zeravshanicus* low in our NIN section in an interval referred to the *pireneae* Zone, well below the entry of *P. dehiscens* (see sections 3.2.2 and 3.2.3).

Polygnathus zeravshanicus (BARDASHEV & ZIEGLER, 1992)

(Pl. 8, Fig. 17; Pl. 9, Fig. 22)

Remarks: For synonymy see MAWSON (1998, p. Pl. 2, Figs. 4–5). *P. zeravshanicus* has a relatively deep, narrow and gently curved platform lacking adcarinal grooves. It differs from *P. pireneae* in having a deeper, less linguiform platform. MAWSON (1998) suggested that the narrow form, *Eognathodus sulcatus kindlei* LANE & ORMISTON (= *E. sulcatus* lambda morph), developed a third row of denticles centrally along the platform to become *P. zeravshanicus*, which in turn gave rise to the lineage *P. pireneae-dehiscens-nothoperbonus-inversus-serotinus*. In our NIN and NUM sections, *P. zeravshanicus* occurs with other forms consistent with allocation to the *pireneae* Zone.

Polygnathus n. sp. A

(Pl. 10, Figs. 12, 18–23)

Remarks: Ten specimens from one sample, a clast from DIN 6, appear to be an undescribed species of *Polygnathus*. Because of small numbers and occurrence in a clast, no formal name is given. The new polygnathid is tiny, with a narrow, abbreviated platform terminating approximately where the carina bends. The open basal cavity on the lower surface terminates at the same point, or extends as an open groove under the carina. Adcarinal grooves are well developed, bearing weakly defined, elongate nodes along the outer margins, but are smooth in the trough. *P. boucotia* is similarly small with an abbreviated platform but the new species from the Limekilns area does not have the bend in the carina characteristic of that form. *P.* n. sp. A occurs with *P. dehiscens*, *P. perbonus* and *P. nothoperbonus*, species indicative of a *perbonus* Zone (= *gronbergi* Zone) assemblage.

Incertae Sedis

Genus and species undet.

(Pl. 13, Figs. 8–15)

Remarks: Numerous fragments of an undetermined genus and species of possible biochronologic significance are documented because of their presence in several of our sampled sections. Straight and slightly curved bars (Pl. 13, Figs. 8, 9, 13, 14) are surmounted by node-like protuberances (Pl. 13, Figs. 8–10, 13–15). Each node is knob-like with distinct pustular microsculpture on the uppermost surface (e.g. Pl. 13, Fig. 10). The "stem" of each node has finer microstructure on its outer lateral margins parallel to the length of the bar (e.g. Pl. 13, Figs. 13–15) but is smooth on its inner margin between nodes (e.g. Pl. 13, Fig. 15).

It has been suggested that polygonal surface microstructure evident on the surface of many groups possibly represents impressions of epithelial secreting cells (e.g. HASS, 1941; PIERCE & LANGENHEIM, 1970; BURNETT, 1988; VON BITTER & NORBY, 1994). As pointed out by VON BITTER & NORBY (1994), such ornament occurs in many invertebrate and vertebrate groups, e.g. in early vertebrates (SCHULTZE, 1977; SMITH, 1977; BLIECK, 1982; LELIÈVRE et al., 1983), brachiopods (LINDSTRÖM, 1973; CURRY & WILLIAMS, 1983), arthropods (WILMONT, 1990a, b, 1991; GIRAUD-GUILLE, 1984; OKADA, 1981), and tommotiids (CONWAY-MORRIS & MENGE, 1990). The microstructure is polygonal in all the above. The ornament on the nodes of the present material is less systematic; the pustules are discrete rather than organised into a well-defined polygonal net (cf. illustrations presented by VON BITTER & NORBY, 1994).

In the study area, nodose bars occur low in the MAC section (MAC 2 and 3), in DMR 109, in eight horizons of the MBS section between MBS 7.1 and MBS 108.6, in five horizons in the TAN section between TAN 71 and 121.2, and from spot locality 7. These occurrences span the interval *pesavis* Zone to *kindlei* Zone.

6. Appendix: Locality Register

Emphasis in sampling was on stratigraphic sections, supplemented by numerous spot samples. A low proportion of acid-leached samples produced biostratigraphically useful conodonts. This was presumably because clasts at all scales including the largest olistoliths consist predominantly of massive, pale grey shoal-water limestones, representing environments which rarely yield conodonts, or produce very rare coniform elements. Locations of sampled stratigraphic sections and spot samples (Tables 2–14) are shown on Text-Figs. 4A, 4B and 5. Grid references are to 1 : 50,000 topographic sheets 8732 – I & IV Burrendong, 8632 – II & III Cumnock, 8732 – II & III Euchareena, and 1 : 100,000 topographic sheet 8831 Bathurst.

Spot Localities Productive for Conodonts

Mumbil area (Text-Fig. 4A)

1) Calcarenite very low in the Cunningham Formation at 893_0 828_0 Burrendong 1 : 50,000 topographic map, about 50 m from the entrance gate to “Nindethana“.
2) Allodapic limestone from predominantly mudrock sequence very low in the Cunningham Formation at 893_3 828_5 .
3) Limestone clast approximately 30 cm diameter from conglomerate in the Cunningham Formation, “Red Hill”, outcropping in paddock at 905_1 832_5 .
4) Limestone clast from Cunningham Formation, “Red Hill“, at 904_7 832_8 .
5) Allodapic limestone in predominantly mudrock sequence (? along strike equivalent of Tolga Member of Cunningham Formation) outcropping in gully at 896_9 836_6 .
6) Ditto at 897_9 837_6 .
7) Limestone clasts from Cunningham Formation, loose beside the railway line at 901_0 795_7 .
8) Tiny quarry in coarse bioclastic limestone lense (presumed channel deposit like Red Hill Member of Cunningham Formation) on west side of road from Mumbil to “Tolga” at 901_2 787_0 .
9) Thin bioclastic limestone outcropping in predominantly mudrock sequence in gully at 915_6 740_5 .
10) Ditto at 915_5 740_5 .

Stuart Town – Euchareena area (Text-Fig. 5)

11) Matrix at 863_0 654_5 .
12) Limestone clast at 867 8650_4 .
13) Clast from 26 m upslope from “Canobla” shearer’s quarters at 864_8 652_7 .
14) 866_0 643_0 .
15) 866_0 645_0 .
16) Small clasts from south of “Elephant Rock” at 872646.
17) Outcropping in bed of Nubrigyn Creek at 875_5 640_5 .
18) Beside fence line at 867_4 649_8 .
19) Limestone clast of evidently Silurian age with cf. *Schedohalysites orthopteroides* (ETHERIDGE) reported by WRIGHT & BYRNES (1980, p. 200).
20) 899_9 644_9 .
21) Silurian limestone at gate at 879_0 531_5 .
22) 888562.
23) Clast from outcrop in bed of Nubrigyn Creek at 889565.
24) 893_5 586_0 .
25) 893_5 586_2 .
26) 893_5 586_5 .
27) Limestone olistolith at 903_5 572_2 .
28) Clasts from beside “Cronga Peak” road at 915_5 547.

Plate 1

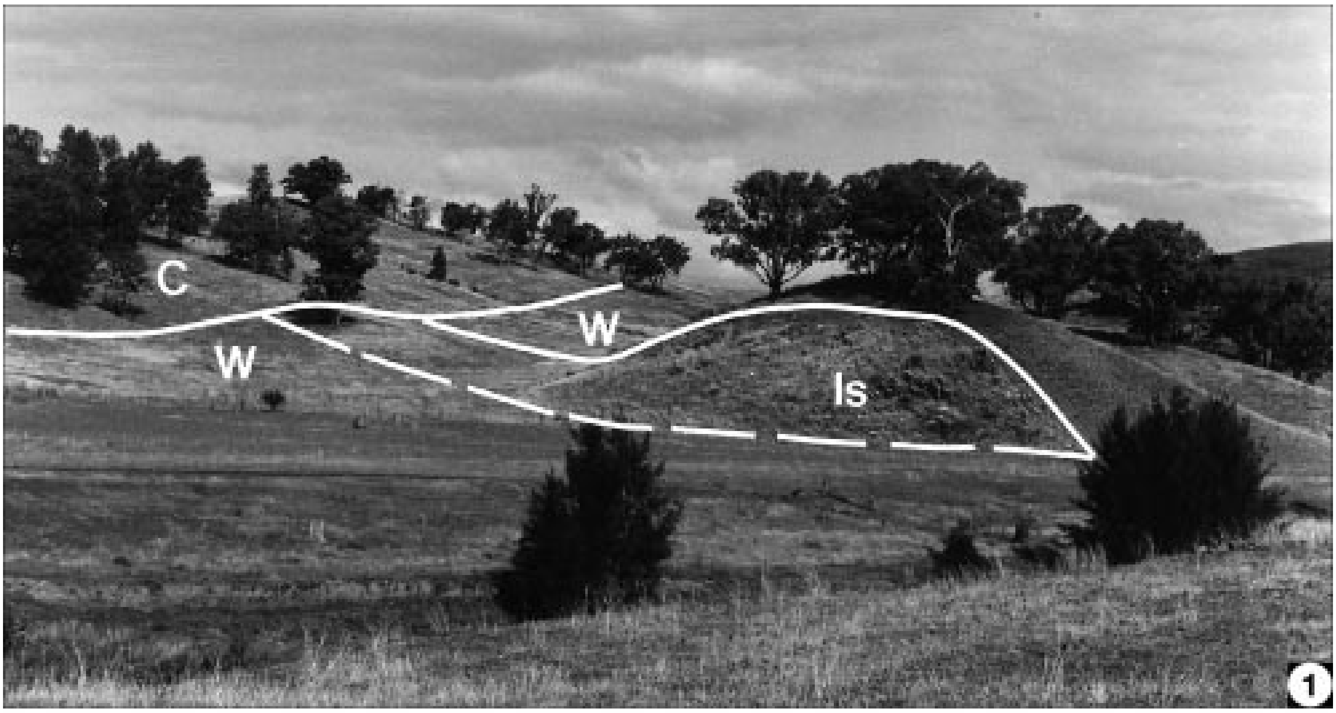
Typical exposures of Wallace Shale, Cunningham Formation
and Tolga and Nubrigyn Members of the Cunningham Formation (eastern Australia).

