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The Academic Senate on 22 February 00 resolved that the candidate had satisfied requirements for admission to the degree of PhD.
This thesis represents a major part of the prescribed program of study.

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USE OF THESES

NAME	DATE	NAME	DATE

The charm of first discovery is our own...
Lyell, 1830

He who calls what has vanished back again into being, enjoys a bliss like that of creating.
Niebuhr, 1828

...we cannot but look forward with the most sanguine expectations to the degree of excellence to which geology may be carried, even by the labours of the present generation.
Lyell, 1830

TAXONOMY AND BIOSTRATIGRAPHY OF SILURIAN-DEVONIAN FORAMINIFERA FROM EASTERN AUSTRALIA

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This thesis is submitted to fulfil the requirements for the degree of Doctor of Philosophy from Macquarie University. All results and interpretations reported in this thesis are the original work of the author except where otherwise stated. No part of this work has been submitted previously for a higher degree.

February 1999

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TABLES

LIST OF ABBREVIATIONS USED

BON Bonanza Gully, Bindi, V.

BOO Boola Quarry, V.

D&P B Middle Devonian locality, Tamworth area, NSW.

DSC Middle Silurian locality , Borenore, NSW.

ERC Middle Silurian locality, Borenore, NSW.

EUR Lower Devonian locality, Wellington, NSW.

GCR Lower Devonian locality, Wellington, NSW.

ISIS Middle Devonian locality, Tamworth area, NSW.

Ma 13 Gelantipy Road, north of Buchan, V.

MSh Middle Devonian locality, Siberia.

MUNG Lower Devonian locality, Wellington, NSW.

MW Martins Well, Broken River area, Qld.

NCCQ Middle Devonian locality, Tamworth area, NSW.

NSW New South Wales

OKE Middle Devonian locality, Tamworth area, NSW.

ORCQ Old Rocky Camp Quarry, Buchan, V.

OTRC Old Taravale Road Cutting, Buchan, V.

PIG Pigna Barney, NSW.

Q Lower Devonian locality, Windellama, NSW.

Qld. Queensland

QU Lower Devonian locality, Windellama, NSW.

RUN Lower Devonian locality, Wellington, NSW.

S Upper Silurian locality, Windellama, NSW.

SALC South arm, Limestone Creek, Bindi, V.

SULC Middle Devonian locality, Tamworth area, NSW.

Tas. Tasmania

TIM Middle Devonian locality, Tamworth area, NSW.

V Victoria

WA Western Australia

WERR Middle Silurian locality, Borenore, NSW.

YAR 6 Middle Devonian locality, Tamworth area, NSW.

NOTE

Excerpts of this thesis have been published or accepted for publication :

* Simpson, A.J., Bell, K.N., Mawson, R. and Talent, J.A. 1993. Late Silurian (Ludlow) conodonts and foraminifers from Cowombat, SE Australia. *Memoirs of the Association of Australasian Palaeontologists* 15:141-159.
* Bell, K.N. 1996. Early Devonian agglutinated foraminiferan from Buchan and Bindi, Victoria, Australia. *Proceedings of the Royal Society of Victoria* 108: 73-106.
* Winchester-Seeto, T. and Bell, K.N. Microforaminiferal Linings from the Early Devonian of eastern Australia, and their generic placement. *Journal of Paleontology* 68: 200-207.
* Bell, K.N. and Winchester-Seeto, T. 1999. Linings of agglutinated Foraminifera from the Devonian; taxonomic and biostratigraphic implications. *Journal of Micropalaeontology* 18. (due for publication in April, 1999).
* Winchester-Seeto, T. and Bell, K.N. 1999. Foraminiferal linings and other organic microfossils from the Tamworth Belt, northern New South Wales, Australia. *Alcheringa* 23. (due for publication in December, 1999).

ABSTRACT

Silurian to Middle Devonian sequences in Eastern Australia are shown to contain a large foraminiferan fauna. This fauna includes both agglutinated test and calcareous test species and comprises 19 families, 43 genera and 100 species of which four genera (*Cystingarhiza, Cylindrammina, Patellammina* and *Vermiculammina*) and 37 species are proposed as new. The new specific taxa include six species described from the inner organic wall linings.

The Silurian to Early Devonian faunas are entirely of agglutinated species, with the earliest calcareous test foraminiferan entering in the Emsian (*serotinus* Conodont Zone). The later faunas are dominated by the calcareous forms.

Significant time range extensions have been found for the genera *Pelosina, Sagenina, Reophanus, Trochammina* and *Nanicella*.

As well as the normal-sized foraminiferans in the fauna there were found, for the first time, organic linings which are considered to be the remains of agglutinated foraminiferans. They are a smaller size range of foraminiferans than is usually studied and represent foraminiferans which may or may not have had an inorganic outer wall. Many can be identified with known normal-sized foraminiferal genera and species and six new species, known only from organic linings, are described. These linings, recovered from samples from Australia, France, Siberia and Pakistan, also show usefulness as intra-continental and inter-continental correlation indicators.

A biostratigraphic zonation for the Silurian and Early-Middle Devonian of Eastern Australia, based on both normal foraminiferans and the organic linings, is proposed.

1. INTRODUCTION

This thesis is a series of studies on the foraminiferan faunas found in Early Silurian to Middle Devonian carbonate sequences in various localities in Victoria and New South Wales, eastern Australia.

The objectives of the study were to :

1: Document and describe the foraminiferan faunas present, in stratigraphic sections already dated by conodonts;

2: Present a biozonation for foraminiferans from the time period Early Silurian to Middle Devonian for Eastern Australia;

3: Investigate any foraminiferal linings occurring in the samples;

4: Compare and contrast foraminiferal faunas from eastern Australia with contemporaneous faunas globally.

1.1 BACKGROUND.

Little detailed work has been carried out on Australian Early and Middle Palaeozoic foraminiferans. Previously only passing mention of their occurrence has been made. Chapman (1918) described a supposed fauna of agglutinated and calcareous foraminiferans from the Middle Devonian at Tamworth, NSW but examination of his slides in the Museum of Victoria (Wood 1957; pers. obs.) shows that the specimens are not foraminiferan but fortuitous clumps of sand grains. Work undertaken in this study, however, has shown both agglutinated and calcareous foraminiferan species to be present in the Tamworth area. Later Chapman (1933) described two species, one from the Silurian mudstones at Mitcham, Victoria, as *Trochammina busaria* but which has since been referred to *Thuramminoides sphaeroidalis* Plummer (Conkin & Conkin 1968; Bell 1996), and the other from the Devonian Cave Hill Limestone at Lilydale as *Hemigordius lilydalensis* . This latter specimen, however, is agglutinated and thus should not be referred to the calcareous genus *Hemigordius*. More recently Sherwin (1971, 1973) reported three forms, *Glomospirella* sp., *Bathysiphon* sp. and *B.* sp. cf. *B. curvus*, without description or figures from the Molong Limestone and Mumbidgle Formation in central NSW. Three genera (*Tolypammina, Sorosphaeroidea, ?Hyperammina*) were reported without description from the Cowombat Formation in northeastern Victoria (Conkin & Conkin 1968).

A small Late Devonian fauna from Western Australia was described by Crespin (1961) with subsequent modifications to the taxonomy by Conkin & Conkin (1965). Late Devonian - Carboniferous foraminiferans have been described by Mamet & Belford (1968) and Belford (1969) from Western Australia.

The only reported occurrence of Late Silurian foraminiferans is by Bell (in Simpson *et al.* 1993) where the Ludlow (*crispa* Conodont Zone) fauna from Cowombat is discussed and 10 species described.

Microforaminiferal linings from the Early - Middle Devonian (*delta - serotinus* conodont zones) in NSW and Victoria have been reported by Winchester-Seeto & Bell (1994), Bell & Winchester-Seeto (1998, in press) and Winchester-Seeto & Bell (submitted). These linings, believed to be the organic sheath which surrounds the foraminiferal sarcode, were identified with normal-sized agglutinated foraminiferans that occurred in horizons of the same age, but not necessarily from the same samples.

Bell (1996) described the Early Devonian (Emsian) agglutinated foraminiferan fauna (45 species) from eastern Victoria.

Detailed studies on the conodonts of the early Palaeozoic carbonate sediments in NSW and Victoria by Assoc. Prof. Ruth Mawson, Prof. John Talent and their many students from the Centre of Ecostratigraphy and Palaeontology, Macquarie University, NSW, have made available a huge supply of light fraction residues from the acetic acid digestion of the limestones. These residues have been studied and show that there is a large and varied foraminiferan fauna present throughout the Silurian and Devonian in eastern Australia. The conodonts have given a precise biostratigraphical zonal scheme in accord with the world-wide scheme, thus foraminiferan faunas can be precisely dated. The oldest foraminiferan faunas studied are from the Early Silurian at Borenore, NSW (Wenlock, *ranuliformis* Conodont Zone); the youngest are from the Middle Devonian (late Givetian, *disparilis* Zone) sequences, possibly ranging as high as the Late Devonian (Frasnian, *falsiovalis* Zone) at Tamworth, NSW. The early faunas are composed entirely of agglutinated foraminiferan species with the calcareous form appearing late in the Emsian (*serotinus* conodont Zone). In Middle Devonian (Eifelian) sequences, calcareous forms appear in great numbers and dominate the faunas thereafter. The number of foraminiferan specimens per sample varied greatly; less than 10% of the samples contained any foraminiferans and, in the Silurian to early Devonian, were present in low numbers (about 10 per kg of dissolved sample); with the incoming of the calcareous faunas the numbers greatly increased to about 100/kg of sample dissolved.

1.2 METHODS

The samples available were the light fraction residues of acetic acid digested sediments, floated off when sodium polytungstate was used to obtain a heavy fraction to concentrate conodonts.

(a) Dilute acid (10%)Method.

As many of the Siluro-Devonian carbonate sequences in Eastern Australia are of shallow water origin and have a paucity of conodont elements present (Mawson *et al.* 1988), large samples (5-10 kg) are routinely treated in the acid leaching laboratory at Macquaire University. The methods have been clearly detailed and discussed by Talent *et al.* (1987) and Anderson *et al.* (1995). In short, a sample of approximately 5 kg is leached in 10% acetic acid buffered to 3.5pH (using spent liquor from previous leachings) for 7 days. The insoluble residues are washed, dried and floated off in sodium polytungstate with a specific gravity of 2.76-2.79 g cm^{-3}. The light fraction from this flotation comprised the samples studied although some heavy fractions were occassionally checked for foraminiferans. The residues were picked under a binocular microscope as normal floatation techniques for separating foraminiferans from residue proved unsuitable. Each light fraction available ranged from 30-400g.

(b) Concentrated acid (96 %) Method.

The residues from some localities in the Tamworth area had many internal casts of what were assumed to be calcareous walled foraminiferans . Study of thin rock sections of these samples proved useless as the foraminiferans were uncommon (about 50/kg rock). To see if the calcareous foraminiferans could be extracted from the recrystallized limestones the method reported by Tarsilli & Warne (1997) for the extraction of ostracodes from Devonian limestones was tried. This method, a variation of the Zolnaj (1979) method, involved using 96 % acetic acid as the leaching agent and leaching for 24 hours. I found that this leaching time too short and leached samples up to three days. Entire, unetched calcareous foraminiferans were recovered, apparently quite unaffected by the stronger acid.

For Scanning Electron Microscopy specimens where stubbed then either gold or chromium plated and photographed in a JEOL JSM-840 electon microscope , using Ilford FP4 Plus (ISO 125/22°) film.

1.3 ACKNOWLEDGEMENTS

This thesis owes much to the diverse help given to me by many friends and colleagues over the years. I am most grateful to my supervisors Professor John Talent, Associate Prof. Ruth Mawson at Macquarie University and Dr. David Holloway, Museum of Victoria, who enabled me to begin this work, who supplied copious samples, advice and access to literature and who had the optimism that I could make something of 'my little lumps of sand'.

Numerous fellow students and colleagues at Macquarie University helped in many essential ways - from supplying samples from their light fraction residues to advising on methods, microscopy and darkroom techniques - in bringing this work to fruition. In particular I would like to mention Theresa Winchester-Seeto, Glenn Brock and Michael Engelbretsen who were always willing to listen to my concerns and of the development of the research.

My thanks also to the librarians of both the Macquarie University Library and the Museum of Victoria Library for their help in obtaining literature that enabled this research to be more comprehensive than it may have been. Mrs. Karin Bell kindly translated some of the German literature for me.

I am indebted to Mss. Sue Doyle, Carol Gilkeson and Jenny Norman, Microscopy Unit, School of Biological Sciences, Macquarie University for patiently initiating me into the use of scanning electron microscopy.

2. STRATIGRAPHY

This section details the geographic localities (Fig. 1), the ages of the various sections and the stratigraphy of these sections from which foraminiferans (both normal foraminiferans and foraminiferal organic linings) were recovered. Figure 2 shows the location of the Silurian and Devonian sedimentary areas in eastern Australia that were studied in this research. Table 2 shows the chronological ages and relationships of the sections studied.

1. Victoria.

1.1 ***Cowombat Plain.*** (Fig. 3)

In the upper reaches of the Indi River and along Limestone Creek in NE Victoria, isolated limestone lenses occur (Whitelaw 1953) which are referred to as part of the Cowombat Siltstone within the Enano Group (Talent 1967; Talent *et al.* 1964, 1975; VandenBerg *et al.* 1988). In the Enano Group massive to finely banded siltstones predominate with minor quartz sandstones and volcanogenic pebbly mudstones, conglomerates and carbonate lenses and thin beds of calcareous clastics also present. The lithology and distribution of the Enano Group is fully discussed in VandenBerg *et al.* (1984).

At Cowombat Plain small, but richly fossiliferous limestone lenses crop out. These are considered to be *in situ* even though they usually have obscure boundaries (VandenBerg *et al.* 1984). The beds contain a diverse shelly fauna of rugose and tabulate corals, brachiopods, bivalves, trilobites and stromatoporoids (Talent 1959;

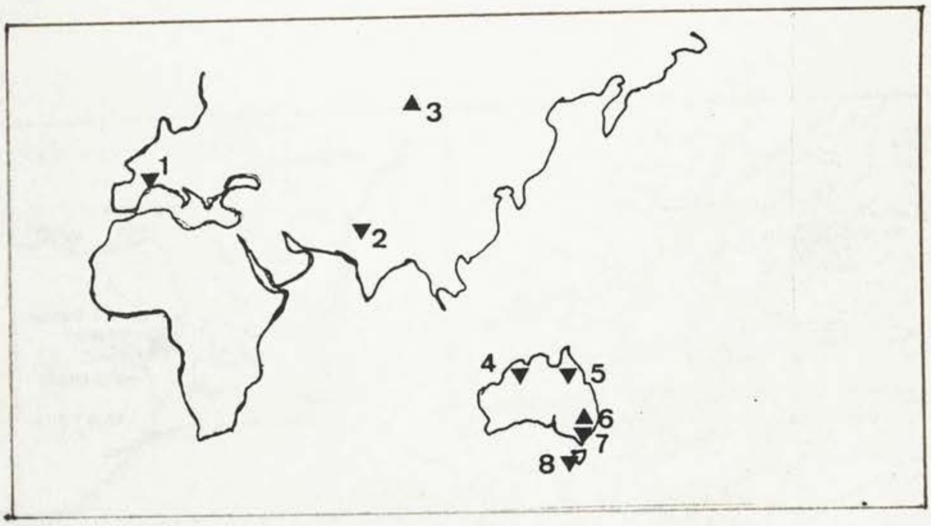


Figure 1. World map showing general location of sites from which samples have been studied. 1. France. 2. Pakistan. 3. Siberia. 4. Canning Basin, Western Australia. 5. Broken River, Queensland. 6. New South Wales (see *Figure 2* for detailed map). 7. Victoria. 8. Point Hibbs, Tasmania.

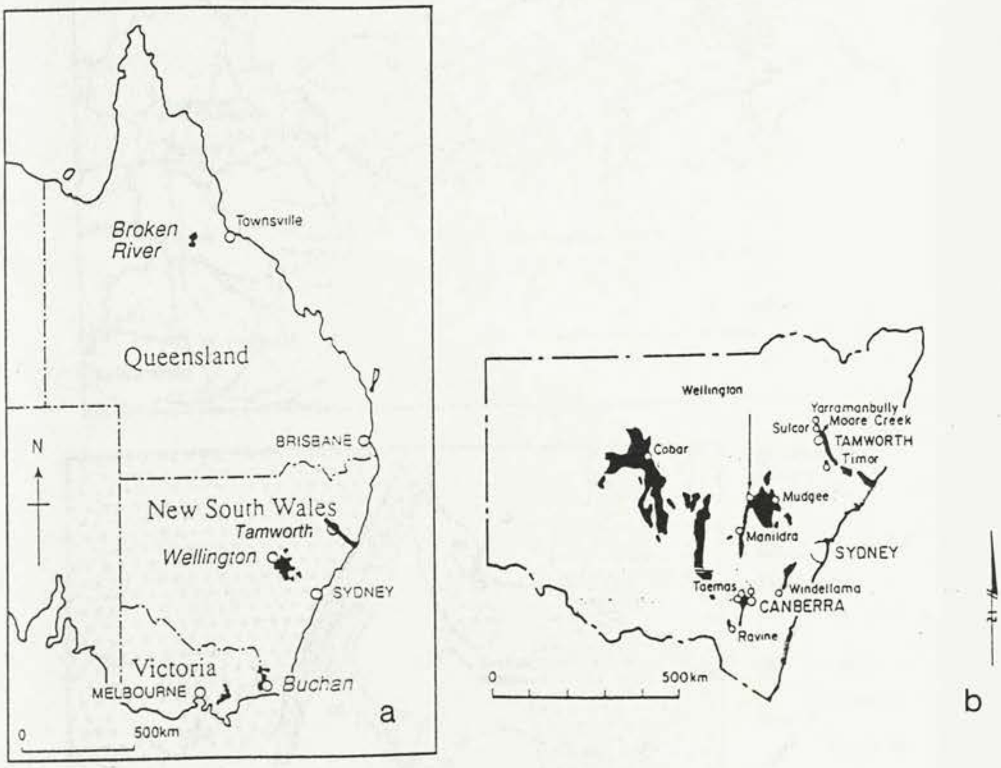


Figure 2. a. Eastern Australia, showing major regional distribution of Early Devonian to Middle Devonian rocks (exclusive of intrusives).
b. New South Wales, showing major regional distribution of Early Devonian to Middle Devonian rocks (exclusive of intrusives).