Fig. 1: View southwards across the valley of Nubrigyn Creek 1 km west of “Canobla” to prominent limestone lens (ls) interpreted as lobe of a limestone fan or a channel deposit in the Wallace Shale.
The high angle truncation of the Wallace Shale sequence (W) by basal Cunningham Formation (C) has been interpreted as a fault but may be an angular unconformity. Sampled section TEZ crosses the limestone lens on the hill in centre field.

Fig. 2: South face of railway cutting through upper Cuga Burga Volcanics (CB) and Tolga Member of Cunningham Formation (T).
Note pillow structure in the former and overturning of strata towards the east. Sampled section MAC was along the opposite face of the cutting. For location see Fig. 4A.

Fig. 3: Tolga Member of Cunningham Formation showing graded bedding from fine matrix-supported rudite at the base (clasts generally around 3 mm, limestone and mudstone, poorly sorted) passing upwards to mudstone.
Note cleavage in 15 cm mudstone interval on right indicating overturning of strata. Coin (20 mm) provides scale. Same locality as Fig. 2.

Fig. 4: Megabreccia with olistoliths and smaller angular clasts of limestone (o), resting on shales (sh) in Nubrigyn Member of Cunningham Formation 500 m north-west of “Canobla” homestead.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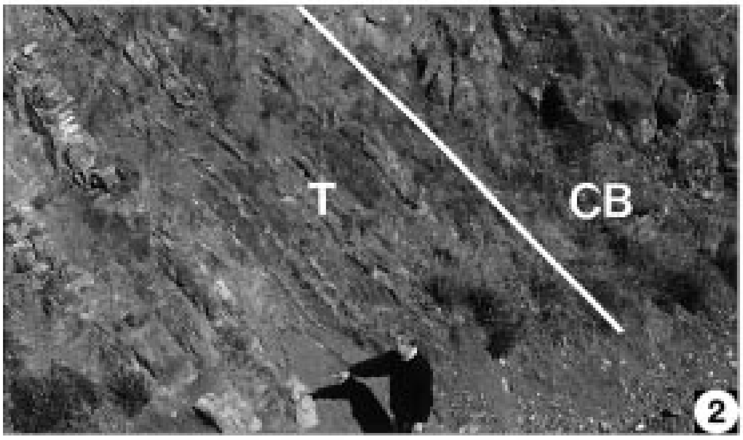
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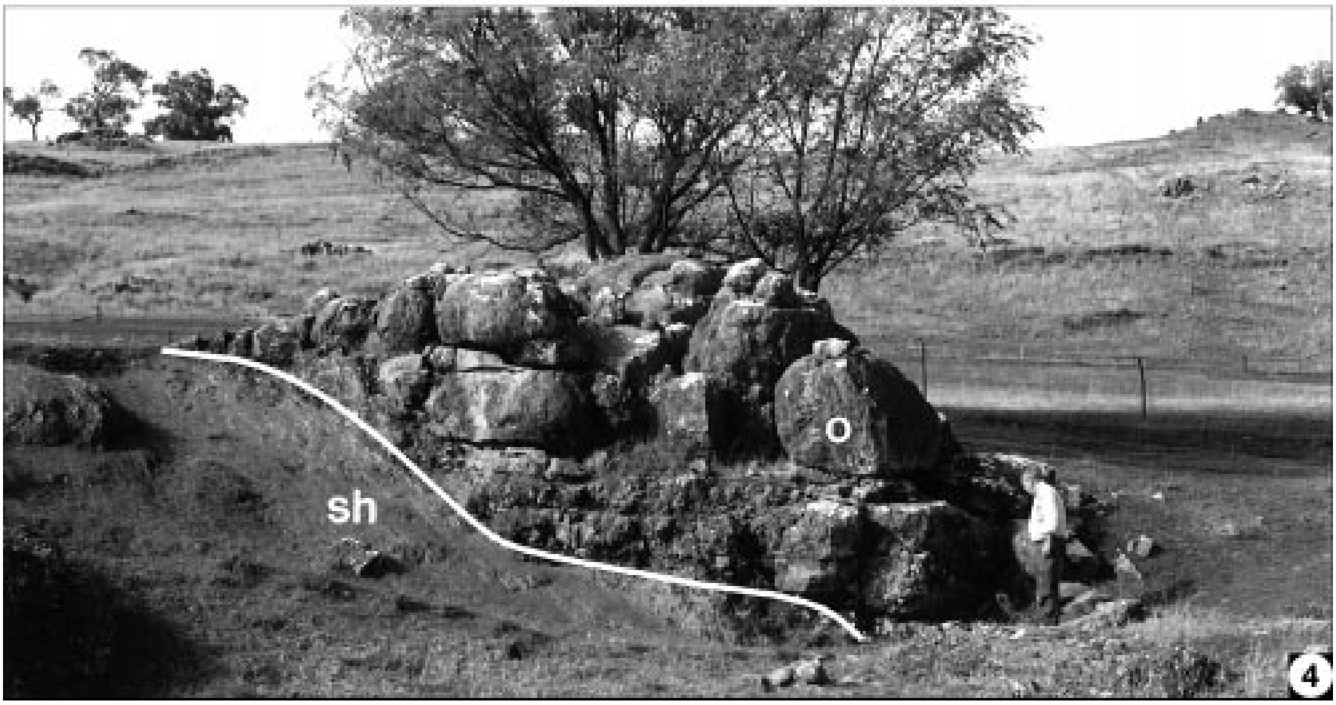
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Plate 2

Typical exposures of Nubrigyn Member of the Cunningham Formation (eastern Australia).

Fig. 1: Example of exhumed limestone olistoliths and megabreccias in landscapes developed on the Nubrigyn Member of the Cunningham Formation.
This group is 500 m north-west of “Canobla” homestead. The central body is an end view of the extraordinary “Woolpacks” olistolith.

Fig. 2: View looking north-east across Nubrigyn Creek to the valley of Boduldura Creek from a point 1.5 km WSW of “Merrrimount” showing typical expression of rhythmicity in sedimentation made manifest by differential weathering of graded bedded calcarenites and breccias relative to more recessive siltstones and pebbly siltstones of the Nubrigyn Member of the Cunningham Formation.

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Plate 3

Figs. 1,2: ***Kockelella ranuliformis* (Walliser, 1964).**
Fig. 1: Upper view of Pa element AMF104785.
TEZ6.8 (×110).
Fig. 2: Upper view of Pa element AMF104786.
TEZ67.8 (×75).

Figs. 3,4: ***Distomodus staurognathoides* (Walliser, 1964).**
Fig. 3: Lateral view of AMF104787.
TEZ6.8 (×90).
Fig. 4: Lateral view of AMF104788.
TEZ6.8 (×110).

Fig. 5: ***Panderodus greenlandensis* Armstrong, 1990.**
Lateral view of AMF104789.
TEZ22.6 (×60).

Figs. 6–8: ***Coryssognathus dubius* (Rhodes, 1953).**
Fig. 6: Lateral view of AMF104790.
MOS82.4 (×105).
Fig. 7: Lateral view of AMF104791.
MOS80.1 (×90).
Fig. 8: Lateral view of AMF104792.
MOS82.4 (×45).

Figs. 9–15: ***Distomodus staurognathoides* (Walliser, 1964).**
Fig. 9: Lateral view of AMF104793.
TEZ9 (×90).
Fig. 10: Lateral view of AMF104794.
TEZ2.8 (×60).
Fig. 11: Lateral view of AMF104795.
TEZ9 (×120).
Fig. 12: Lateral view of AMF104796.
TEZ13.3 (×60).
Fig. 13: Lateral view of AMF104797.
TEZ13.9 (×90).
Fig. 14: Lateral view of AMF104798.
TEZ13.9 (×60).
Fig. 15: Lateral view of AMF104799.
TEZ9 (×90).

Figs. 16–19: ***Panderodus greenlandensis* Armstrong, 1990.**
Fig. 16: Lateral view of AMF104800.
TEZ40 (×60).
Fig. 17: Lateral view of AMF104801.
TEZ24 (×45).
Fig. 18: Lateral view of AMF104802.
TEZ24 (×45).
Fig. 19: Lateral view of AMF104803.
TEZ24 (×45).

Figs. 20–22: ***Panderodus* n. sp. Simpson, this volume.**
Fig. 20: Lateral view of AMF104804.
TEZ24 (×45).
Fig. 21: Lateral view of AMF104805.
TEZ24 (×30).
Fig. 22: Lateral view of AMF104806.
TEZ24 (×45).


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Plate 5

Fig. 1: ***Ozarkodina excavata excavata*** **(Branson & Mehl, 1934).**
Lateral view of M element AMF104807.
TEZ21.6 (×60).

Fig. 2: ***Oulodus*** **sp.**
Lateral view of Pb element AMF104808.
TEZ35.1 (×90).

Figs. 3,4: ***Ozarkodina excavata excavata*** **(Branson & Mehl, 1934).**
Fig. 3: Lateral view of Pb element AMF104809.
TEZ13.9 (×90).
Fig. 4: Lateral view of M element AMF104810.
TEZ21.4 (×60).