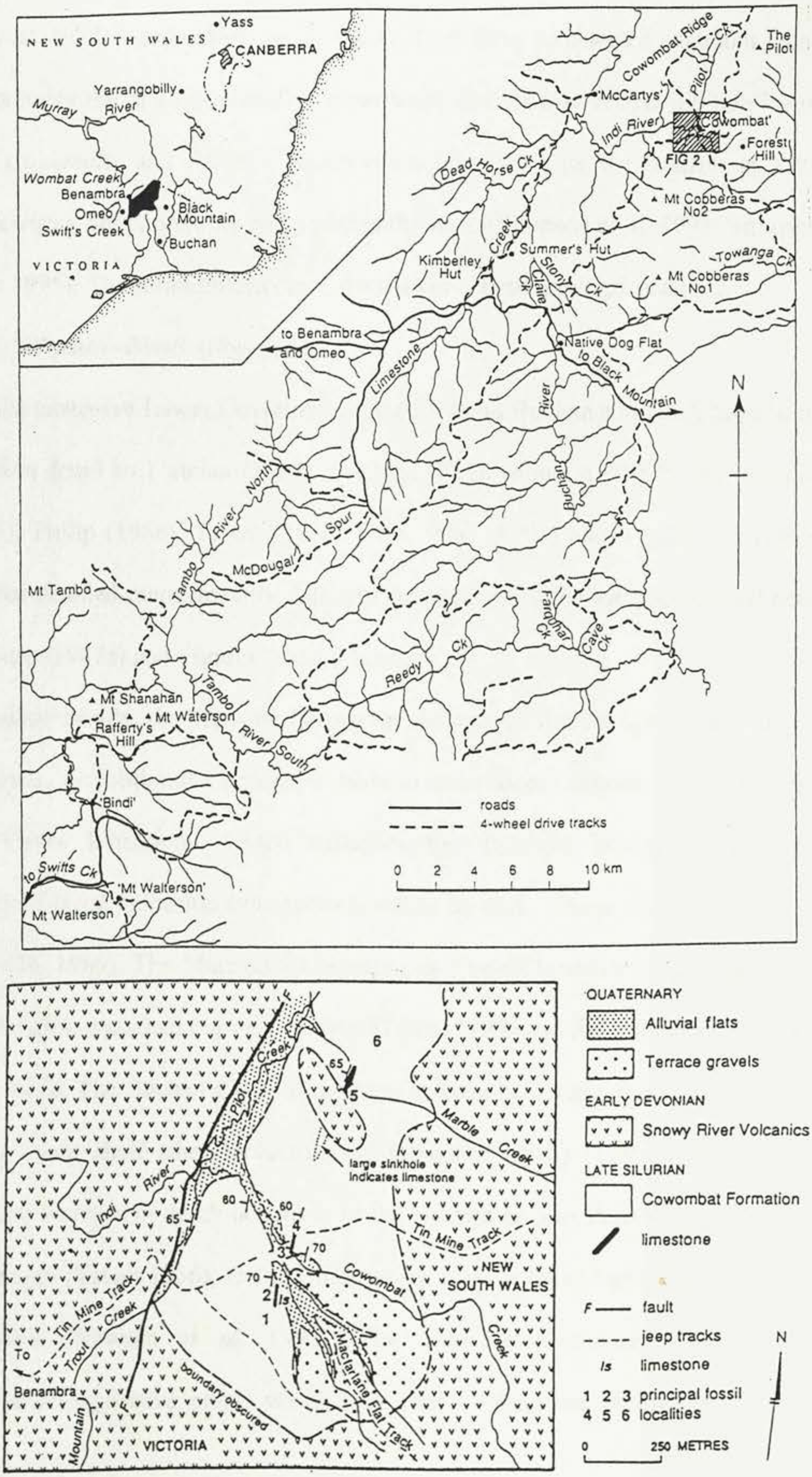


Figure 3. Geological and fossil locations about Cowombat Flat, Victoria. (after Simpson *et al.* 1993).

Talent *et al.* 1975; VandenBerg *et al.* 1984). They have produced a conodont fauna which includes the stratigraphically significant *Ozarkodina crispa, O. confluens, Belodella anomalis* and *Pedavis ?thorsteinssoni* which date the horizon as Late Ludlow *crispus* Zone, possibly early within the zone (Simpson *et al.* 1993; Simpson & Talent 1995). The foraminifera came from a very small quarry, Locality 2.

1.2 ***Buchan-Bindi***. (Figs 4, 5)

The extensive Lower Devonian sediments about Buchan and Bindi have been described in detail by Fletcher (1963), Gaskin (1933), Mawson (1987a), Mawson *et al.* (1985), Philip (1966), Talent (1956, 1965, 1967, 1969) and Teichert & Talent (1958). For detailed maps, locality data and stratigraphy of the samples studied here see Mawson (1987a) and Figures 4 and 5 herein.

Lithologically, the Taravale Formation consists of 'impure limestone nodules and irregular, discontinuous limestone beds in mudstones' (Mawson 1987a). The Buchan Caves Limestone, which underlies the Taravale Formation, consists essentially of basal dolomitic limestones overlain by dark, fine-grained calcarenites (Talent 1956, 1969). The Murrindal Limestone is a small lenticular limestone body deposited during a gradual regressive event (Talent 1989) and lies entirely within the *perbonus* Zone. The Buchan Caves Limestone is thought to have been deposited on a shallow, wide shelf (the Buchan-Indi-Combienbar Shelf) (Talent 1965, 1969, 1989). Slow increase in depth occurred; in the Buchan area as demonstrated by the faunal changes (Talent 1956), and at Bindi where five conodont biofacies have been distinguished (Mawson *et al.* 1993). The Taravale Formation represents a diachronous transgressive phase which took place during the *dehiscens* Zone at

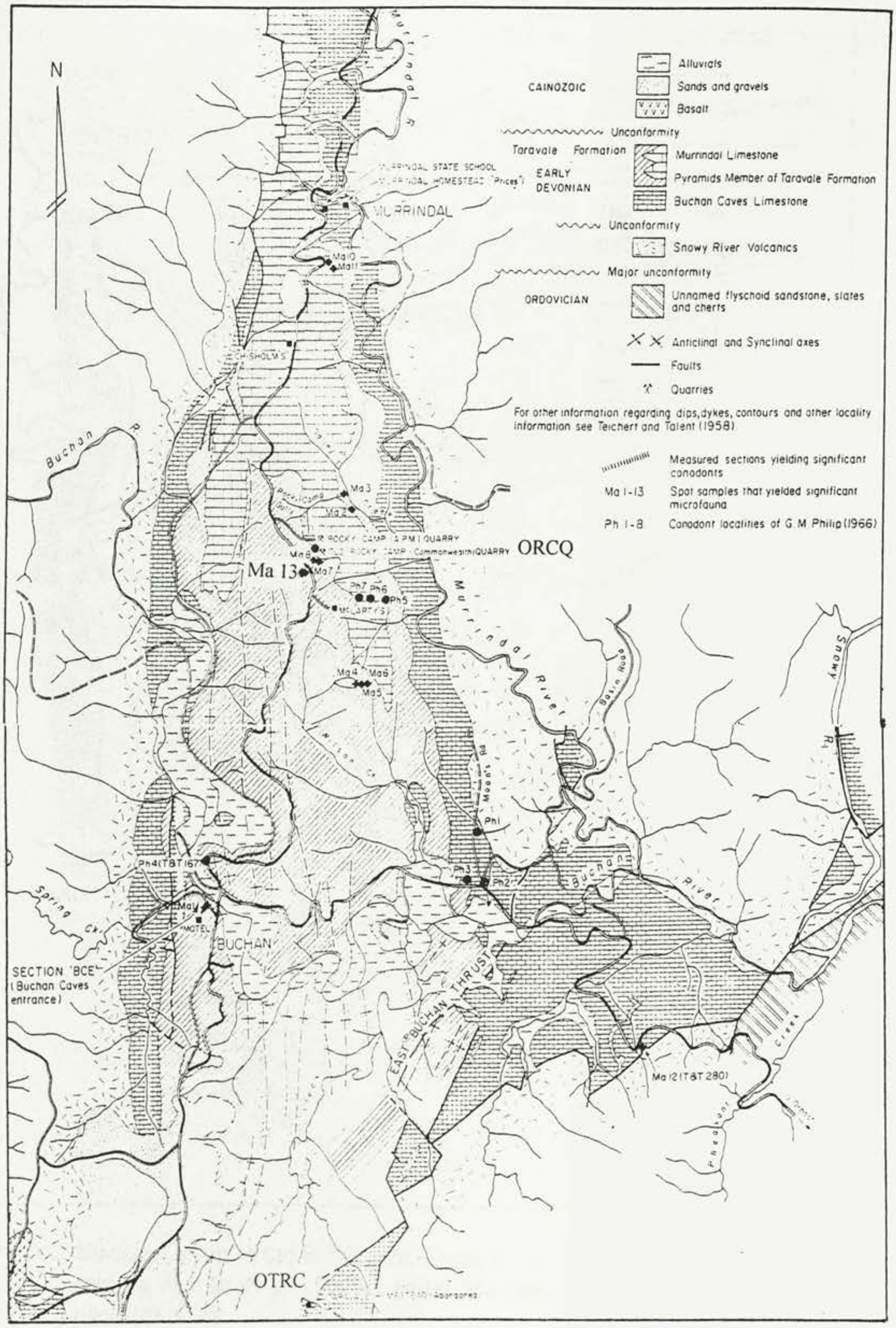


Figure 4. Buchan Group at Buchan, Eastern Victoria, showing location of sample sites OTRC, Ma 13, ORCQ10-15. (after Mawson 1987). For abbreviations used see p. iix.

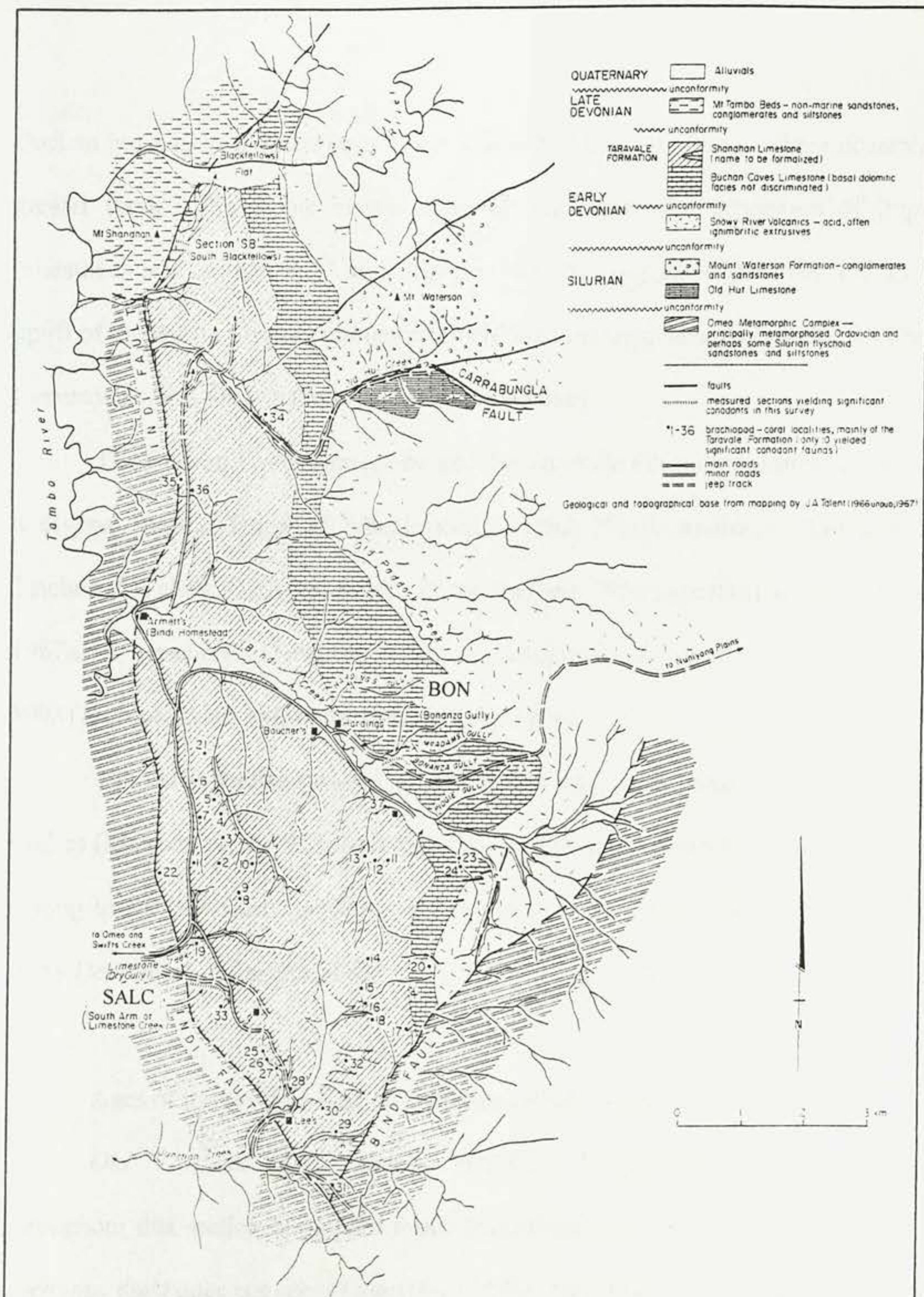


Figure 5. Buchan Group in the Bindi area, Eastern Victoria, showing location of sample sites BON and SALC. (after Mawson 1987). For abbreviations used see p. iix.

Buchan but within the *perbonus* Zone at Bindi (Mawson 1987a). There occurred a greater input of insoluble clastic material leading to the deposition of impure limestones and mudstones. VandenBerg (1988) has suggested that this was due to uplift of the Buchan-Indi-Combienbar Shelf. He also suggested that the Rocky Camp Limestone was a very shallow-water carbonate bank.

The Buchan Caves Limestone and the Taravale Formation sediments contain a diverse marine fauna of brachiopods (Talent 1956), molluscs (Talent 1956; Teichert & Talent 1958), ostracodes (Krommelbein 1954), corals (Hill 1950; Pedder 1967a, b), ammonites (Teichert 1948), stromatoporoids (Ripper 1937; Webby *et al.* 1993) and conodonts (Mawson 1987a, Philip 1966).

The early studies pointed to an Emsian age; with more detailed conodont studies (Mawson *et al.* 1985; Mawson 1987a) it is now known that these sediments belong to the *dehiscens, perbonus-gronbergi, inversus* and *serotinus* zones of the Early Devonian, i.e. Emsian Stage.

Ages of the sections studied at Buchan-Bindi (Table 1):

Old Taravale Road cutting (OTRC): *Polygnathus dehiscens* occurs throughout this section but whilst forms transitional to *P. perbonus* are present, *P. perbonus* itself does not occur (Mawson 1987a). Thus this section lies wholly within the *dehiscens* Zone.

Bonanza Gully, Bindi (BON): In this section *P. dehiscens dehiscens* is found in a short interval from sample BON 25-27.5 (123.9-125 m above base) to sample BON 46-50 (129.6-131.5 m above base) with *P. perbonus* first occurring in sample

STAGE	CONODONT ZONE
E M S I A N	*patulus*
	serotinus
	inversus
	perbonus
	dehiscens

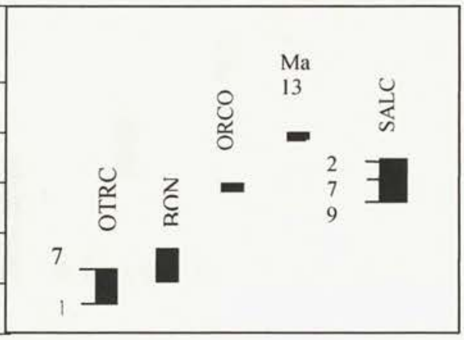


Table 1. Stratigraphic ranges of the Emsian (Early Devonian sequences at Buchan and Bindi.

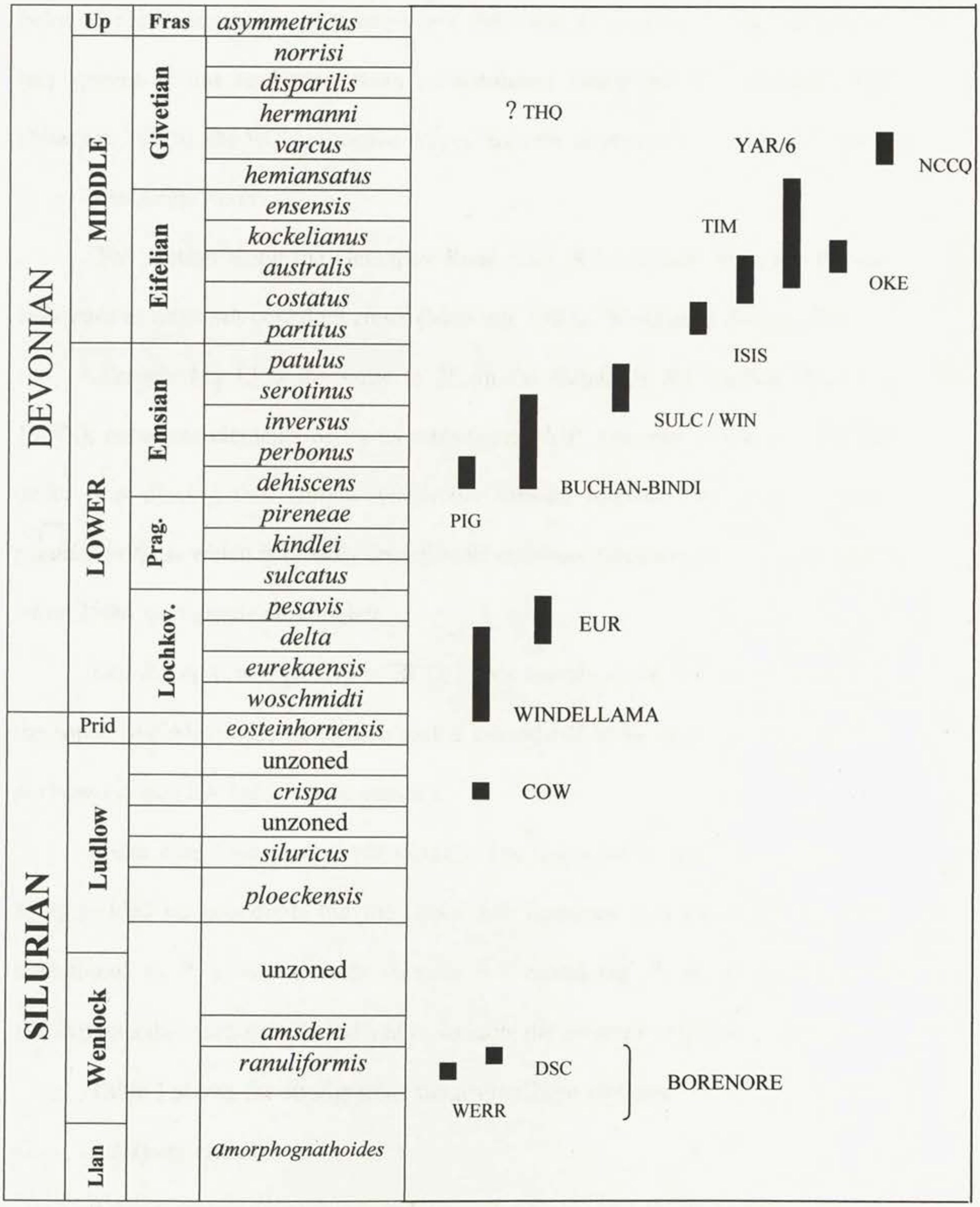


Table 2. Chronological chart showing conodont zones and the ages of the sections studied from Victoria and New South Wales. For abbreviations used see p. viii

BON 45-50 and persisting in higher samples (Mawson *et al.* 1993). In samples below the first occurrence of *P. dehiscens dehiscens, O. prolata* is common and, as this species is not known to occur in sediments below the *P. dehiscens* Zone (Mawson 1987b), the BON sequence ranges from the *dehiscens* to *perbonus* zones.

Gelantipy Road.

The section along the Gelantipy Road (Gel. Rd.) extends from the Emsian *dehiscens* to *serotinus* conodont zones (Mawson, 1987a; Winchester-Seeto, 1996).

Sample Ma 13 is the same as 28 on the Gelantipy Rd. section (Mawson 1987a); conodont elements of forms transitional to *P. inversus* and of *P. inversus* occur thus placing this sample within the Emsian *inversus* conodont Zone. *P. pseudoserotinus* which is broadly coeval with *serotinus* (Mawson 1987a) first occurs some 250m stratigraphically higher.

Old Rocky Camp Quarry (ORCQ): This sample came from 10-15 m above the top of the Murrindal Limestone and is considered to be at the very top of the *perbonus* Zone (J.A.Talent, pers. comm.).

South Arm, Limestone Creek (SALC): The lower part of this section (samples 8, 9) yielded no conodonts but the upper part (samples 7-2) contained elements transitional to *P. serotinus* with samples 6-4 containing *P. serotinus* (Mawson 1987a); thus this section is considered to straddle the *inversus-serotinus* boundary.

Table 1 shows the stratigraphic ranges for these sections.

1.3 ***Tyers*** **and** ***Boola.***

Pragian faunas were recovered from the Tyers and Boola quarries (Tyers, BOO) in the limestones of the Coopers Creek Formation, eastern Victoria.

Conodonts date the two sections as spanning the *sulcatus-kindlei* conodont zones (Mawson & Talent, 1994), and chitinozoans included *Bulbochitina bulbosa*, an important zone fossil for the *kindlei Zone* (Winchester-Seeto, 1993). Palaeoenvironmental interpretation of the area is controversial (see Mawson & Talent, 1994; Rehfisch & Webb, 1993).

2. New South Wales.

2.1 **Central NSW.** (Fig. 6, 7)

Near Borenore, to the west of Molong, central-western N.S.W., is a sequence of Middle Silurian beds. The Boree Creek Limestone is overlain by the Mirrabooka Formation and its lateral limestone equivalent, the Borenore Limestone (Pickett 1982). The foraminiferal – bearing samples from the Boree Ck. Limestone (WERR 13.0, WERR 16.2, WERR 18.3) are of lower *ranuliformis* age, based on the conodont assemblages present (Cockle 1998). The overlying Mirrabooka Formation and the Borenore Limestone, which in this area are about 123 m thick and interdigitate (Cockle 1998), span the Wenlock and into the Ludlow – *ranuliformis, amsdeni* and into the *variabilis* conodont zones (Fig. 7; Cockle 1998). The single foraminiferal – bearing sample from the Mirrabooka Formation, DSC 230, is close to the *ranuliformis-amsdeni* boundary *i.e.* early Wenlock, the actual age is not definite as the zone fossil, *Kockelella amsdeni*, occurred in one sample, approximately 8 m above the foraminiferal sample, but *K. ranuliformis* elements present in DSC 124 and DSC 181.2 are consistent with this age (Cockle 1998). The samples from the ERC section, which

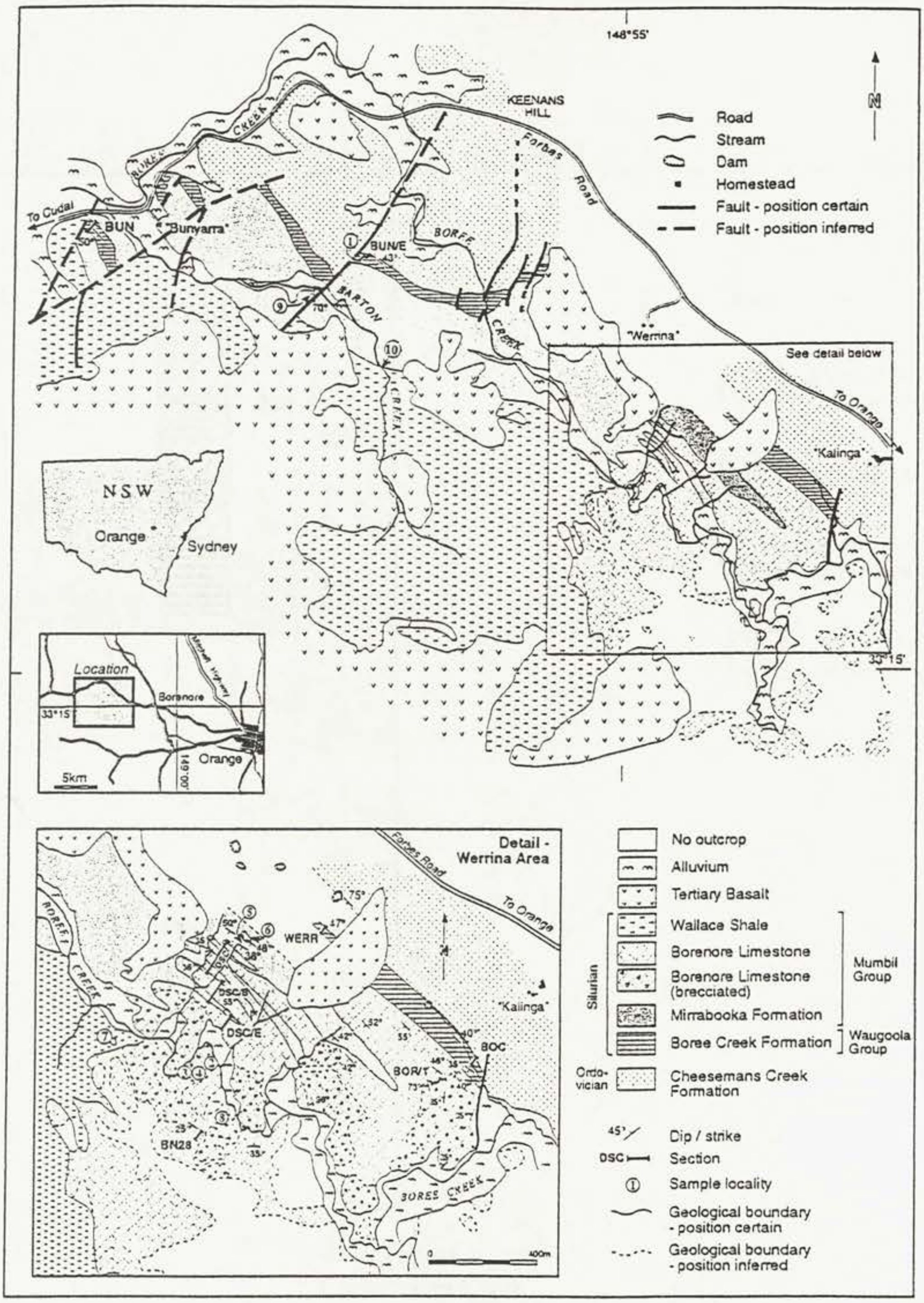


Figure 6. Location and geological map of the Borenore are N.S.W., showing location of sample sites DSC, WERR. (after Cockle 1998). For abbreviations used see p. ~~iix~~ viii.

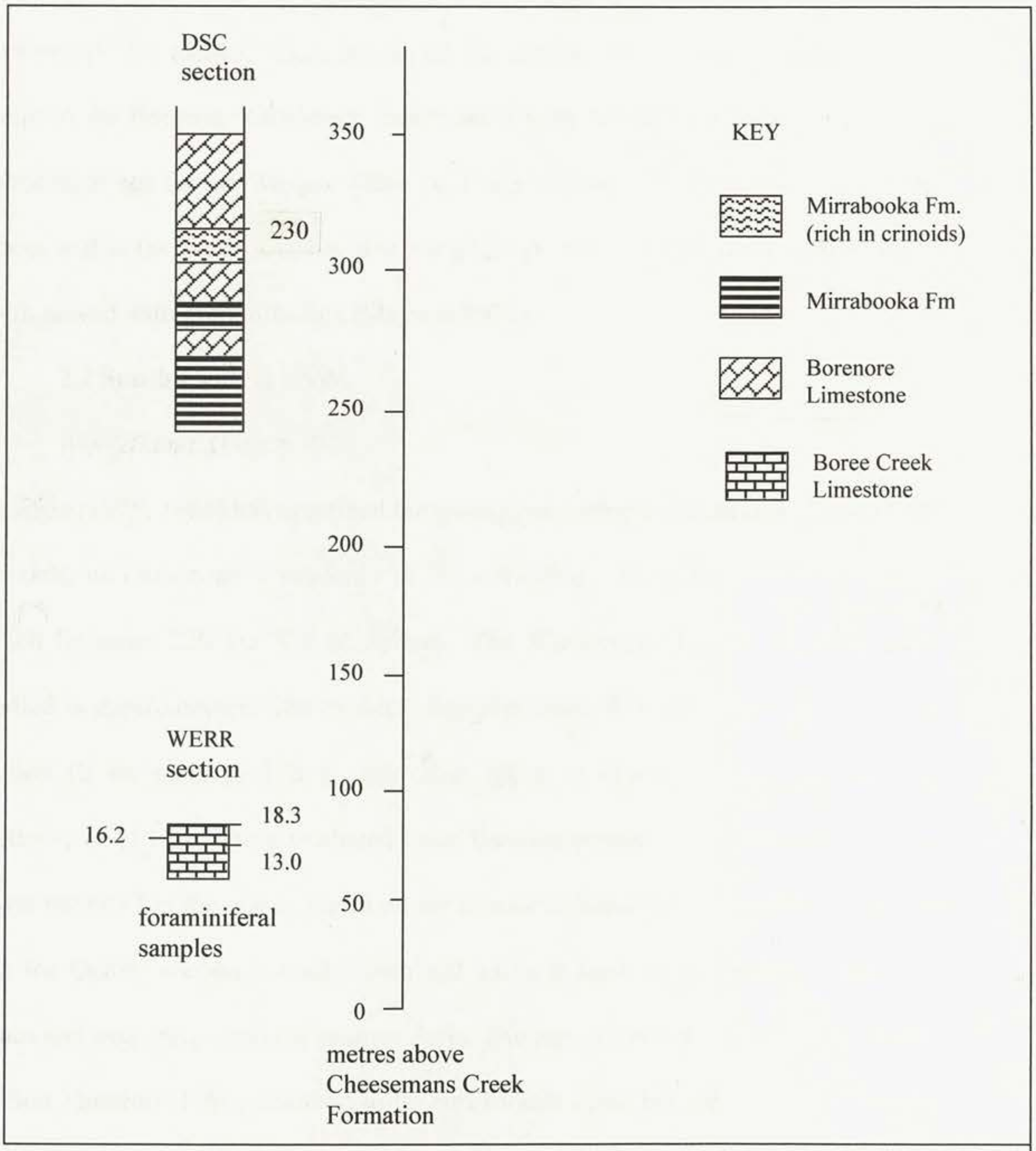


Figure 7. Borenore stratigraphic section, showing relative positions of WERR and DSC sections, productive foraminiferal samples and lithology. (adapted from Cockle 1998) is in the Wallace Shale, contained either fragmentary conodonts or ones too poorly preserved for identification. However, the conodont *Kockelella variabilis,* from high in the Borenore Limestone (interbedded with the Wallace Shale), provides a maximum age for the Wallace Shale *i.e.* Early Ludlow *variabilis* Zone. Conodonts from within the Wallace Shale give a slightly younger age – *siluricus-crispa* zones – in accord with graptolite data (Sherwin 1971).

2.2 **South Central NSW.**

Windellama. (Figs.8, 9).