Fig. 5: **?*Amydrotaxis* sp.**
Lateral view of ?Pb element AMF104811.
TAN73 (×75).

Fig. 6: ***Icriodus steinachensis*** **Al-Rawi 1977 eta morph.**
Upper view of I element AMF104812.
TAN91.5 (×60).

Figs. 7–9: ***Pedavis mariannae*** **Lane & Ormiston, 1979.**
Fig. 7: Upper view of juvenile I element AMF104813.
TAN91.5 (×60).
Fig. 8: Lateral view of M2d element AMF104814.
TAN154 (×75)
Fig. 9: Lateral view of M2a element AMF104815.
TAN154 (×150)

Fig. 10–21: ***Amydrotaxis druceana*** **(Pickett, 1980).**
Fig. 10: Lateral view of Pb element AMF104816.
TAN73 (×75).
Fig. 11: Lateral view of Pb element AMF104817.
TAN73 (×60).
Fig. 12: Lateral view of Pa element AMF104818.
TAN73 (×60).
Fig. 13: Upper view of Pa element AMF104819.
TAN91.5 (×90).
Fig. 14: Upper view of Pa element AMF104820.
TAN154 (×60).
Fig. 15: Lateral view of M element AMF104821.
TAN67.8 (×60).
Fig. 16: Lateral view of Sb element AMF104822.
TAN63 (×45).
Fig. 17: Lateral view of Sa element AMF104823.
TAN100 (×60).
Fig. 18: Lateral view of Sa element AMF104824.
TAN91.5 (×60).
Fig. 19: Lateral view of M element AMF104825.
TAN154 (×90).
Fig. 20: Lateral view of Sc element AMF104826.
TAN73 (×75).
Fig. 21: Lateral view of Sb element AMF104827.
TAN63 (×60).

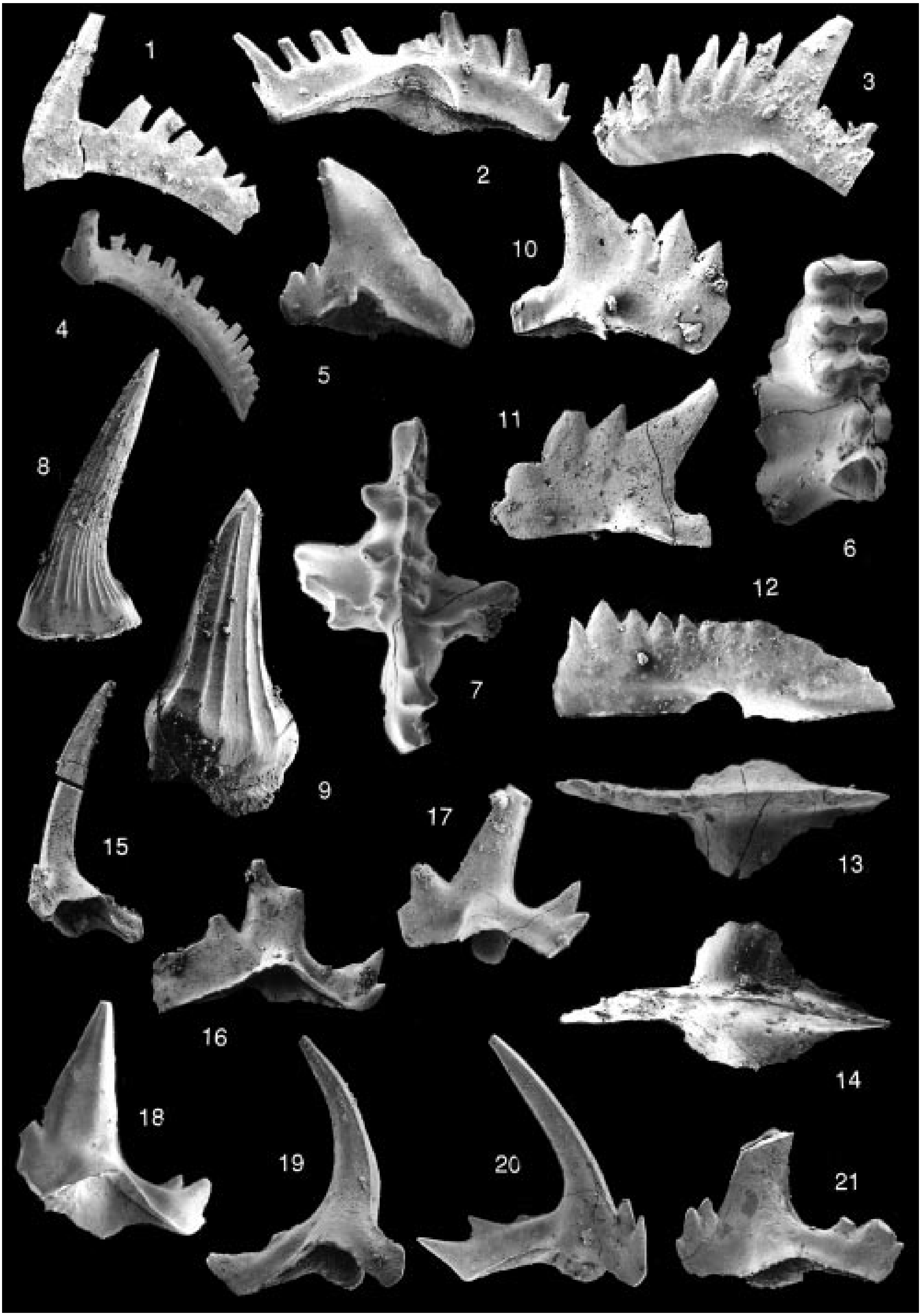
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Plate 5

Figs. 1–4: ***Ozarkodina excavata excavata*** **(Branson & Mehl, 1934).**
Fig. 1: Upper view of Pa element AMF104828.
TAN154 (×60).
Fig. 2: Upper view of Pa element AMF104829.
TAN67.8 (×60).
Fig. 3: Upper view of Pa element AMF104830.
TAN154 (×60).
Fig. 4: Upper view of Pa element AMF104831.
TAN73 (×75).

Fig. 5: ***Pandorinellina optima*** **(Moskalenko, 1966).**
Lateral view of Pa element AMF104832.
TAN154 (×60).

Figs. 6–9: ***Ancyrodelloides omus*** **Murphy & Matti, 1983.**
Fig. 6: Upper view of Pa element AMF104833.
TAN73 (×90).
Fig. 7: Upper view of Pa element AMF104834.
TAN154 (×60).
Fig. 8: Upper view of Pa element AMF104835.
TAN78 (×90).
Fig. 9: Upper view of Pa element AMF104836.
TAN73 (×75).

Fig. 10: ***Amydrotaxis druceana*** **(Pickett, 1980).**
Fig. 10: Upper view of Pa element AMF104837.
TAN140 (×75).

Figs. 11,12: ***Pandorinellina steinhornensis miae*** **(Bultynck, 1971).**
Lateral and upper views respectively of Pa element AMF104838.
TAN124.7 (× 90).

Figs. 13–18: ***Ozarkodina remscheidensis remscheidensis*** **(Ziegler, 1960).**
Fig. 13: Upper view of Pa element AMF104839.
TAN100 (×75).
Fig. 14: Lateral view of Pa element AMF104840.
TAN114 (×60).
Fig. 15: Upper view of Pa element AMF104841.
TAN86 (×90).
Fig. 16: Lateral view of Pa element AMF104842.
TAN63 (×75).
Fig. 17: Upper view of Pa element AMF104843.
TAN78 (×90).
Fig. 18: Lateral view of Pa element AMF104839.
TAN100 (×75).

Figs. 19–24: ***Pandorinellina steinhornensis miae*** **(Bultynck, 1971).**
Fig. 19: Upper view of Pa element AMF104844.
TAN114 (×75).
Fig. 20: Lateral view of Pa element AMF104845.
TAN73 (×75).
Fig. 21: Lateral view of Pa element AMF104846.
TAN71 (×75).
Fig. 22: Lateral view of Pa element AMF104847.
TAN73 (×75).
Fig. 23: Lateral view of Pa element AMF104848.
TAN71 (×75).
Fig. 24: Lateral view of Pa element AMF104849.
TAN63 (×75).