Mawson (1975, 1986) has described the geological setting and conodont fauna of the Windellama Limestone, a sequence of ?Late Silurian – Early Devonian carbonates, which lie some 220 km SW of Sydney. The Windellama Limestone in the area studied is approximately 280 m thick. Samples came from two sections – a lower section (S samples) of 128 m, the other upper or Quarry section (Q, and QU sections) of 161 m. These produced quite variable numbers of conodonts, 4 in the lower but 6657 in the upper. Based on the conodont faunas Mawson (1986) suggested that the Quarry section is Lochkovian and spans at least the *eurekaensis* and *delta* zones and may range into the *pesavis* Zone. The age of the lower part of the Quarry section Mawson (1986) assumed to be *eurekaensis* Zone but she indicated that the incoming of *Amydrotaxis corniculans* and *Ozarkodina excavata* at 143.2 and 146.4 m above the base suggests that samples Q7 and QU23 may be of *hesperius* age. The age of the lower Windellama section is less certain but, if the identification of a juvenile *O. remscheidensis eosteinhornensis* is correct, then a Late Silurian, Pridoli,

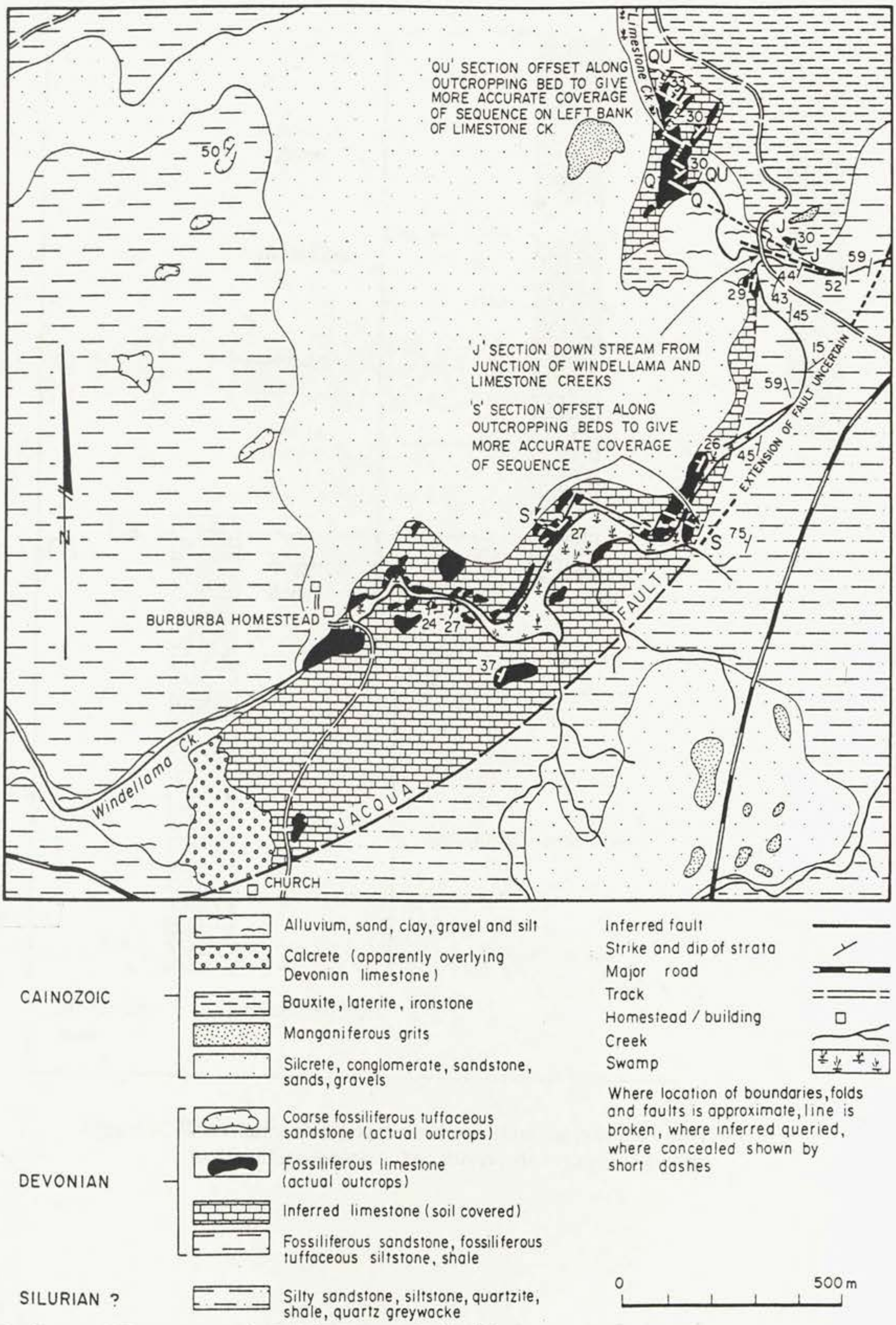


Figure 8. Location and geological map of the Windellama Limestone, Windellama, N.S.W., showing stratigraphic sections S, Q, QU. (after Mawson 1975). For abbreviations used see p. xviii

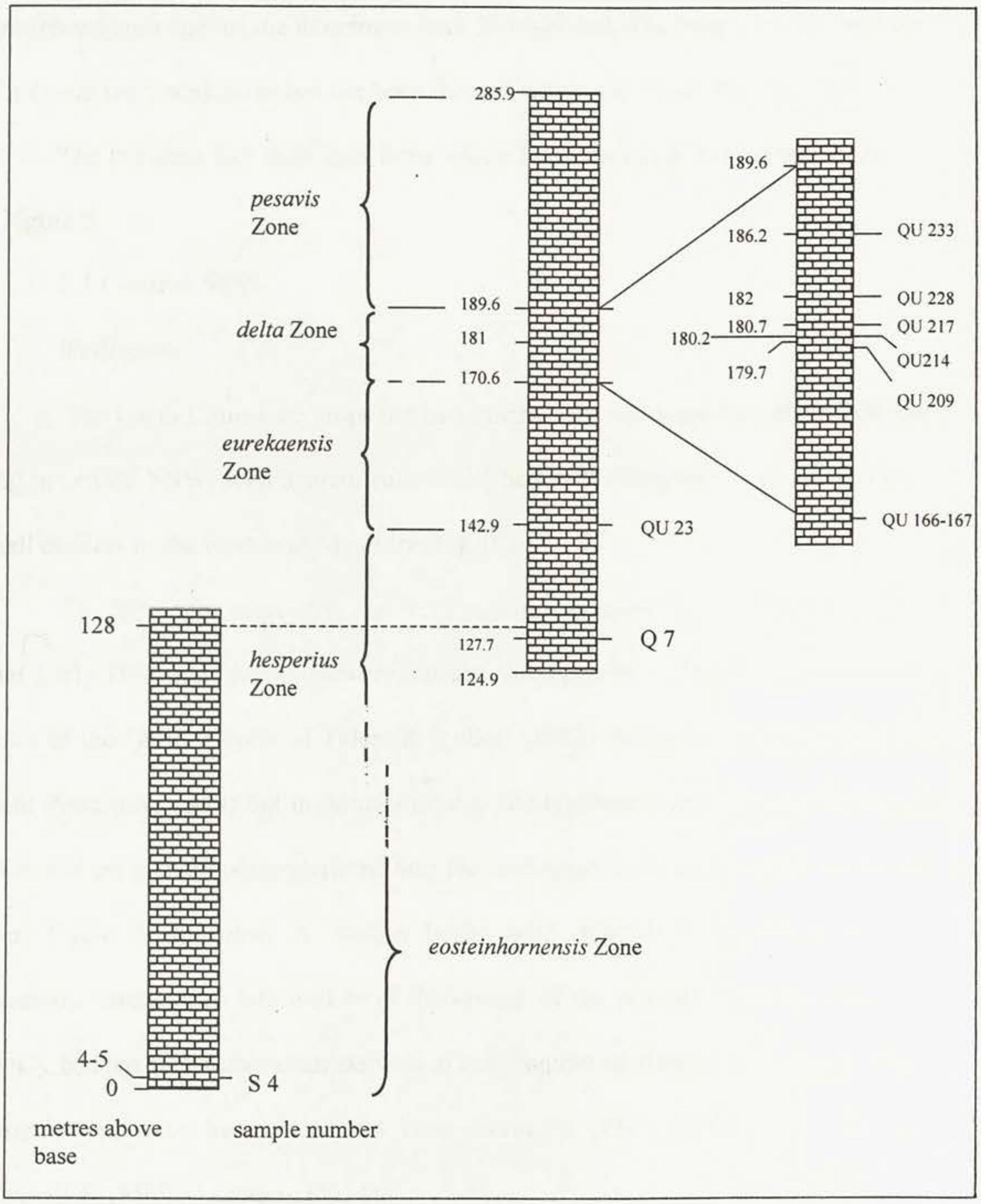


Figure 9. Windellama stratigraphic sections, showing position of S, QU and Q foraminiferal samples. For abbreviations used see p. viii

eosteinhornensis age for the lowermost beds is suggested. The boundary between the Pridoli and the Lochkovian has not been located within the Windellama Limestone.

The horizons and their ages from which foraminiferans were found is shown in Figure 9.

2.3 **Central NSW.**

Wellington.

The Garra Limestone crops out in a northwest - southeast belt about 100 km long in central NSW, with a small subparallel belt at Wellington Caves and isolated small outliers to the west near Manildra (Fig 10).

The lithologic succession and stratigraphy is discussed in Johnson (1975). In brief Early Devonian volcanics were initially onlapped by carbonates of deepening facies of the Garra 1 cycle of Talent & Yolkin (1987) during late *delta* time in the south (Sorentino 1989) but in *pesavis* time in the northern areas (Wilson 1989) and continued on a shallowing platform into the mid-*pesavis* Zone; in the late- *pesavis* Zone Cycle 2 of Talent & Yolkin began with deposition of mudstones and calcareous mudstones followed by a shallowing of the platform and deposition of thickly bedded carbonates characteristic of tidal-supratidal flats in the *sulcatus* Zone. Foraminifera have been recovered from Eurimbla (EUR section, Fig. 12) and Mungallala (MUNG section, Fig. 11).

At Eurimbla (Figs 12, 13) the sedimentary sequence (about 140 m) consists of a basal rubbly limestone passing into a shale and nodular limestone series followed by calcareous shales and mudstones and the limestone. The base of the section is within the *delta* Zone as the incoming of the conodont *Kimognathus*

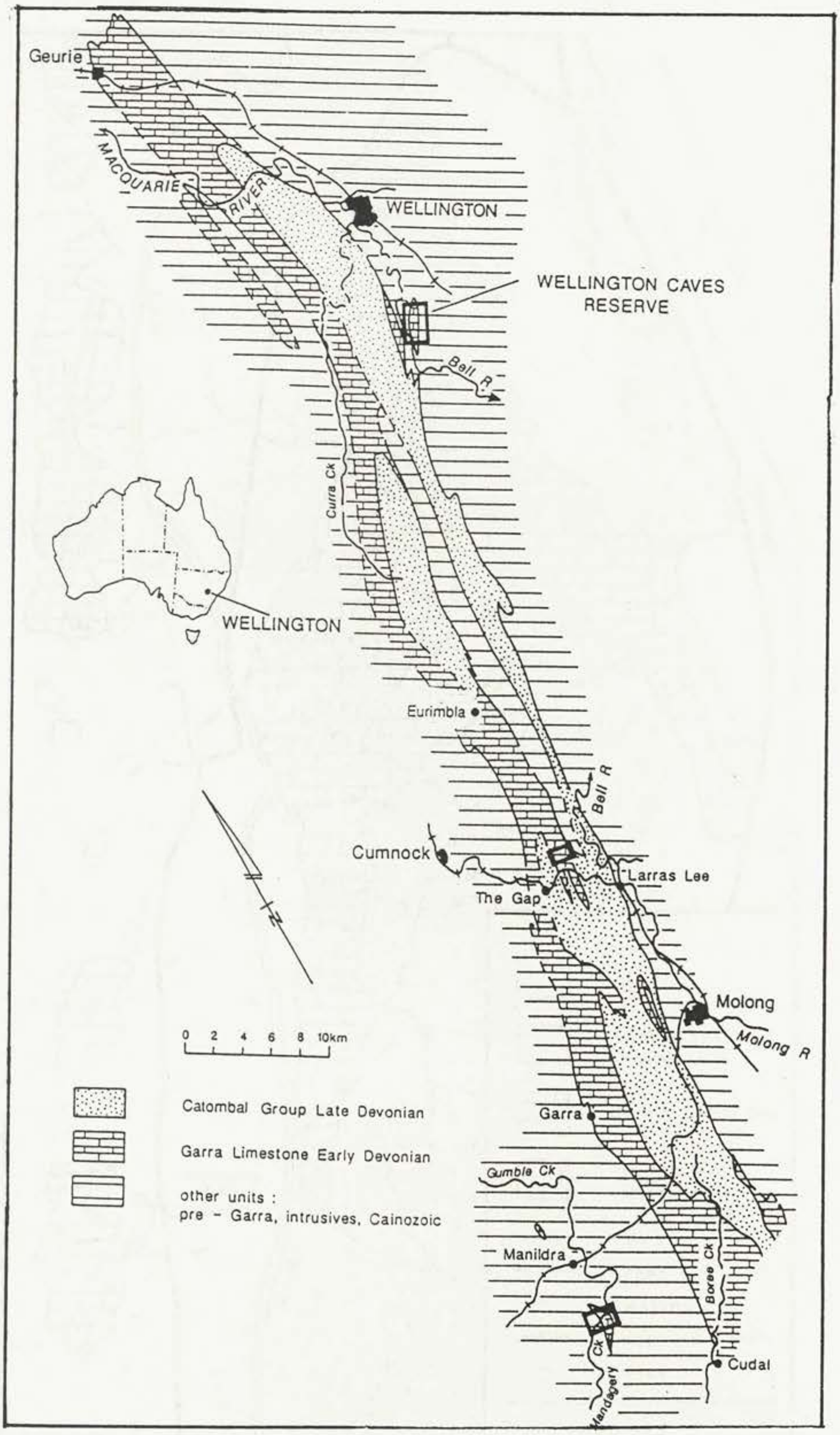


Figure 10. Location and geological map of the Garra Limestone, Wellington, N.S.W., (from Geurie to Manildra), showing EUR sample site. (after Mawson *et al.* 1988). For abbreviations used see p. viii.

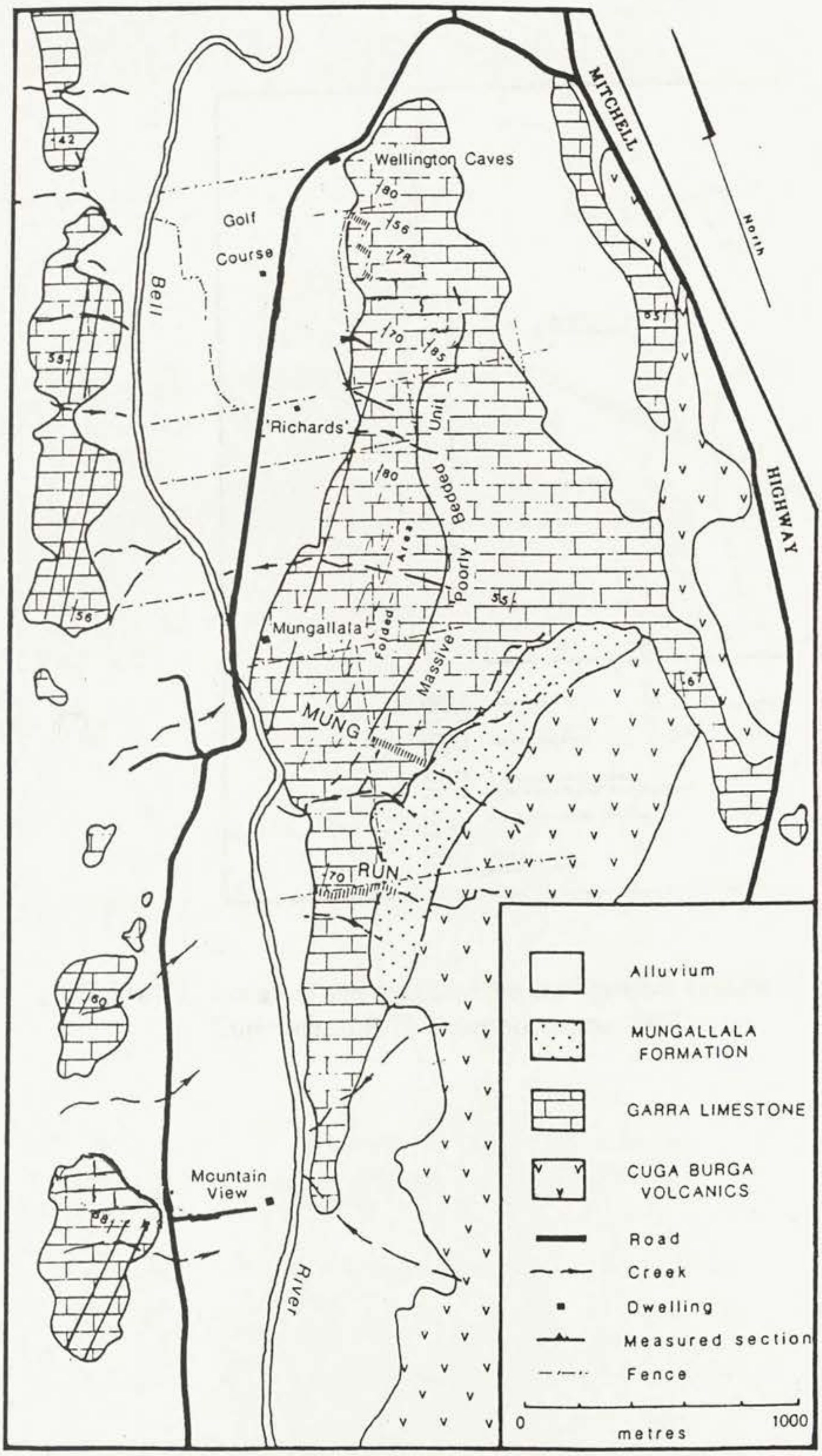


Figure 11. Location and geological map of the Garra Limestone, Wellington, N.S.W., showing MUNG and RUN sample sites. (after Wilson 1989). For abbreviations used see p. viii

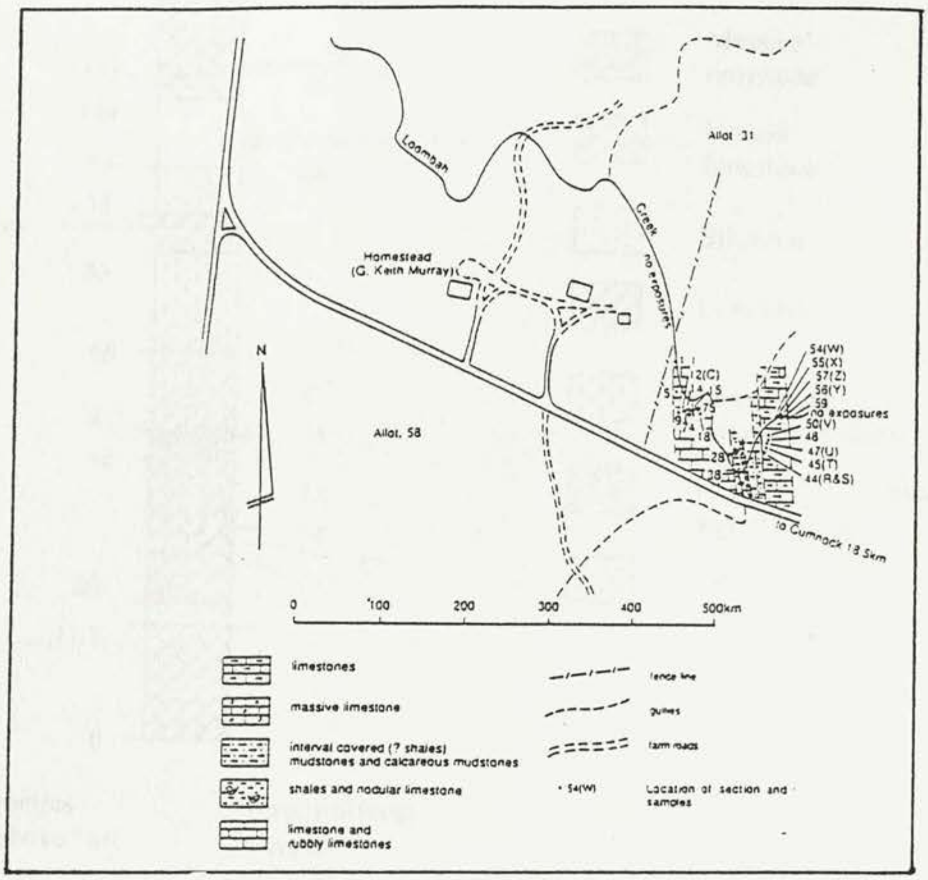


Figure 12. Location and details of the stratigraphic section EUR, Loombah Creek, Eurimbla, N.S.W. (after Sorentino 1989).

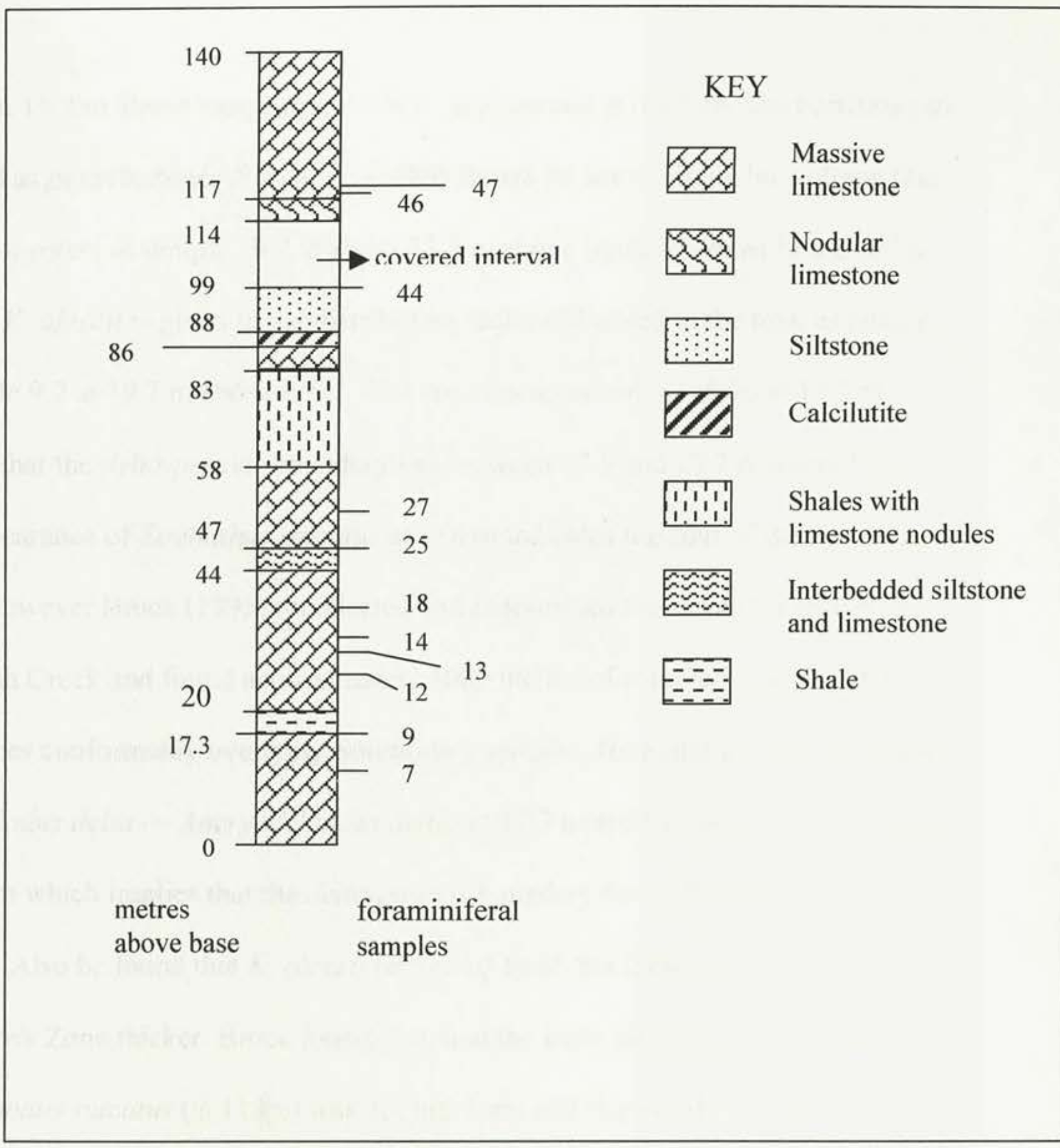


Figure 13. EUR stratigraphic section, showing productive foraminiferal samples and lithology. For abbreviations used see p. ~~iii~~ viii

alexeii at 19.7 m above base suggests that , in Australia at least, the the horizons can be dated as *pesavis* Zone. Sorentino (1989) shows on her stratigraphic column that *K. alexeii* enters at sample 19.7 at about 37.3 m above base; this must be a printing error as *K. alexeii* is given in the distribution table, and stated in the text, as entering in sample 9.7 at 19.7 m above base . The last appearance of *O. delta* at 17.3 m implies that the *delta-pesavis* boundary lies between 17.3 and 19.7 m above base. The appearance of *Eognathus sulcatus* at 118 m indicates the start of the *sulcatus* Zone. However Brock (1995) recollected and redescribed the Eurimbla section in Loombah Creek and found approximately 1000 metres of calcareous shales and mudstones conformably overlying Sorentino's section. He found the last occurrence of *Cruciodus delta (= Ancryodelloides delta)* at 17.3 m and the incoming of *K. alexii* at 19.7 m which implies that the *delta-pesavis* boundary lies within this 2.4m interval. Also he found that *K. alexeii* ranged up to 65.9m (Sorentino 55.2m) making the *pesavis* Zone thicker. Brock found, too, that the form identified by Sorentino as *Eognathodus sulcatus* (at 118 m) was not that form and that recollecting the entire sequence did not produce any true *E. sulcatus* until at 793 m when *E. sulcatus eosulcatus* entered. Therefore there is about 730 m of sequence in the section referable to the *pesavis* Zone. Thus all of the samples studied here for foraminiferans, which came from Sorentino's material, are of either *delta* or *pesavis* age *i.e.* Lochkovian.

At Mungallala (Fig.14) the MUNG sequence (approx. 60 m) consists of almost uniformly bedded massive limestone. The section lies entirely within the *pesavis* Zone (Wilson 1989).

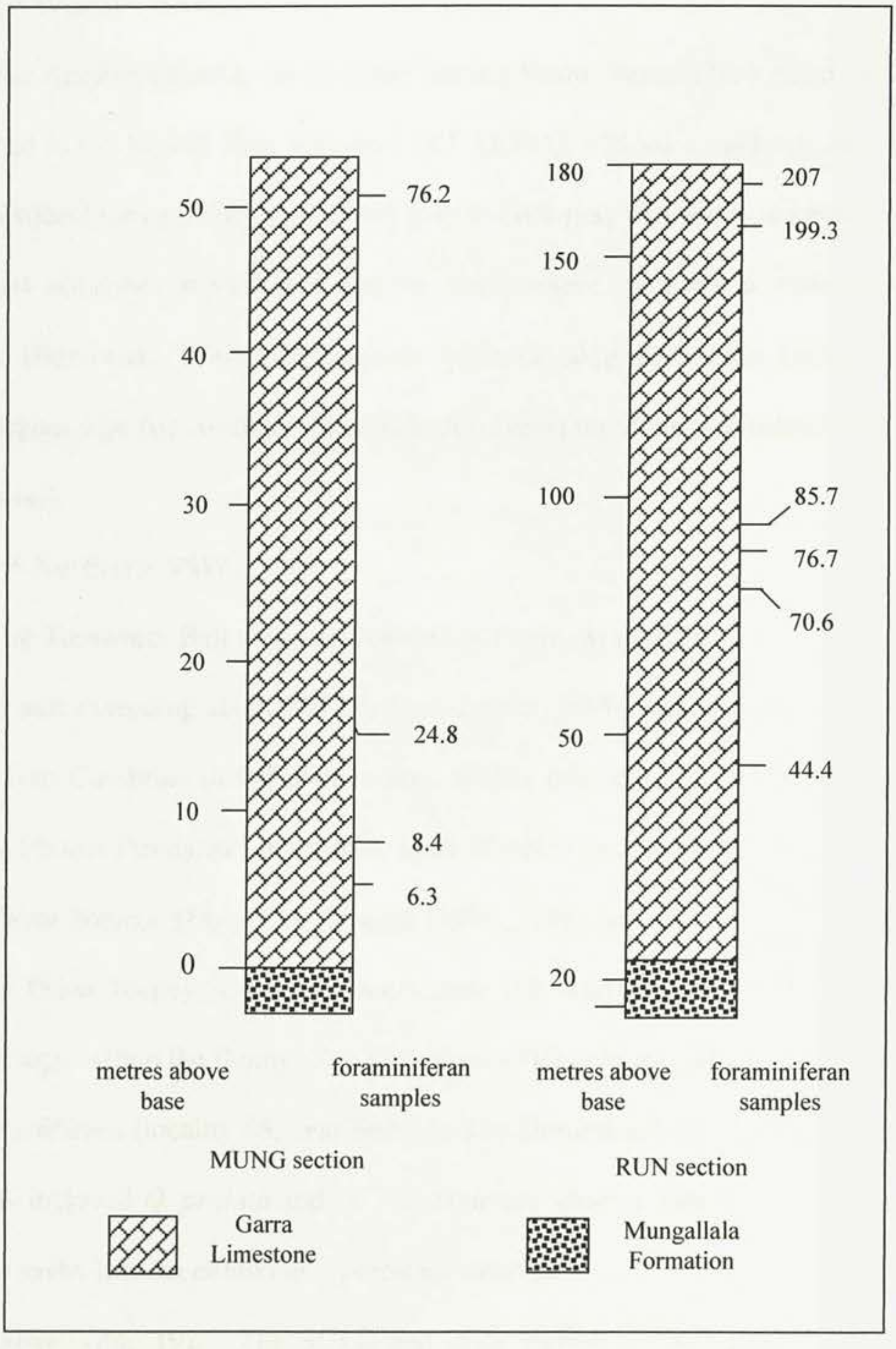


Figure 14. MUNG and RUN stratigraphic sections showing productive foraminiferal samples and lithology. (adapted from Wilson 1989).

2.4 **Western NSW.**

The Amphitheatre Group from the Darling Basin, western New South Wales, represented in the Kewell East bore-core (KE DDH1), yielded a moderate diversity of foraminiferal linings. The interbedded gray to dark gray claystones, carbonaceous shales and siltstones represent a marine environment, possibly a transgressive sequence (Bembrick, 1997). Chitinozoan evidence suggests a Late Lochkovian-Early Pragian age (no younger than *sulcatus* conodont Zone [Winchester-Seeto, unpub. data]).

2.5 Northern NSW.

The Tamworth Belt (Fig.15; Table 3) is a narrow, north-north-west trending structural unit extending about 250 km from Forster, NSW. and contains sediments ranging from Cambrian to Permian in age. Within this sequence are a number of Early and Middle Devonian Limestones, some of which have been studied herein.

Pigna Barney (Fig. 18). Dongal (1994, 1995) has shown that in the area along the Pigna Barney River limestones crop out discontinuously. Only one of these outcrops within the Benny' Top Limestone (PIG section) produced conodonts and foraminiferans (locality 48, near Benny's Top Homestead; GR 7350 8120). The conodonts included *O. prolata* and *O. ?buchanensis* which constrain the age of the limestone to the Emsian *dehiscens – perbonus* interval.

Sulcor (Fig. 19). The SULC and WIN section of the Sulcor Limestone Member of the Yarrimie Formation lie entirely within the Emsian *serotinus* Zone (Mawson & Talent 1998). Lithology of the Sulcor Limestone, at the measured section at the type locality (Sulcor Quarry), varies from mainly massively bedded

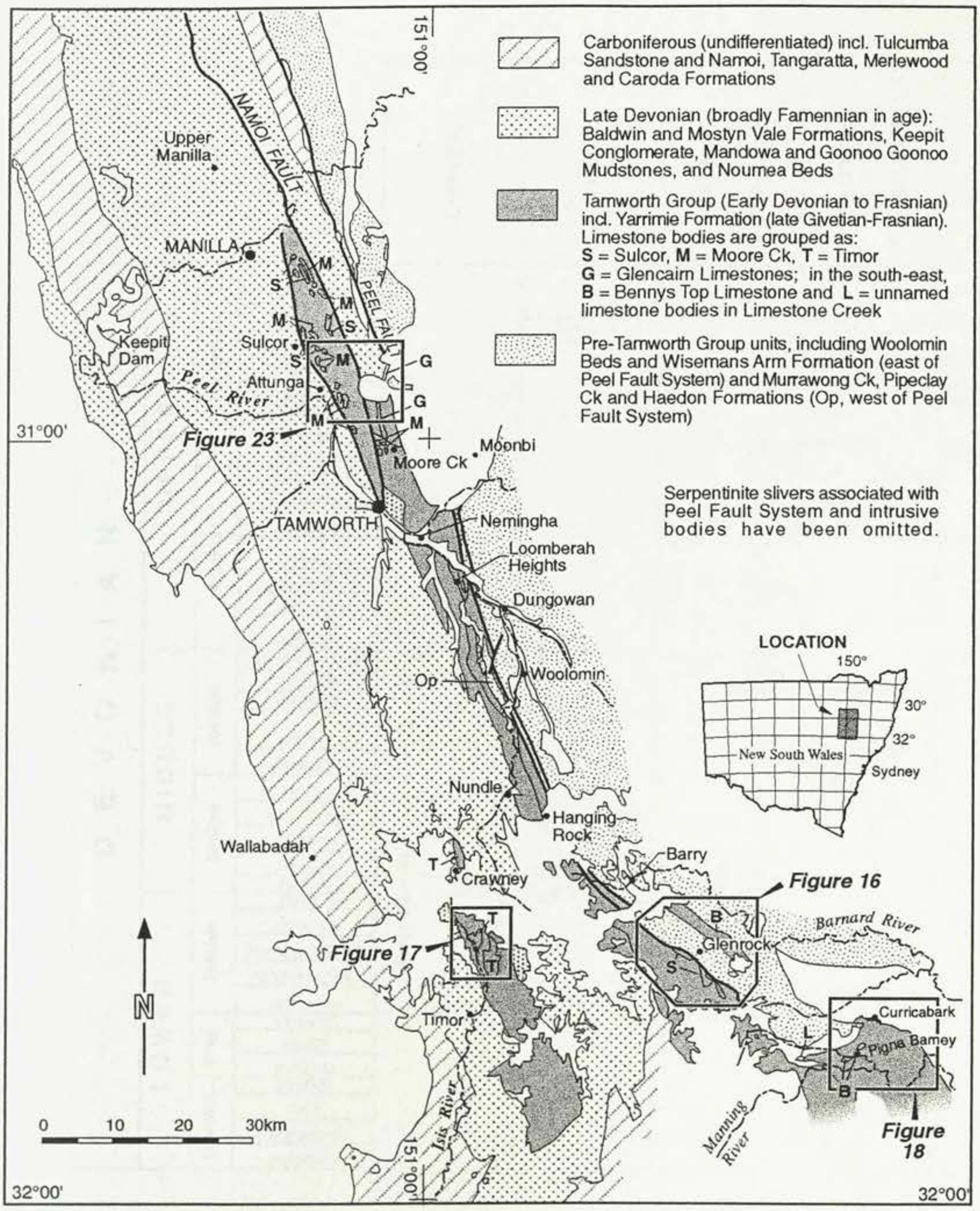


Figure 15. Generalized geological map of the Tamworth , N.S.W. region. Positions of enlarged map areas (*Figures 16, 17, 18, 23*) are indicated.