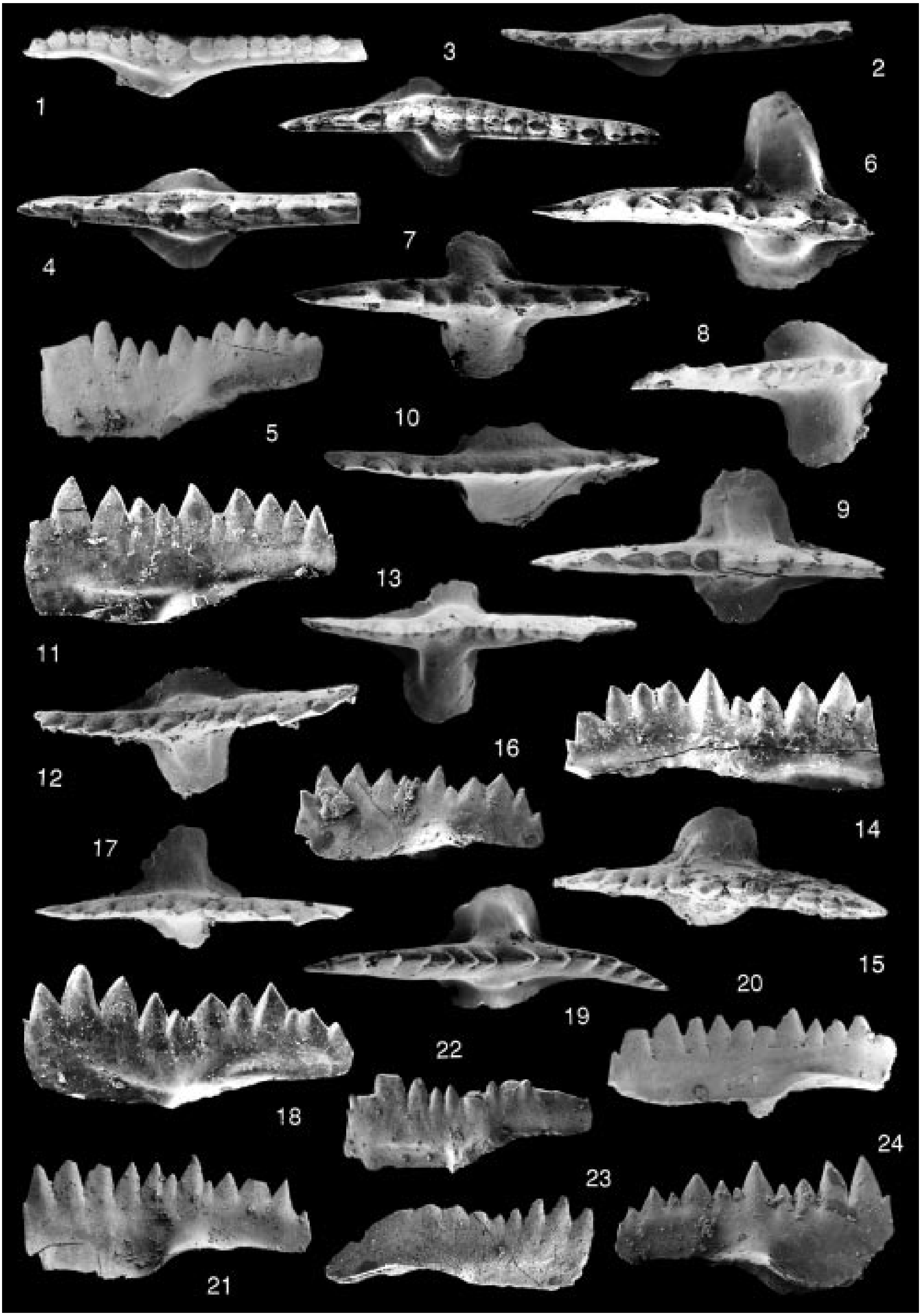
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Plate 6

Figs. 1,2: ***Oulodus aclys*** **Mawson, 1986.**
Fig. 1: Lateral view of Sc element AMF104850. TAN73 (×75).
Fig. 2: Lateral view of Sc element AMF104851. TAN114 (×60).

Figs. 3–10: ***Oulodus*** **n.sp. A.**
Fig. 3: Lateral view of Pa element AMF104852. TAN73 (×60).
Fig. 4: Lateral view of Pa element AMF104853. TAN71 (×75).
Fig. 5: Lateral view of Pb element AMF104854. TAN71 (×60).
Fig. 6: Lateral view of Pb element AMF104855. TAN113 (×75).
Fig. 7: Lateral view of M element AMF104856. TAN67.8 (×60).
Fig. 8: Lateral view of Sa element AMF104857. TAN73 (×75).
Fig. 9: Lateral view of Sb element AMF104858. TAN71 (×75).
Fig. 10: Lateral view of Sc element AMF104859. TAN71 (×90).

Figs. 11,12: ***Oulodus greilingi hirpex*** **Mawson, 1986.**
Fig. 11: Lateral view of Pa element AMF104860. TAN113 (×90).
Fig. 12: Lateral view of Sc element AMF104861. TAN124.7 (×60).

Figs. 13–15: ***Oulodus spicula*** **Mawson, 1986.**
Fig. 13: Lateral view of Sa element AMF104862. TAN71 (×110).
Fig. 14: Lateral view of Pb element AMF104863. TAN140 (×45).
Fig. 15: Lateral view of Sc element AMF104864. TAN71 (×60).

Fig. 16: ***Oulodus walliseri*** **(Ziegler, 1960).**
Lateral view of Sa element AMF104865. TAN124.7 (×75).

Fig. 17: ***Oulodus spicula*** **Mawson, 1986.**
Lateral view of Sb element AMF104866. TAN71 (×60).

Fig. 18: ***Oulodus walliseri*** **(Ziegler, 1960).**
Lateral view of Pa element AMF104867. TAN73 (×45).

Figs. 19–22: ***Ozarkodina excavata excavata*** **(Branson & Mehl, 1934).**
Fig. 19: Lateral view of Pb element AMF104868. TAN91.5 (×60).
Fig. 20: Lateral view of Sc element AMF104869. TAN110 (×75).
Fig. 21: Lateral view of Sb element AMF104870. TAN113 (×60).
Fig. 22: Lateral view of Sa element AMF104871. TAN71 (×75).

Fig. 23: ***Oulodus*** **n.sp. A.**
Lateral view of Sc element AMF104872. TAN67.8 (×60).


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Plate 7

Fig. 1: ***Belodella devonica*** **(Stauffer, 1940).**
Lateral view of AMF104873.
TAN110 (×90).

Figs. 2–4: ***Dvorakia*** **sp.**
Fig. 2: Lateral view of AMF104874.
TAN73 (×75).
Fig. 3: Lateral view of AMF104875.
TAN71 (×60).
Fig. 4: Lateral view of AMF104876.
TAN124.7 (×75).

Figs. 5,6: ***Icriodus steinachensis*** **Al-Rawi 1977 eta morph.**
Fig. 5: Upper view of I element AMF104877.
DRM109 (×75).
Fig. 6: Upper view of I element AMF104878.
MAC87.5 (×45).

Figs. 7–8: ***Pandorinellina optima*** **(Moskalenko, 1966).**
Fig. 7: Lateral view of Pa element AMF104879.
MAC2 (×45).
Fig. 8: Lateral view of Pa element AMF104880.
MAC2 (×45).

Fig. 9: ***Pandorinellina exigua philipi*** **(Klapper, 1969).**
Lateral view of Pa element AMF104881, transitional between *Pand. r. repetitor* and *Pand. exigua philipi*.
MAC50 (×60).

Fig. 10: ***Ozarkodina*** **sp.**
Lateral view of Pa element AMF104882.
MAC2 (×45).

Fig. 11: ***Ozarkodina remscheidensis repetitor*** **(Carls & Gandl, 1969).**
Lower view of Pa element AMF104883.
MAC31 (×45).

Fig. 12: ***Ozarkodina remscheidensis remscheidensis*** **(Ziegler, 1960).**
Upper view of Pa element AMF104884.
MAC3 (×45).

Fig. 13: ***Ancyrodelloides omus*** **Murphy & Matti, 1983.**
Upper view of Pa element AMF104885.
MAC31 (×60).

Fig. 14: ***Ozarkodina excavata excavata*** **(Branson & Mehl, 1934).**
Upper view of Pa element AMF104886.
MAC3 (×75).

Figs. 15,16: ***Amydrotaxis johnsoni*** **(Klapper, 1969) alpha morph.**
Fig. 15: Upper view of Pa element AMF104887.
MBS108.6 (×90).
Fig. 16: Upper view of Pa element AMF104888.
MBS108.6 (×45).

Figs. 17,18: ***Ozarkodina remscheidensis repetitor*** **(Carls & Gandl, 1969).**
Fig. 17: Upper view of Pa element AMF104889.
MBS57.4 (×60).
Fig. 18: Upper view of Pa element AMF104890.
MBS62 (×75).

Figs. 19,20: ***Oulodus aclys*** **Mawson, 1986.**
Fig. 19: Lateral view of M element AMF104891.
MBS106.8 (×60).
Fig. 20: Lateral view of Sb element AMF104892.
MBS106.8 (×60).

Fig. 21: ***Amydrotaxis*** **sp.**
Lateral view of Sa element AMF104893.
MAC39 (×30).