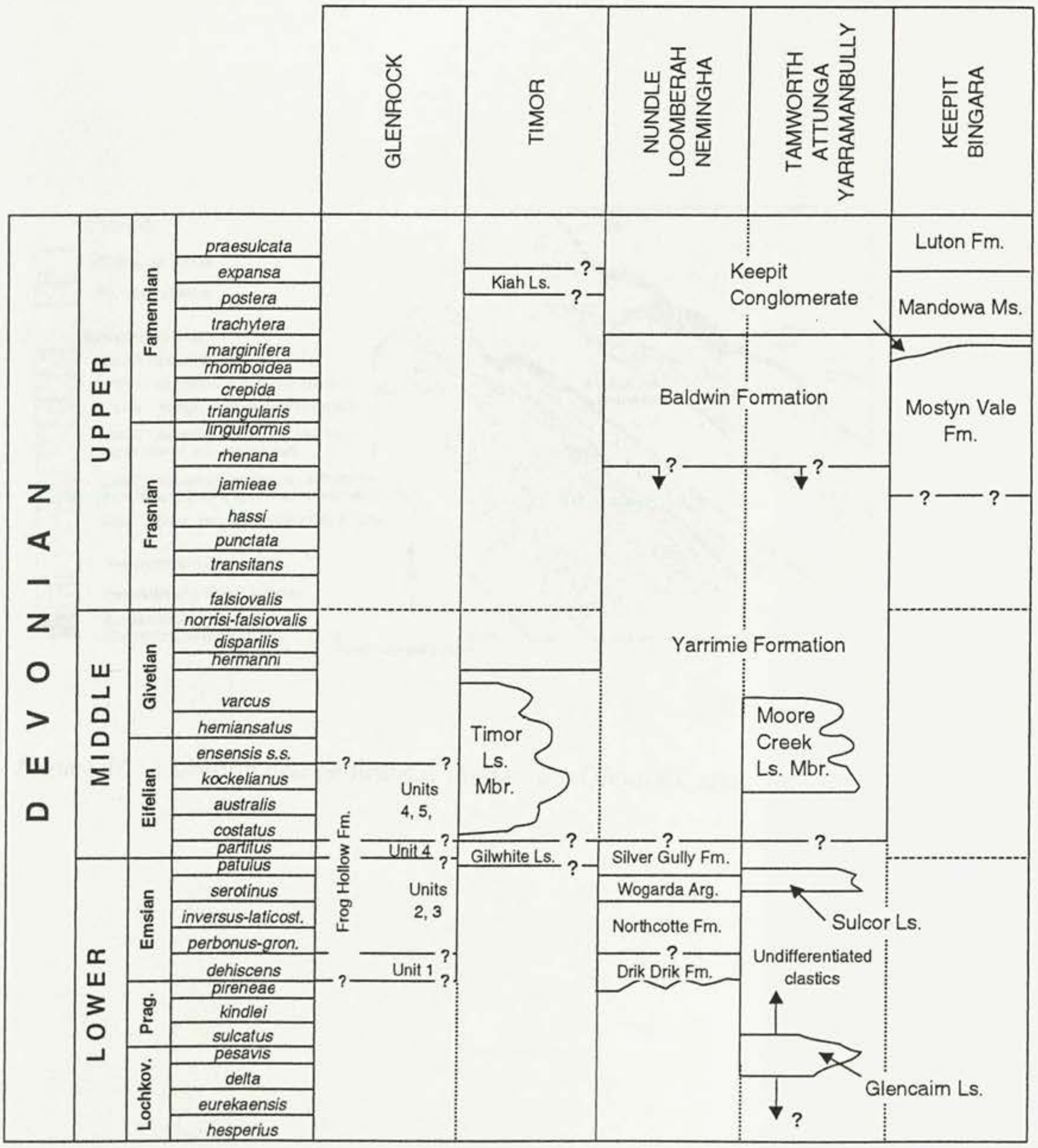


Table 3. Stratigraphic columns, showing the ages and relationships between the studied sections in the Tamworth region. (adapted from Mawson & Talent 1998).

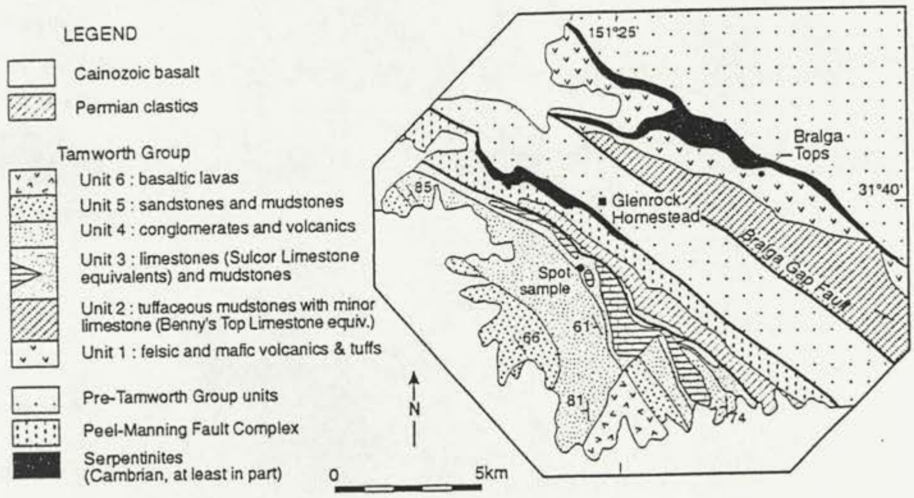


Figure 16. Location and geological map of the Glenrock area, N.S.W.

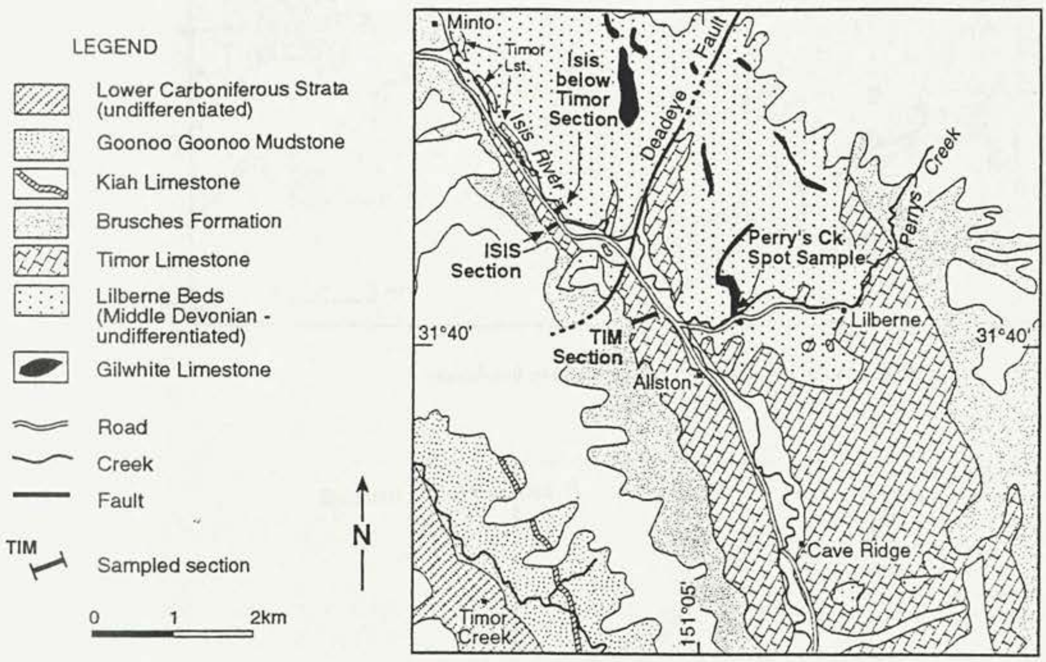
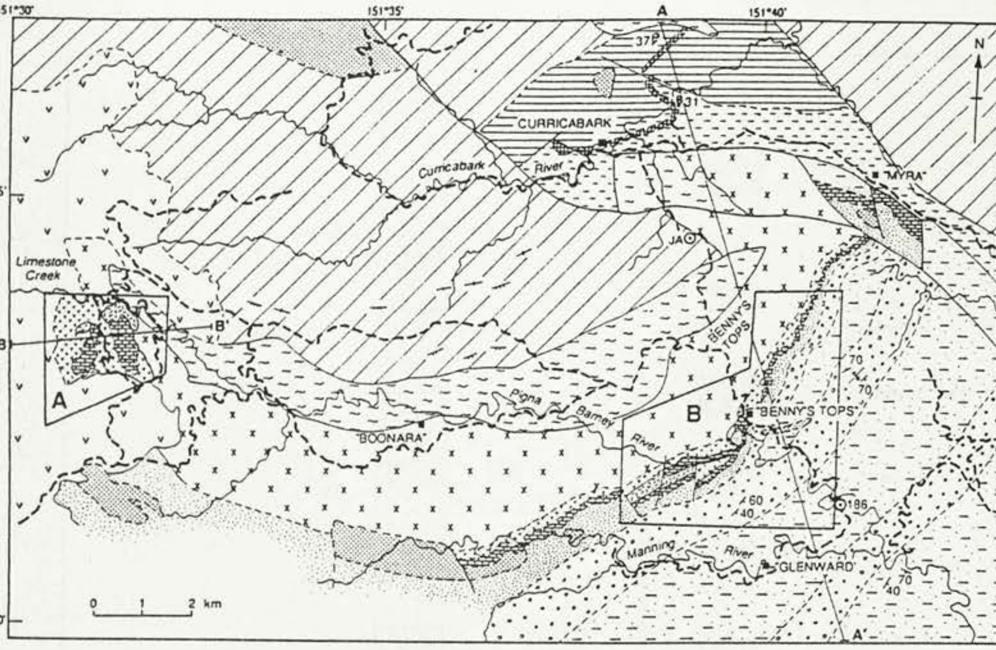


Figure 17. Location and geological map of the TIM, ISIS area, N.S.W. For abbreviations used see p. viii



Generalised geology of the Pigna Barney-Curricabark area.

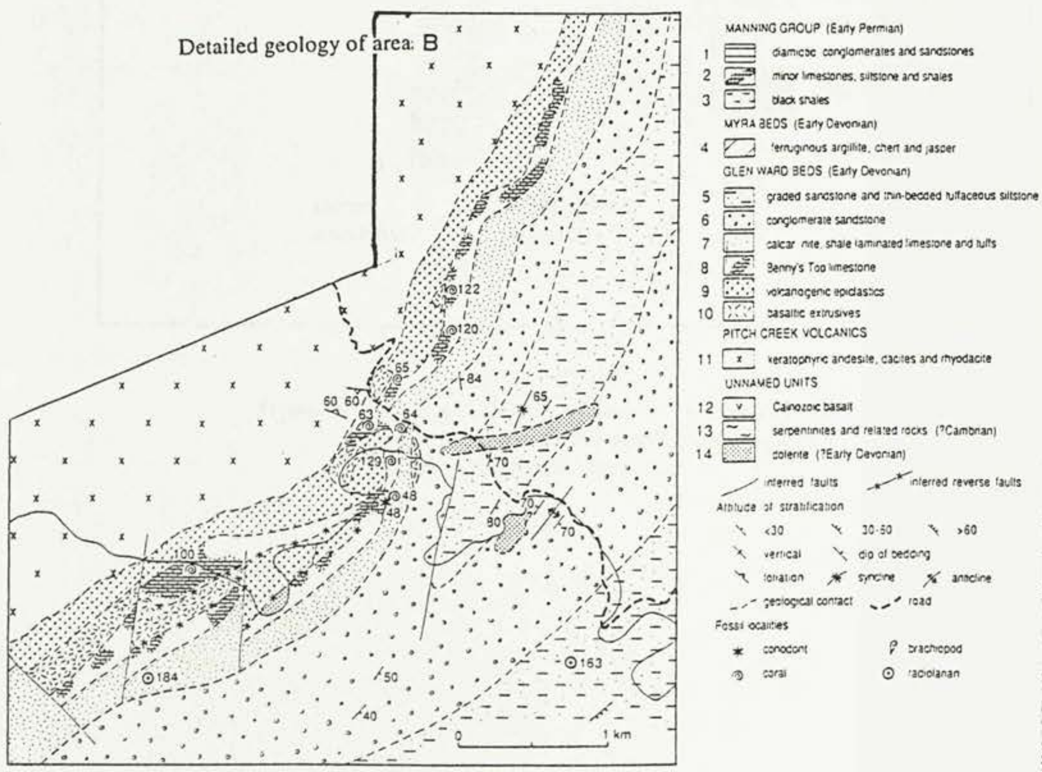


Figure 18. Location and geological map of the Pigna Barney (PIG) sample site. (after Dongal 1995). For abbreviations used see p. xxvii

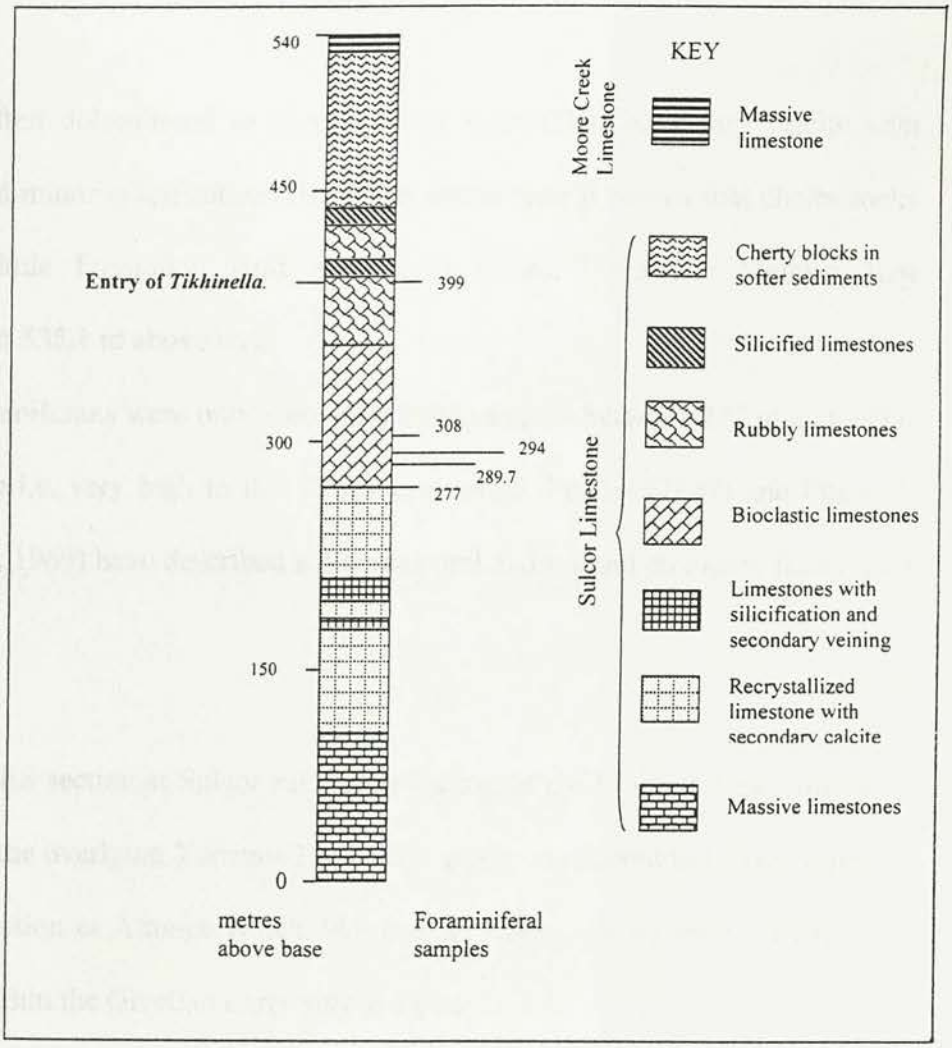


Figure 19. SULC stratigraphic section, showing position of productive foraminiferal samples and lithology. For abbreviations used see p. iix.

limestone, often dolomitized or recrystallized with thick secondary calcite vein formation and minor silicification. At 405 m above base it passes into cherty rocks of the Yarrimie Formation with the Moore Creek Limestone Member first outcropping at 535.1 m above base.

Foraminiferans were only recovered from samples between 277 m and 399.6 m above base i.e. very high in the Sulcor Limestone. Pedder (1967) and Philip & Pedder (1968, 1969) have described a diverse coral and a small conodont fauna from these beds.

CES.

The CES section at Sulcor runs from the top of the Moore Creek Limestone Member into the overlying Yarrimie Formation and is considered to be equivalent to the NCCQ section at Attunga which Mawson & Talent (1994) have shown to be most likely within the Givetian Early *varcus* Zone.

Timor (Fig. 17).

The Timor Limestone Member of the Yarrimie Formation extends from the Eifelian *costatus* Zone to the Givetian Middle *varcus* Zone. It consists mainly of a grey bioclastic limestone with intertongues of banded siltstones, shales, arenites, breccias and several nodular chert horizons. The sampled section (TIM section, Fig. 17) commenced at GR 18339510 ISIS RIVER 1:25000 map; the section headed west and is equivalent to section 7 of Pedder *et al.* (1970). Conodonts from sample numbers 17.5, 18.9, 22.3, 33.3, 39.4 and 48.7 indicate that this part of the section can be dated as *costatus* Zone. The incoming of *Polygnathus trigonicus* in sample 78.3 is indicative of *australis* Zone. Samples 83.9 and 85.4 are still within the *australis* Zone as *Kockelianus kockelianus australis* has been recovered from both horizons (R. Mawson, *pers. comm.* 10 March 1998).

Isis. (Fig. 17, 21).

The ISIS section is situated stratigraphically below the TIM section and approximately 2 km to the north along the Nundle-Blandford Road.

The presence of *Bipennatus bipennatus bipennatus* in sample ISIS 11.2 indicates an age no older than the Eifelian *costatus* Zone (*B. bipennatus bipennatus* ranges from the start of the *costatus* conodont Zone, R. Mawson, *pers. comm.*, May, 1998). The earlier samples may be *costatus* age or even perhaps *partitus* Zone but diagnostic conodonts were not recovered from these horizons.

Isis River below Timor.

Samples were collected from both bedded strata and clasts directly below the ISIS section, on the eastern side of the Nundle-Blandford road, down to the rivers edge. The samples yielded specimens of what may have been a chitinozoan, *Bulbochitina* sp., spores, scolecodonts, and foraminiferal linings. The precise nature of the contact is unclear and no conodonts were recovered; the contact is assumed herein to be conformable, and this is not contradicted by the assemblages of organic walled microfossils, thus the age is assumed to be approximately Early Eifelian.

Gilwhite Limestone.

Clasts of the "calcareous conglomerate" Gilwhite limestone Member of the Lilberne beds were collected from Perry's Creek. The age is unknown, but does not appear to be any older than the Timor Limestone.