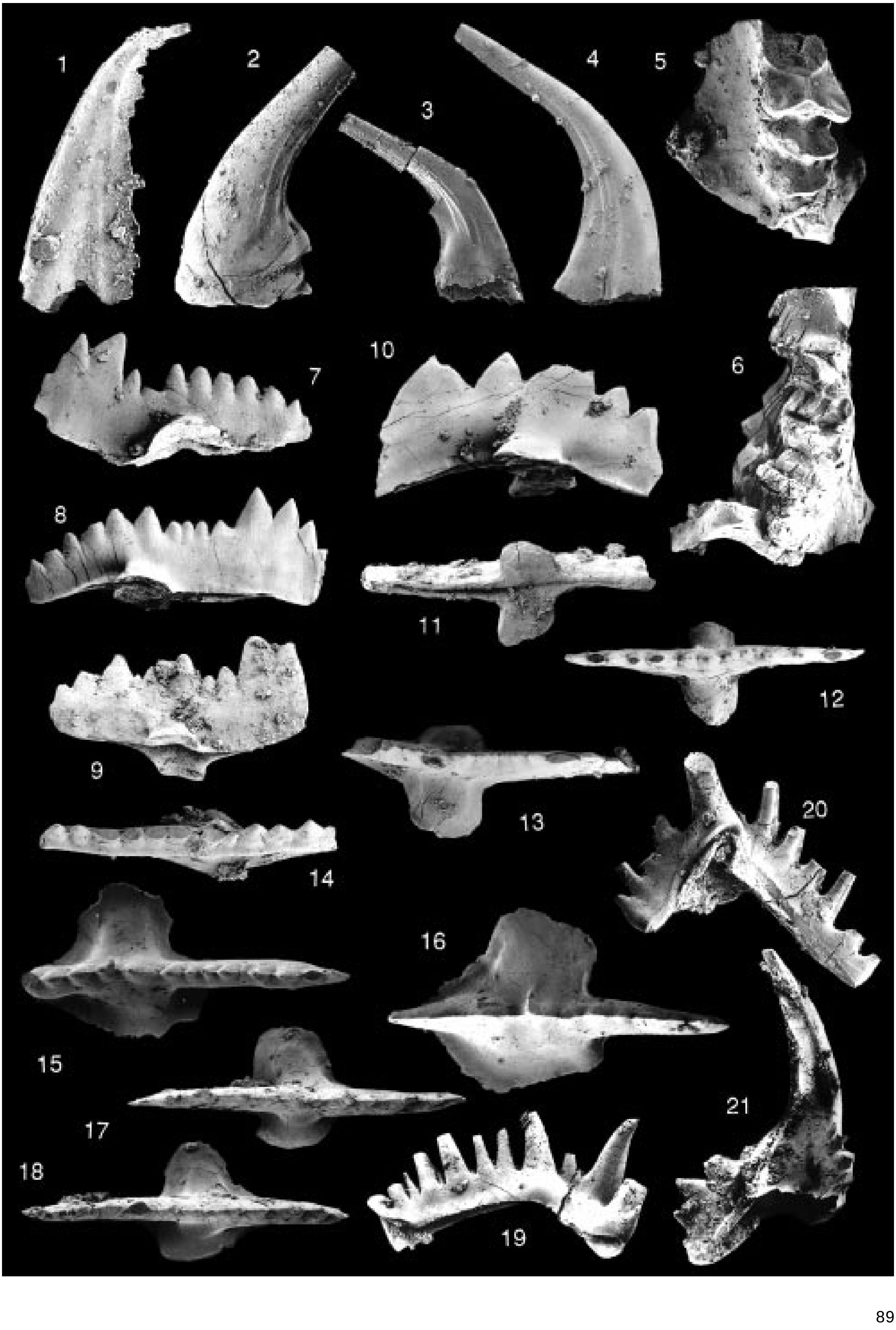
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Plate 8

Fig. 1: ***Ozarkodina remscheidensis remscheidensis* (Ziegler, 1960).**
Lateral view of Pa element AMF104894.
NIN1.3 (×75).

Fig. 2: ***Pandorinellina exigua exigua* (Philip, 1966).**
Lateral view of Pa element AMF104895.
NIN1.3 (×75).

Fig. 3: ***Amydrotaxis druceana* (Pickett, 1980).**
Upper view of Pa element AMF104896.
NIN157 (×45).

Fig. 4: ***Ancyrodelloides omus* Murphy & Matti, 1983.**
Upper view of Pa element AMF104897.
NIN48.6 (×45).

Fig. 5: ***Amydrotaxis druceana* (Pickett, 1980).**
Upper view of Pa element AMF104898.
NIN60.5 (×45).

Fig. 6: ***Pandorinellina exigua exigua* (Philip, 1966).**
Upper view of Pa element AMF104899.
NIN3 (×45).

Fig. 7: ***Amydrotaxis druceana* (Pickett, 1980).**
Upper view of Pa element AMF104900.
NIN65 (×90).

Figs. 8–10: ***Ozarkodina pandora* Murphy, Matti & Walliser, 1981 alpha morph.**
Fig. 8: Upper view of Pa element AMF104901.
NIN60 (×75).
Fig. 9: Upper view of Pa element AMF104902.
NIN1.3 (×45).
Fig. 10: Upper view of Pa element AMF104903.
NIN59.5 (×60).

Fig. 11: ***Ancyrodelloides omus* Murphy & Matti, 1983.**
Upper view of Pa element AMF104904.
NIN48.5 (×45).

Figs. 12,13: ***Oulodus walliseri* (Ziegler, 1960).**
Fig. 12: Lateral view of Pb element AMF104905.
NIN65 (×45).
Fig. 13: Lateral view of Sa element AMF104906.
NIN65 (×60).

Fig. 14: ***Pedavis* sp.**
Lateral view of S element AMF104907.
NIN-1.3 (×75).

Fig. 15: ***Amydrotaxis druceana* (Pickett, 1980).**
Lateral view of Sc element AMF104908.
NIN48.5 (×90).

Fig. 16: ***Belodella resima* (Philip, 1965).**
Lateral view of AMF104909.
NIN36.4 (×75).

Fig. 17: ***Polygnathus zeravshanicus* (Bardashev & Ziegler, 1992).**
Upper view of Pa element AMF104910.
NIN3 (×75).

Fig. 18: ***Polygnathus trilinearis* (Cooper, 1973).**
Upper view of Pa element AMF104911.
NIN36.4 (×90).

Fig. 19: ***Polygnathus pireneae* Boersma, 1974.**
Upper view of Pa element AMF104912.
NIN104.4 (×75).

Fig. 20: ***Polygnathus trilinearis* (Cooper, 1973).**
Upper view of Pa element AMF104913.
NIN3 (×60).

Figs. 21,22: ***Polygnathus pireneae* Boersma, 1974.**
Fig. 21: Upper view of Pa element AMF104914.
NIN122 (×60).
Fig. 22: Upper view of Pa element AMF104915.
NIN117.8 (×60).

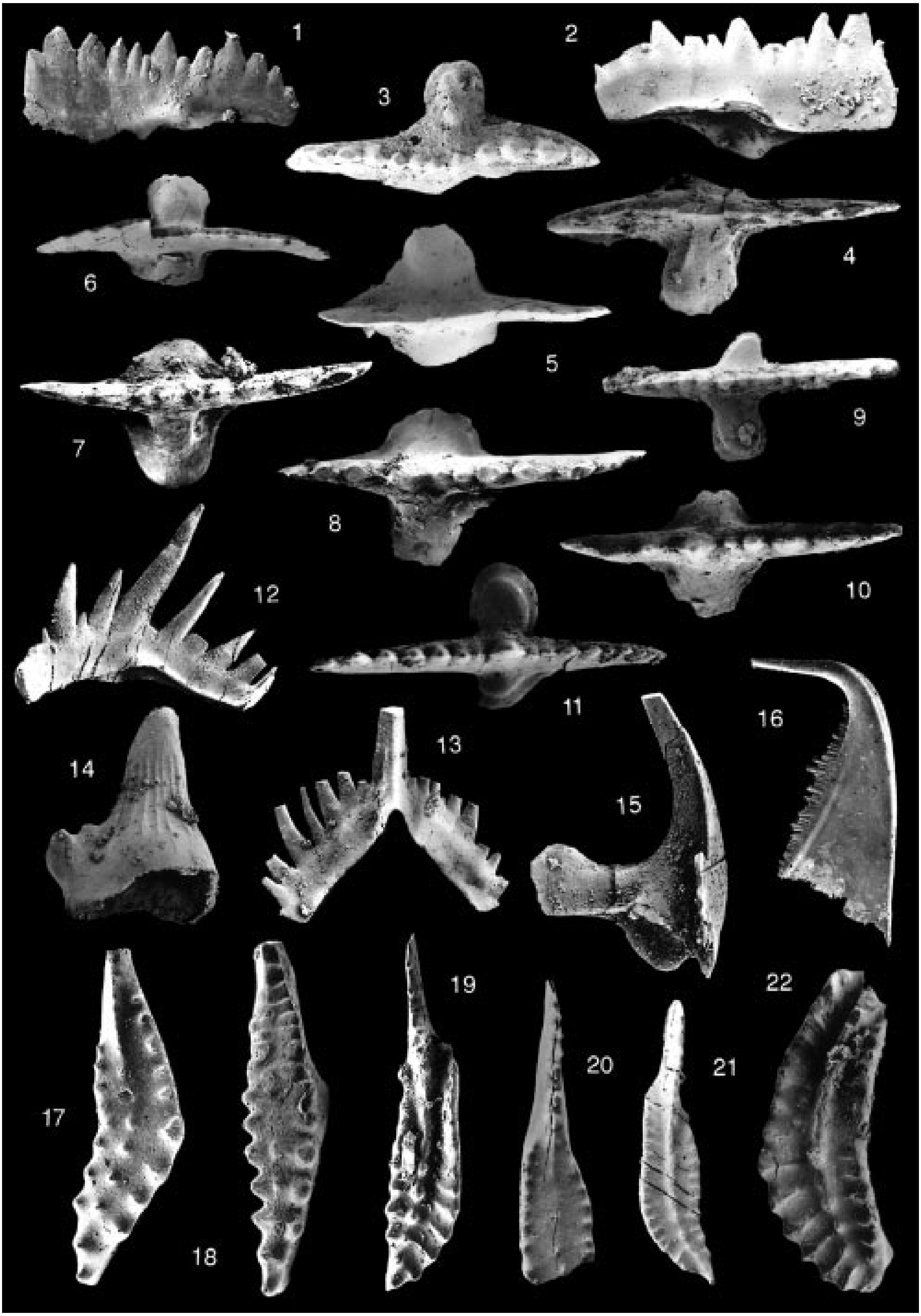
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Plate 9

Figs. 1–7: ***Pandorinellina exigua exigua*** **(Philip, 1966).**
Fig. 1: Lateral view of Pa element AMF104916.
BRA915546 (×45).
Fig. 2: Upper view of Pa element AMF104917.
BRA69 (×45).
Fig. 3: Upper view of Pa element AMF104918.
BRA69 (×60).
Fig. 4: Upper view of Pa element AMF104919.
LDB128 (×45).
Fig. 5: Upper view of Pa element AMF104920.
LDB68 (×60).
Fig. 6: Upper view of Pa element AMF104921.
BRA19.8 (×60).
Fig. 7: Upper view of Pa element AMF104922.
LDB163 (×60).

Figs. 8,9: ***Ozarkodina excavata excavata*** **(Branson & Mehl, 1934).**
Fig. 8: Upper view of Pa element AMF104923.
NUM113 (×30).
Fig. 9: Lateral view of Pb element AMF104924.
NUM113 (×45).

Fig. 10: ***Pandorinellina exigua*** **philipi (Klapper, 1969).**
Upper/lateral view of Pa element AMF104925.
NUM113 (×75).

Fig. 11: ***Polygnathus dehiscens*** **Philip & Jackson, 1967.**
Upper view of Pa element AMF104926.
BRA71.4 (×60).

Fig. 12: ***Polygnathus inversus*** **Klapper & Johnson, 1975.**
Upper view of Pa element AMF104927.
LDB72.5 (×130).

Fig. 13: ***Polygnathus perbonus*** **Philip & Jackson, 1967.**
Upper view of Pa element AMF104928.
LDB163 (×60).

Fig. 14: ***Oulodus murrindalensis*** **(Philip, 1966).**
Lateral view of Sa element AMF104929.
LDB56.6 (×60).

Figs. 15–16: ***Dvorakia*** **sp.**
Fig. 15: Lateral view of AMF104930.
LDB54 (×60).
Fig. 16: Lateral view of AMF104931.
LDB56.7 (×90).

Fig. 17: ***Panderodus unicostatus*** **(Branson & Mehl, 1933).**
Lateral view of AMF104932.
LDB54 (×105).

Fig. 18: ***Panderodus*** **sp.**
Lateral view of Pa element AMF104933.
LDB128 (×75).

Fig. 19: ***Icriodus*** **sp.**
Upper view of I element AMF104934.
NUM135 (×75).

Figs. 20,21: ***Eognathodus sulcatus*** **Philip, 1965 iota morph.**
Fig. 20: Upper view of Pa element AMF104935.
NUM113 (×60).
Fig. 21: Upper view of Pa element AMF104936.
NUM113 (×60).

Fig. 22: ***Polygnathus zeravshanicus*** **(Bardashev & Ziegler, 1992).**
Upper view of Pa element AMF104937.
NUM113 (×60).

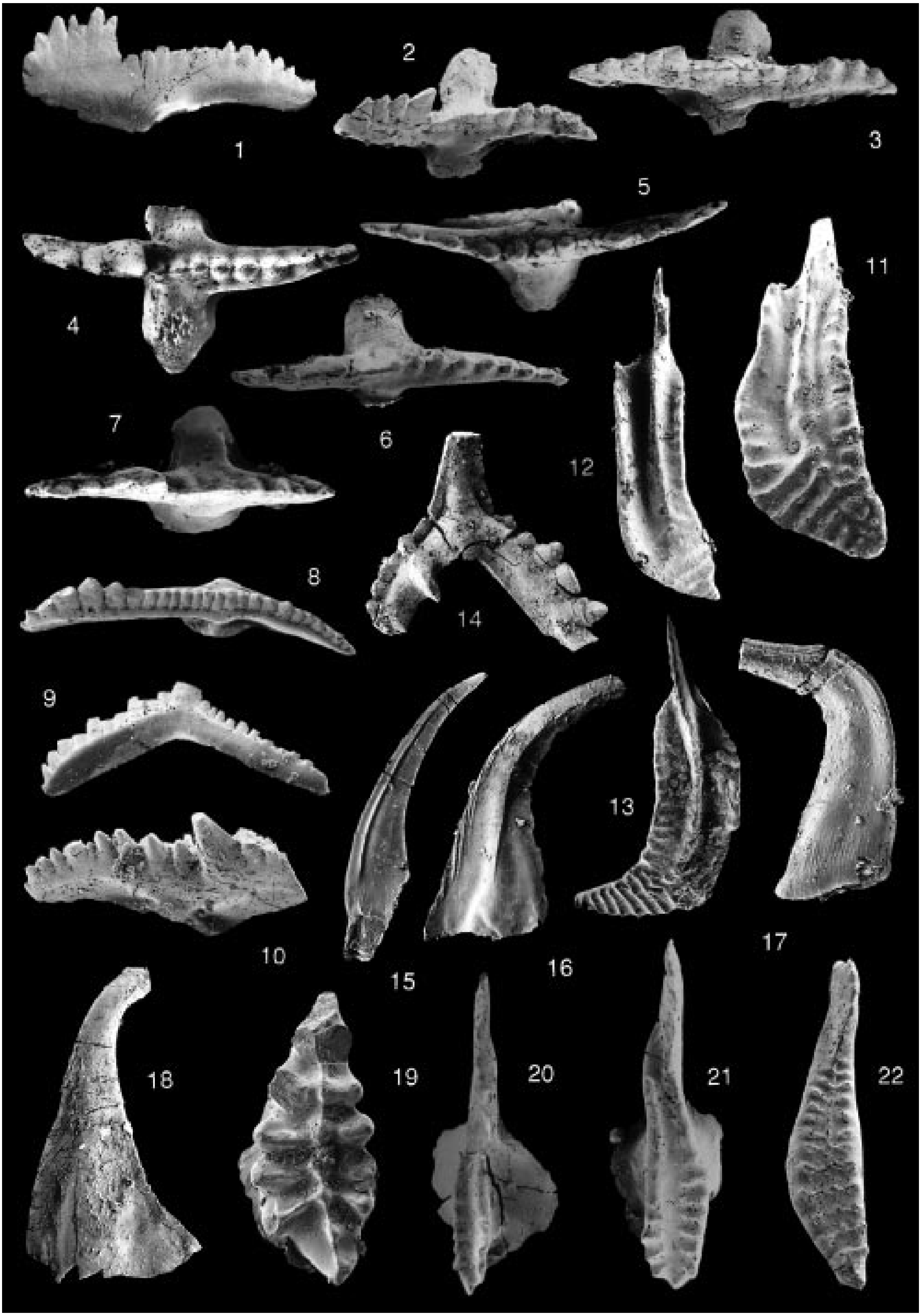
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Plate 10

Fig. 1: ***Polygnathus perbonus*** **(Philip, 1966).**
Upper view of Pa element AMF104938.
DIN0.6 (×60).

Figs. 2–5: ***Polygnathus nothoperbonus*** **Mawson, 1987.**
Fig. 2: Upper view of Pa element AMF104939.
Clast from DIN6 (×45).
Fig. 3: Upper view of Pa element AMF104940.
Clast from DIN8 (×90).
Fig. 4: Upper view of Pa element AMF104941.
Clast from DIN7 (×60).
Fig. 5: Lateral view of Pa element AMF104942.
Clast from DIN8 (×75).

Figs. 6–8: ***Polygnathus perbonus*** **(Philip, 1966).**
Fig. 6: Upper view of Pa element AMF104943.
Clast from DIN6 (×60).
Fig. 7: Upper view of Pa element AMF104944.
Clast from DIN5 (×60).
Fig. 8: Upper view of Pa element AMF104945.
Clast from DIN6 (×60).

Fig. 9: ***Polygnathus nothoperbonus*** **Mawson, 1987.**
Upper view of Pa element AMF104946.
Clast from DIN8 (×60).

Figs. 10–11: ***Polygnathus perbonus*** **(Philip, 1966).**
Fig. 10: Lower view of Pa element AMF104947.
Clast from DIN8 (×60).
Fig. 11: Lower view of Pa element AMF104948.
Clast from DIN8 (×45).

Fig. 12: ***Polygnathus*** **n.sp. A.**
Lower view of Pa element AMF104949.
Clast from DIN6 (×110).

Fig. 13: ***Polygnathus dehiscens*** **Philip & Jackson, 1967.**
Lower view of Pa element AMF104950.
Clast from DIN8 (×45).

Fig. 14: ***Polygnathus perbonus*** **(Philip, 1966).**
Lower view of Pa element AMF104951.
Clast from DIN8 (×60).

Fig. 15: ***Polygnathus dehiscens*** **Philip & Jackson, 1967.**
Lower view of Pa element AMF104952.
Clast from DIN2 (×45).

Fig. 16: ***Polygnathus perbonus*** **(Philip, 1966).**
Lower view of Pa element AMF104953.
DIN5 (×60).

Fig. 17: ***Polygnathus serotinus*** **Telford, 1975.**
Lower view of Pa element AMF104954.
DIN20 (×60).

Figs. 18–23: ***Polygnathus*** **n.sp. A.**
Fig. 18: Lower view of Pa element AMF104955.
Clast from DIN6 (×105).
Fig. 19: Upper view of Pa element AMF104956.
Clast from DIN6 (×110).
Fig. 20: Lower view of Pa element AMF104957.
Clast from DIN6 (×110).
Fig. 21: Lower view of Pa element AMF104958.
Clast from DIN6 (×110).
Fig. 22: Upper view of Pa element AMF104959.
Clast from DIN6 (×105).
Fig. 23: Upper view of Pa element AMF104960.
Clast from DIN6 (×90).