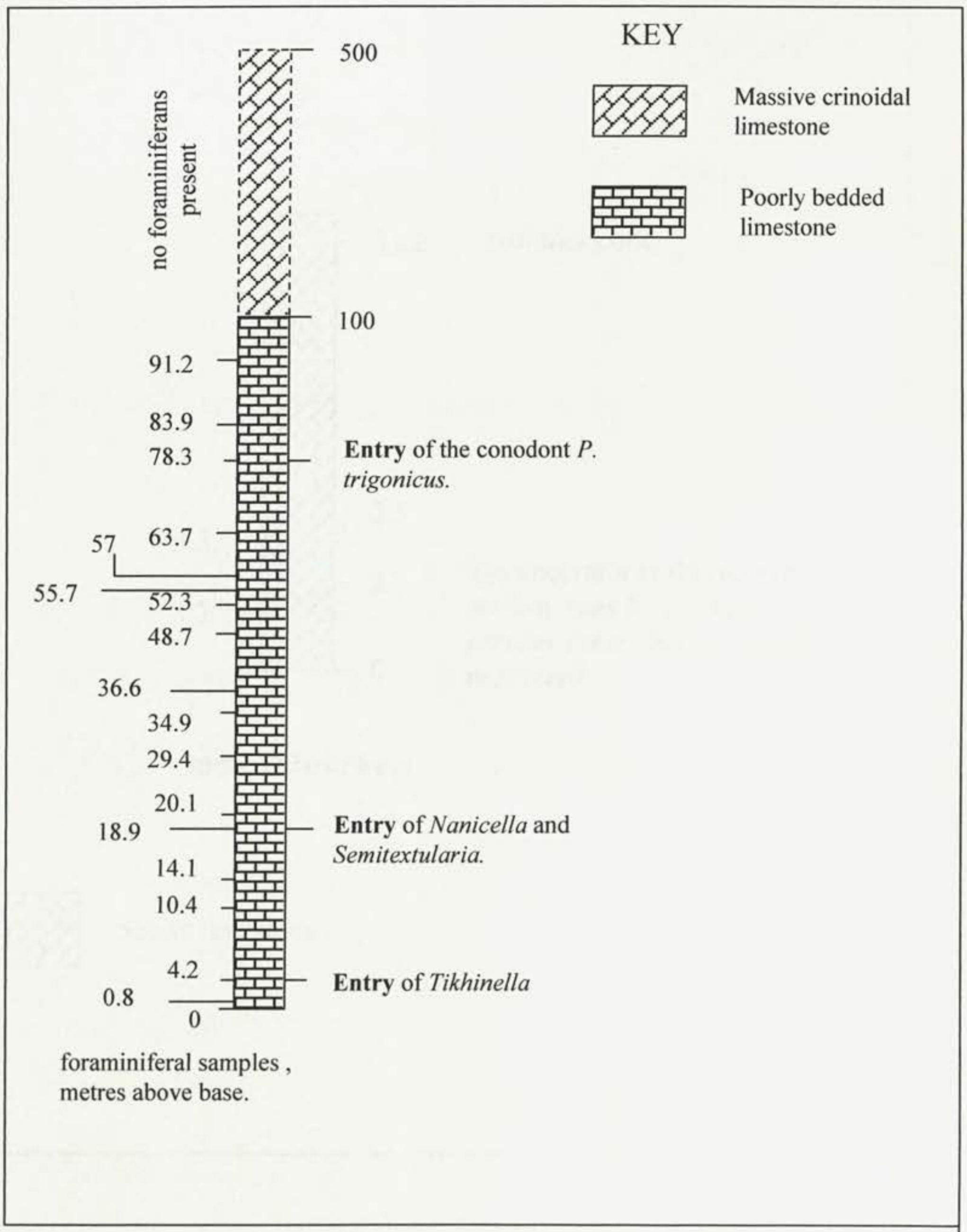


Figure 20. TIM stratigraphic section, showing productive foraminiferal samples and lithology.

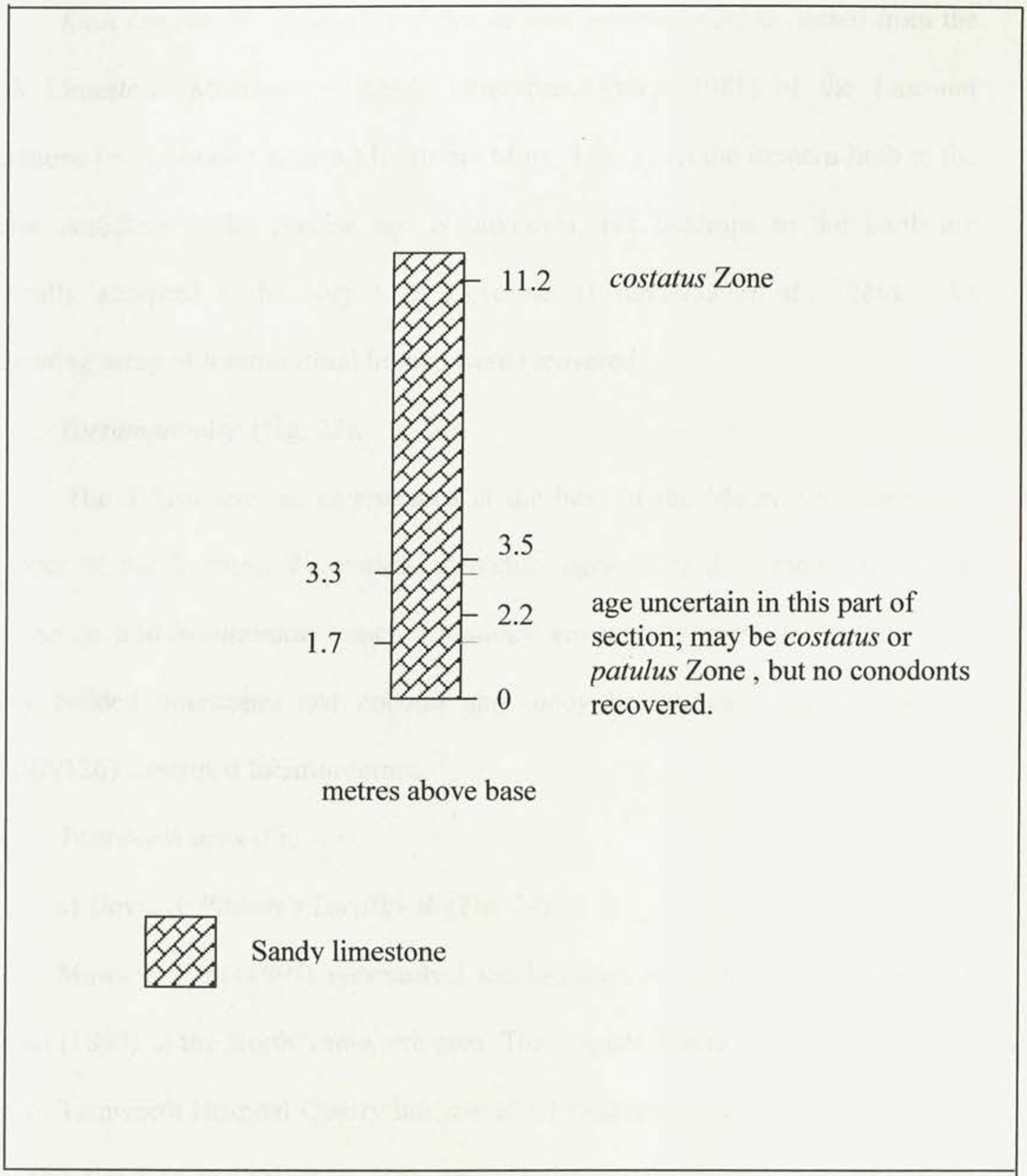


Figure 21. ISIS stratigraphic section showing productive foraminiferal samples, and lithology. For abbreviations used see p. xviii

Kiah Limestone. A small number of spot samples were collected from the Kiah Limestone Member (= Borah Limestone; Mory, 1981) of the Lincount Mudstone (= ?Goonoo Goonoo Mudstone; Mory, 1981), on the western limb of the Timor Anticline. The precise age is unknown, but outcrops to the north are generally accepted to be very Late Devonian (Lischmund *et al.*, 1986). An interesting array of foraminiferal linings were recovered.

Yarramanbully. (Fig. 22).

The YAR6 section, commenced at the base of the Moore Ck. Limestone Member of the Yarrimie Formation. Conodont ages show it to range from mid-*costatus* to mid-*hemiansatus* zones. Lithology varies from massive limestones to thinly bedded limestones and nodular and sandy limestones. Only one sample (YAR6/126) contained foraminiferans.

Tamworth area (Fig. 15).

a) *David & Pitman's Locality B.* (Fig. 24).

Mawson *et al.*(1997) reexamined the localities of T.W.E. David and E.F. Pitman (1899) in the North Tamworth area. They equate David & Pitman's locality B with Tamworth Hospital Quarry horizon HQ 1 (Mawson *et al.* 1997, p. 239) but with HQ 2 and 2A in Table 2 (p. 245). Their investigations showed that, apart from horizon HQ 0, all other limestones in the area were allochthonous, being olistoliths of Moore Creek Limestone redeposited during deposition of the Yarrimie Formation, with conodont ages ranging from Eifelian to Late Givetian. Thus the conodont age is not precise. The calcareous foraminiferan, *Semitextularia thomasi*, which is present in the fauna, is only known to occur in the Eifelian *costatus* Zone

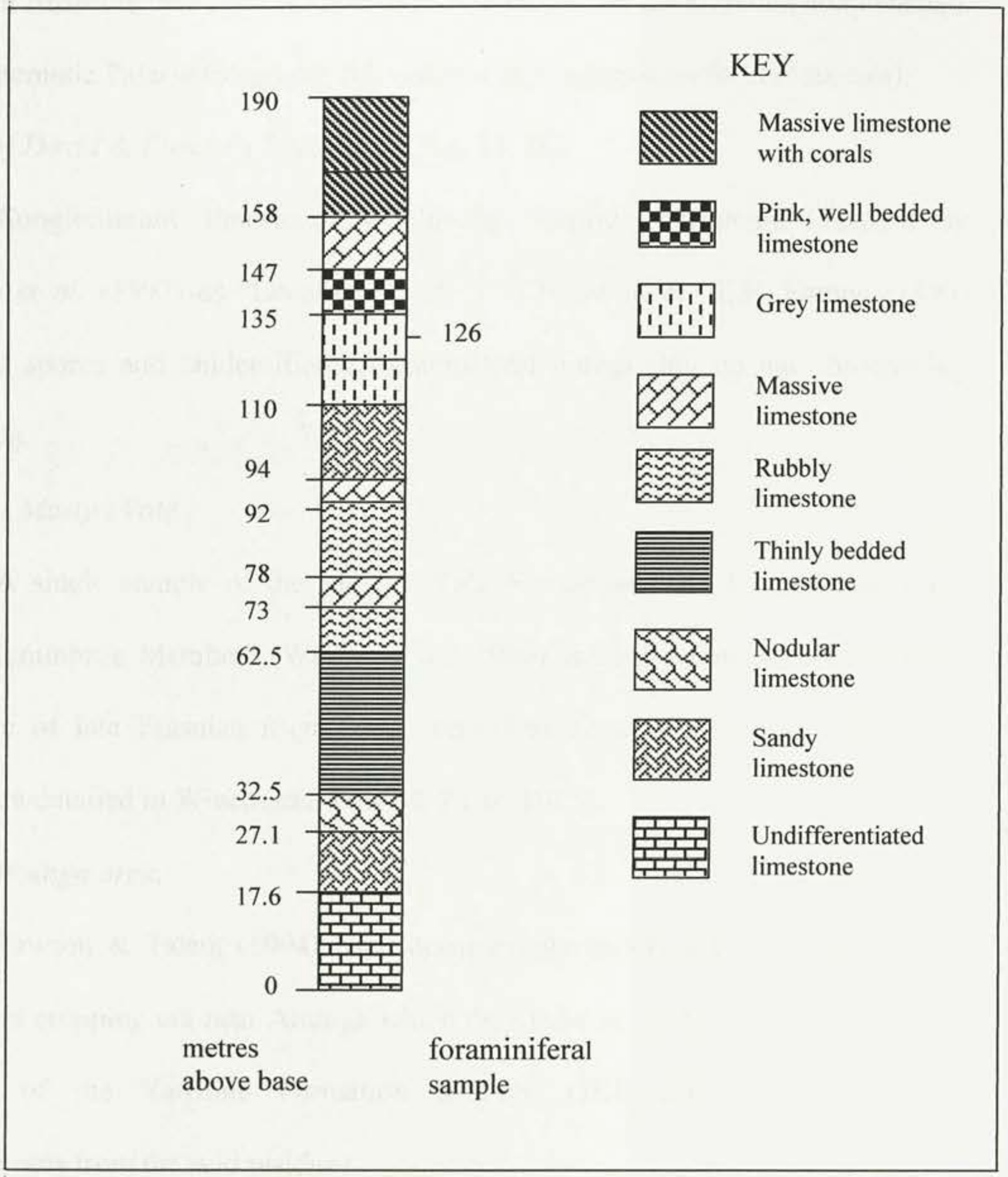


Figure 22. YAR/6 stratigraphic section, showing productive foraminiferal samples and lithology.

in eastern Australia, but overseas it is known to range into the Givetian and Frasnian. (See Systematic Palaeontology for full references to age ranges for this species).

b) David & Pitman's Locality 8. (Fig. 24, 26).

Conglomeratic limestones within the Yarrimie Formation identifed by Mawson *et al.* (1997) as "Locality 8" of T.W.E David & E.F. Pitman (1899) produced spores and unidentifiable foraminiferal linings, but no age-constraining conodonts.

c) Mostyn Vale.

A single sample of the Mostyn Vale Formation from L7 just below the "Bulga Ignimbrite Member" (Wright *et al.*, 1990) yielded a conodont assemblage indicative of late Frasnian *linguiformis* conodont Zone. Chitinozoans from this sample are detailed in Winchester-Seeto & Paris (1995).

Attunga area.

Mawson & Talent (1994) have discussed the stratigraphy and ages of the limestones cropping out near Attunga which they refer to the Moore Ck. Limestone Member of the Yarrimie Formation Sections OKE and NCCQ produced foraminiferans from the acid residues.

a) OKE section. (Figs 23, 27)

A section was measured through the Lower Yarrimie and into Moore Creek Limestone, in the old kiln excavation west of DMM Quarry, Attunga (Mawson & Talent, 1994). Basal horizons of the OKE section have been dated as *costatus* Zone; at 18.3 m above base conodonts indicate the horizon is not older than *australis* Zone and at 18.4 m conodonts indicate an age no younger than *kockelianus* Zone. The

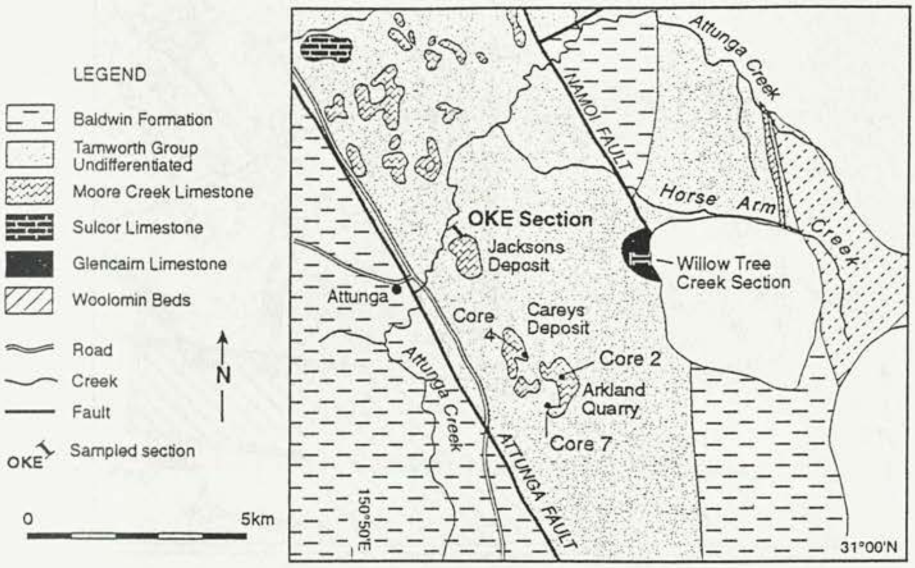


Figure 23. Location and geological map of the OKE sample site, Attunga area, N.S.W. For abbreviations used see p. viii