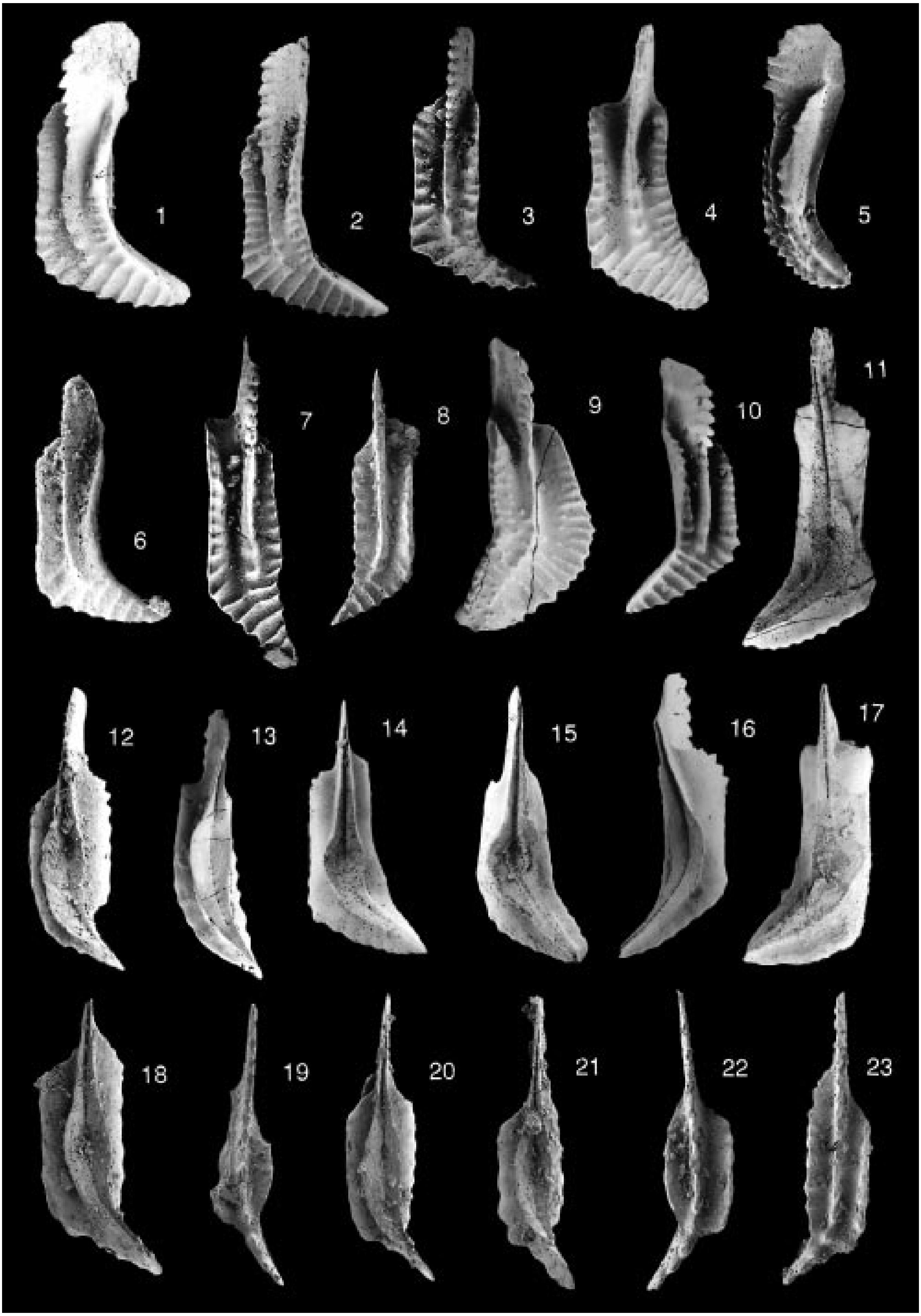
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Plate 11

Figs. 1–5: ***Pandorinellina exigua exigua*** **(Philip, 1966).**
Fig. 1: Lateral view of Pa element AMF104961.
DIN0.6 (×45).
Fig. 2: Lateral view of Pa element AMF104962.
Clast from DIN1 (×60).
Fig. 3: Upper view of Pa element AMF104963.
Clast from DIN1 (×60).
Fig. 4: Lateral view of Pa element AMF104964.
DIN0.6 (×45).
Fig. 5: Lateral view of Pa element AMF104965.
Clast from DIN3 (×60).

Figs. 6,7: ***Ozarkodina prolata*** **Mawson, 1987.**
Fig. 6: Upper view of Pa element AMF104966.
Clast from DIN3 (×60).
Fig. 7: Lower view of Pa element AMF104967.
Clast from DIN5 (×75).

Fig. 8: ***Amydrotaxis druceana*** **(Pickett, 1980).**
Lateral view of Pa element AMF104968.
DIN0.2 (×60).

Figs. 9,10: ***Pandorinellina exigua exigua*** **(Philip, 1966).**
Fig. 9: Lower view of Pa element AMF104969.
DIN85.3 (×60).
Fig. 10: Lateral view of Pa element AMF104970.
Clast from DIN5 (×45).

Fig. 11: ***Kimognathus alexeii*** **Mashkova, 1978.**
Upper view of Pa element AMF104971.
Loc. 11 (×75).

Figs. 12–14: ***Ozarkodina excavata excavata*** **(Branson & Mehl, 1934).**
Fig. 12: Lateral view of Pa element AMF104972.
Loc. 4 (×60).
Fig. 13: Lateral view of Pa element AMF104973.
Loc. 4 (×60).
Fig. 14: Lateral view of Sa element AMF104974.
Loc. 4 (×60).

Fig. 15: ***Amydrotaxis*** **sp.**
Rear lateral view of Sc element AMF104975.
Loc. 12 (×60).

Figs. 16–18: ***Ozarkodina eleanori*** **Lane & Ormiston, 1979.**
Fig. 16: Upper view of Pa element AMF104976.
Loc. 12 (×60).
Fig. 17: Upper view of Pa element AMF104977.
Loc. 4 (×45).
Fig. 18: Lower view of Pa element AMF104977.
Loc. 4 (×45).

Fig. 19: ***Flajsella schulzei*** **(Bardashev, 1989).**
Upper view of Pa element AMF104978.
Loc. 4 (×90).

Fig. 20: ***Flajsella streptostygia*** **Valenzuela Rios & Murphy, 1997.**
Lateral view of Pa element AMF104979.
Loc. 4 (×75).

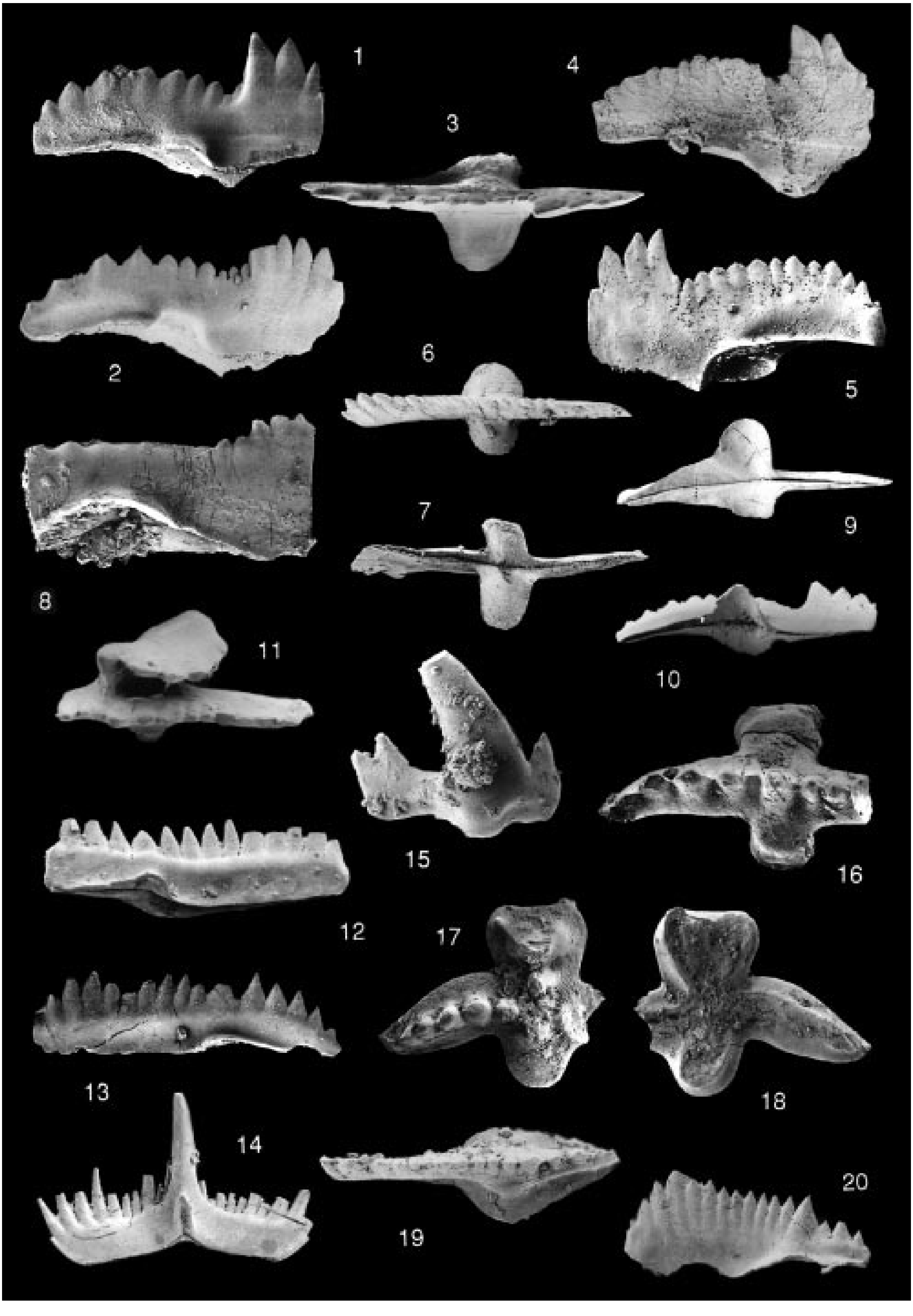
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Plate 12

Figs. 1–4: ***Ozarkodina excavata excavata* (Branson & Mehl, 1934).**
Fig. 1: Lateral view of Pa element AMF104980.
Loc. 21 (×45).
Fig. 2: Lateral view of Pb element AMF104981.
Loc. 21 (×45).
Fig. 3: Lateral view of Sc element AMF104982.
Loc. 21 (×75).
Fig. 4: Lateral view of Sa element AMF104983.
Loc. 21 (×60).

Fig. 5: ***Ozarkodina selfi* Lane & Ormiston, 1979.**
Upper view of Pa element AMP104984.
Loc. 18 (×60).

Figs. 6–9: ***Pandorinellina exigua philipi* (Klapper, 1969).**
Fig. 6: Lateral view of Pa element AMF104985.
Loc. 18 (×60).
Fig. 7: Lateral view of Pa element AMF104986.
Loc. 18 (×60).
Fig. 8: Lateral view of Pa element AMF104987.
Loc. 10 (×60).
Fig. 9: Upper view of Pa element AMF104988.
Loc. 18 (×60).

Fig. 10: ***Ancyrodelloides omus* Murphy & Matti, 1983.**
Upper view of Pa element AMF104989.
Loc. 14 (×60).

Figs. 11–13: ***Pandorinellina steinhornensis miae* (Bultynck, 1971).**
Fig. 11: Upper view of Pa element AMF104990.
Loc. 10 (×60).
Fig. 12: Upper view of Pa element AMF104991.
Loc. 10 (×60).
Fig. 13: Upper view of Pa element AMF104992.
Loc. 10 (×60).

Figs. 14,15: ***Ozarkodina remscheidensis remscheidensis* (Ziegler, 1960).**
Fig. 14: Lateral view of Sb element AMF104993.
Loc. 13 (×60).
Fig. 15: Lateral view of M element AMF104994.
Loc. 13 (×60).

Fig. 16: ***Polygnathus dehiscens* Philip & Jackson, 1967.**
Upper view of Pa element AMF104995.
Loc. 20 (×45).

Fig. 17: ***Icriodus steinachensis* Al-Rawi 1977 eta morph.**
Upper view of I element AMF104996.
Loc. 17 (×60).

Figs. 18–20: ***Panderodus* spp.**
Fig. 18: Lateral view of AMF104997.
NUM135 (×60).
Fig. 19: Lateral view of AMF104998.
TAN121.2 (×75).
Fig. 20: Lateral view of AMF104999.
Loc. 18 (×75).

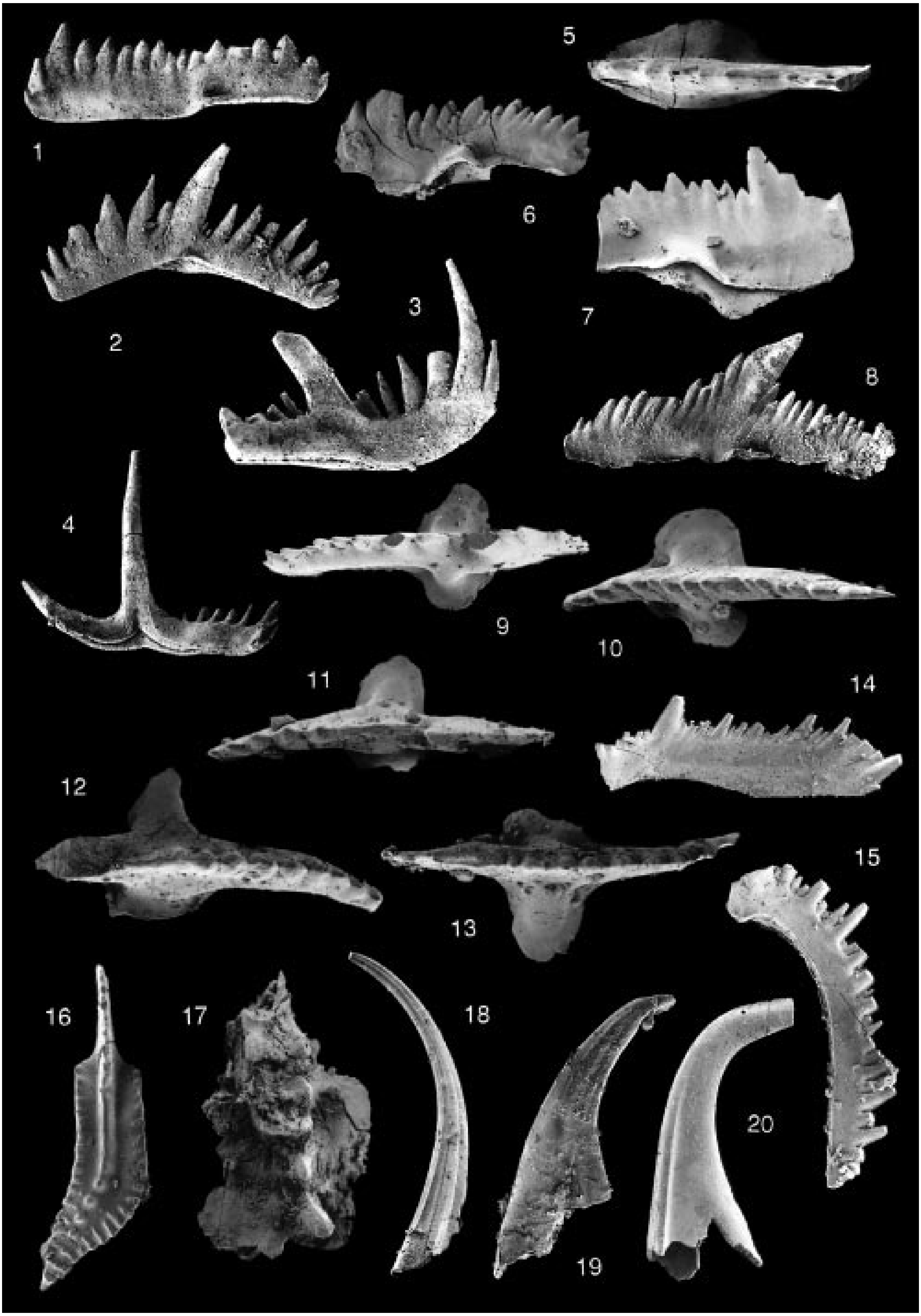
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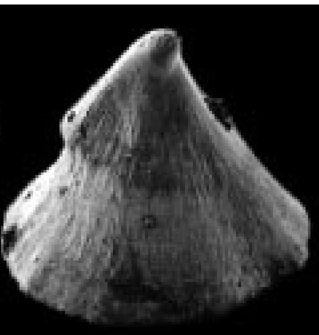
Plate 13

Figs. 1–7: ***Pseudooneotodus beckmanni* (BISCHOFF & SANNEMANN, 1958).**
Fig. 1: Lateral view of AMF105000.
TAN71 (×135).
Figs. 2,3: Upper and lateral views respectively of AMF105001.
TAN71(×125).
Figs. 4,7: Upper and lateral views respectively of AMF105002.
TAN73(×75).
Figs. 5,6: Upper and lateral views respectively of AMF10503.
TAN73(×125).

Figs. 8–15: **Incertae sedis. Genus and species undet.**
Fig. 8: Lateral view of AMF105004.
TAN71 (×60).
Fig. 9: Lateral view of AMF105004.
TAN71 (×125).
Fig. 10: Lateral view of AMF105004.
TAN71 (×550).
Fig. 11: Lateral view of AMF105004.
TAN71 (×400).
Fig. 12: Lateral view of AMF105005.
TAN78 (×550).
Fig. 13: Lateral view of AMF105006.
TAN121.2 (×200).
Fig. 14: Lateral view of AMF105005.
TAN78 (×90).
Fig. 15: Lateral view of AMF105005.
TAN78 (×250).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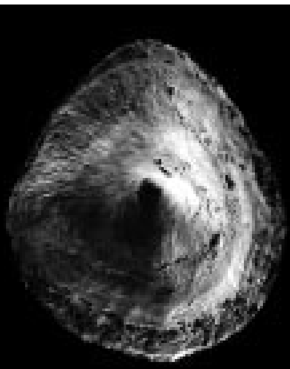
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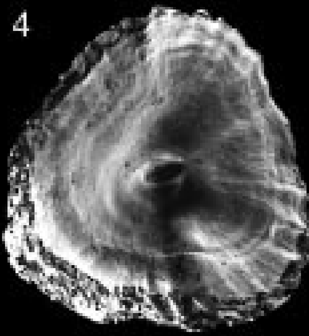
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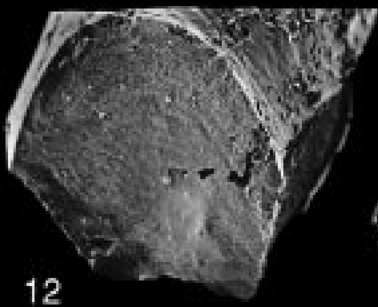
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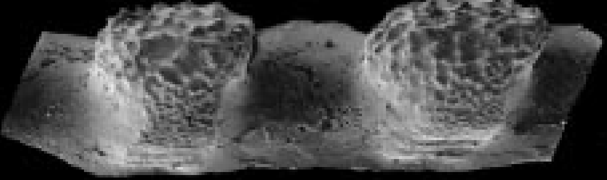
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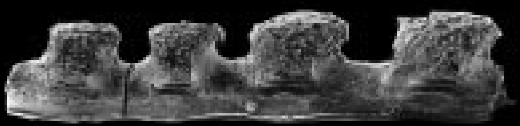
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