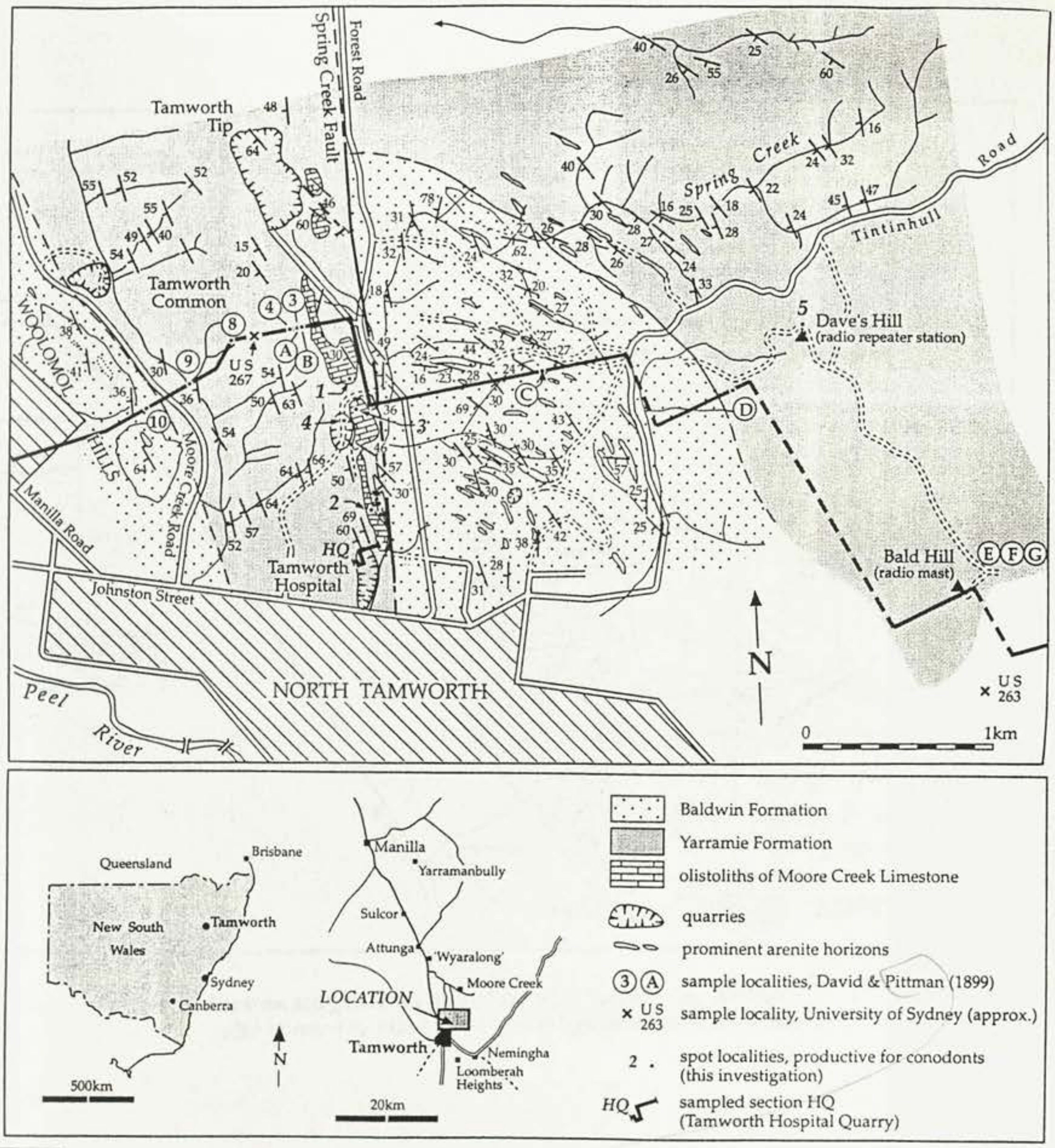


Figure 24. Location and geological map of the Attunga region, showing THQ (David & Pitman B) sample site. (after Mawson *et al.* 1997). For abbreviations used see p. viii

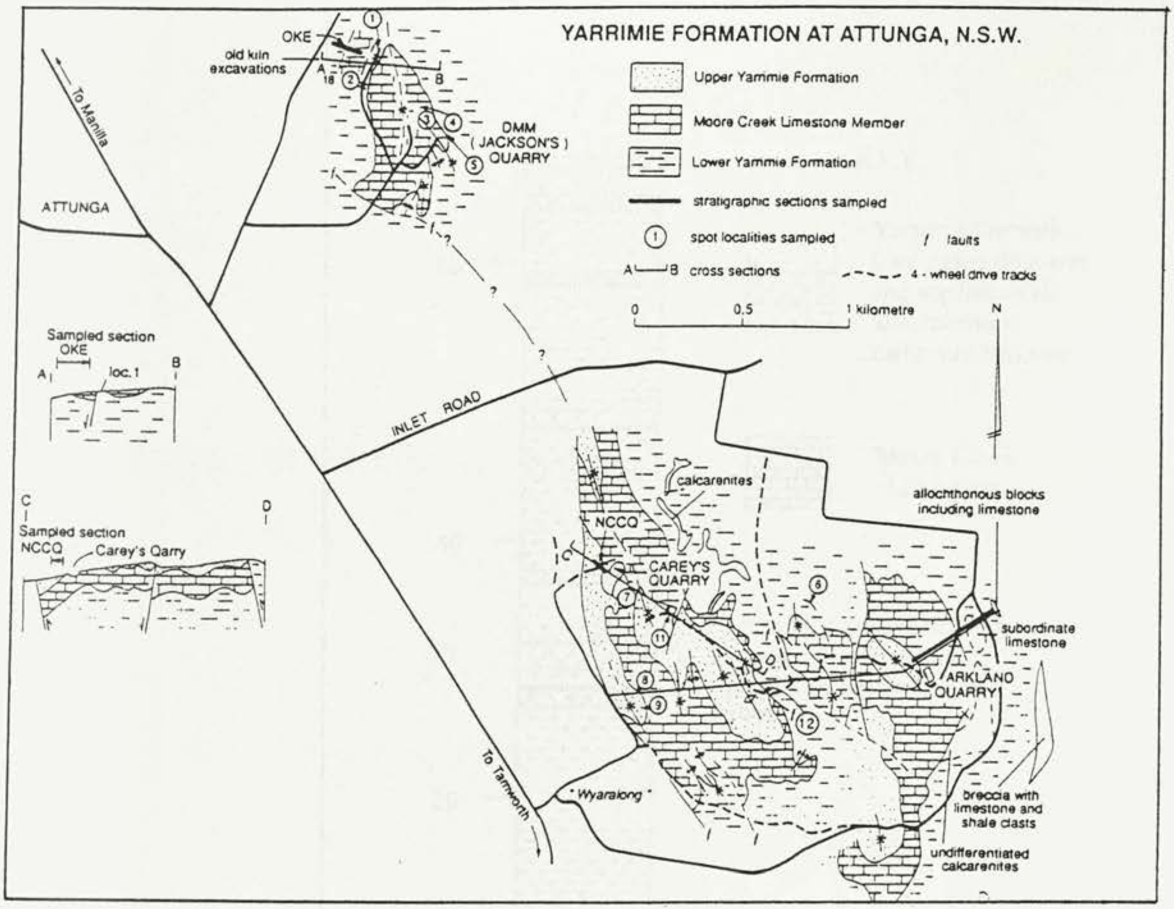


Figure 25. Location and geological map of the NCCQ sample site, Attunga area, N.S.W. (after Mawson & Talent 1994). For abbreviations used see p. viii

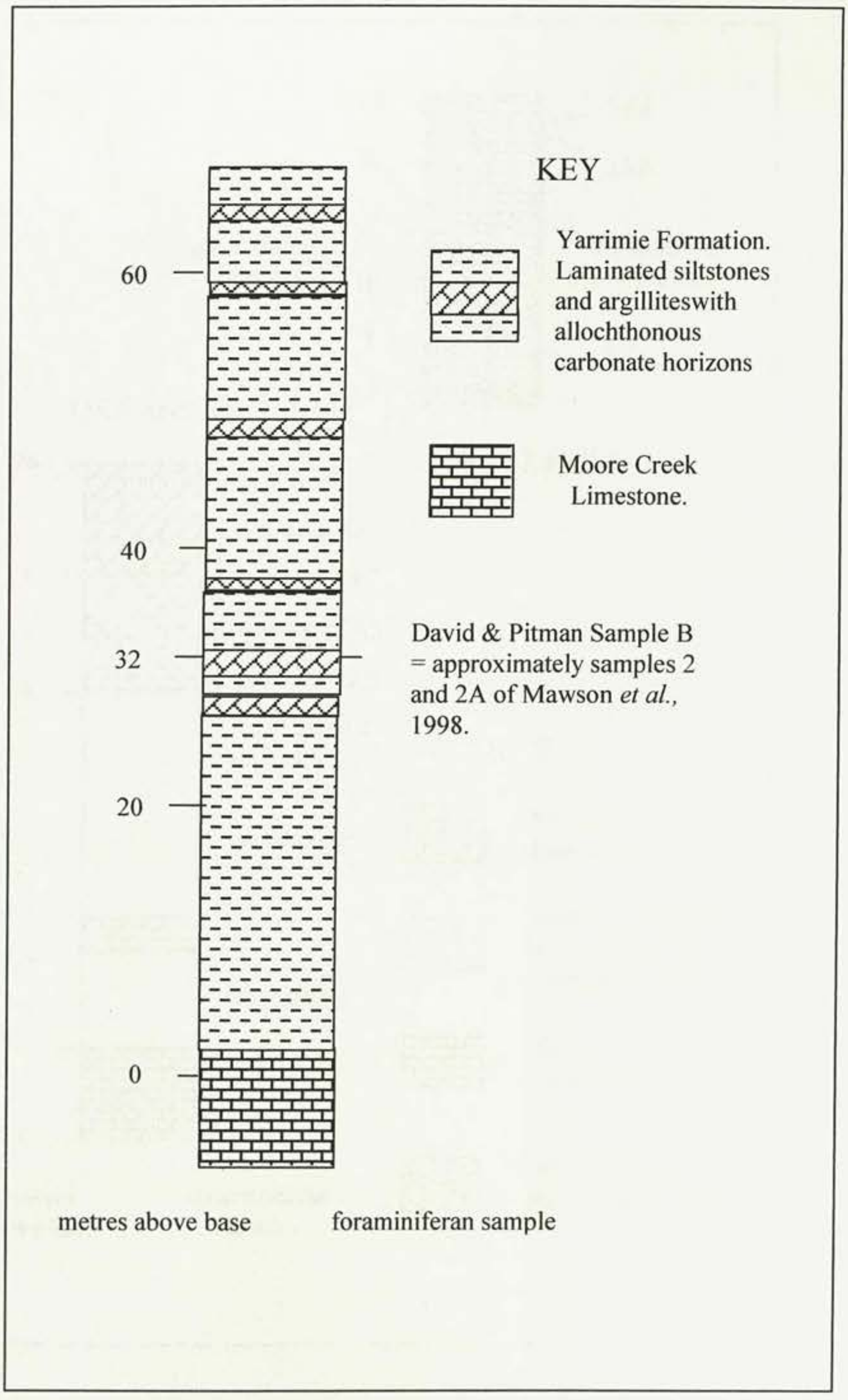


Figure 26. Stratigraphic column for THQ section showing the position of David & Pitman's B sample and lithology.

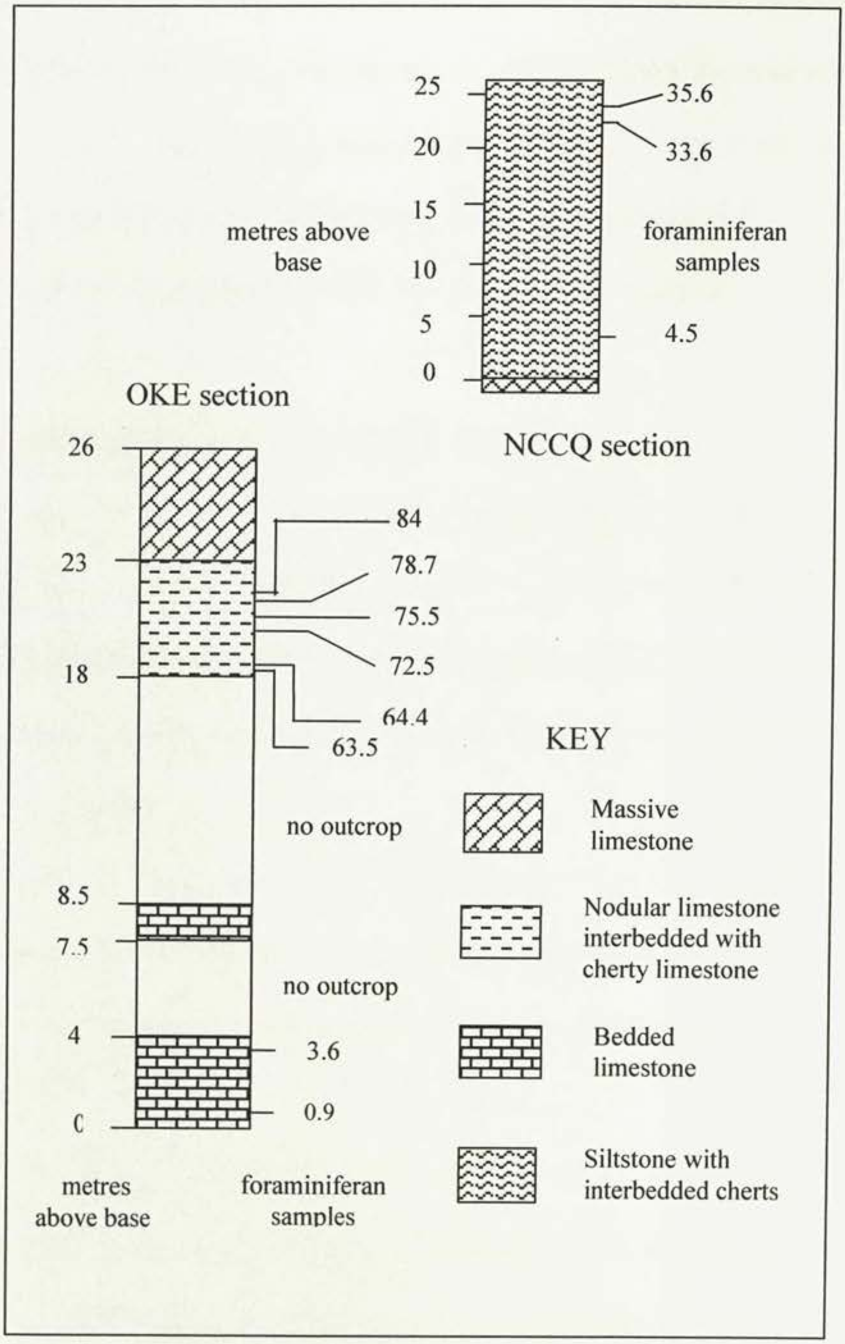


Figure 27. OKE and NCCQ stratigraphic sections showing productive foraminiferan samples and lithology.

stratigraphically youngest bed sampled (102.3 m) contained *Bipennatus bipennatus bipennatus* indicating that horizons up to this level could lie within the *australis* to Middle - *varcus* zones. Organic walled microfossils including spores, scolecodonts and foraminiferal linings were recovered from 4 out of 32 samples (OKE 0.9, 83.5, 100, 120m), spanning the interval *costatus* to *varcus* zones (Mawson & Talent, 1994).

b) Carey's Quarry (NCCQ). (Figs 25, 27).

Samples from a small section through strata overlying the limestone at Wyaralong (=Moore Creek Limestone Member; Mawson & Talent, 1994) yielded a few unidentifable foraminiferal linings. The strata from the NCCQ section were interpreted to be *kockelianus-ensensis* conodont zones by Mawson & Talent (1994).

c) Jacksons Deposit.

A number of spot samples from the DMM Quarry, Attunga, in the Moore Creek Limestone yielded scolecodonts and unidentifable foraminiferal linings. Studies by Mawson & Talent (1994) determined the *australis* conodont Zone at one spot locality within the limestone.

d) Yarrimie below Jacksons Deposit.

A single spot sample from the lower Yarrimie Formation, stratigraphically below Jacksons Deposit, yielded foraminiferal linings. Conodonts from this vicinity suggest an age of *costatus-australis* conodont zones (Mawson & Talent, 1994).

e) Warrawilla.

Klyza (1995) identified an occurrence of Moore Creek Limestone, 4.5km east of Attunga. Conodonts suggest an age spanning the *australis- hemiansatus* conodont zones (Klyza, 1995; Mawson & Talent, 1998; Mawson *et al.*, 1997). Unidentifiable foraminiferal linings were found in one sample and what may be algal or fungal material occurred in several beds near the top of the section.

f) Cores from the Moore Creek Limestone at Wyaralong.

A series of borecores through the limestone at Wyaralong (=Moore Creek Limestone Member, Mawson & Talent, 1994), in the vicinity of Arkland Quarry on "Wyaralong Station" southeast of Attunga were described Pohler & Herbert (1993) and investigated for organic walled microfossils. Samples yielding organic walled microfossils equate to the "nodular limestone" of Pohler & Herbert (1993), especially from cores 2 and 7 (19 samples from core 2 from depths between 50 and 95m). There were also some productive spot samples from cores 4 and 59. Core 2 parallels the WY section sampled by Mawson & Talent (1994), and replicates the interval of WY labelled as "nodular limestone interbedded with cherty siltstone" (p. 40), which commences within the *costatus* conodont Zone and extends into the *kockelianus*-?post-*kockelianus* zones (Mawson & Talent, 1998; Mawson *et al.*, 1997). The cores were, in general, quite productive, yielding chitinozoan fragments (DDH2 62.1m, 73m; DDH4 28m, 49.7m), numerous spores (from 12 samples), scolecodonts and foraminiferal linings.

Nundle area.

a) Copes Creek.

A small number of spot samples of cherts within the Pipe Clay Creek Formation at Copes Creek were processed .These samples repeated those collected by Stewart (1995), who found paraconodonts, suggesting an age of Middle to early

Late Cambrian. Abundant, very small ?scolecodonts were recovered from two samples.

b) Upper Barnard River.

Several spot samples were collected, and a small section was measured on the Upper Barnard River, above the base of the Silver Gully Formation, near Chittick, 55 km SE of Tamworth (Mawson *et al.*, 1995). Mawson & Talent (1998) assign this interval to early *patulus* conodont Zone. (see Mawson *et al.*, 1995 for detailed map of location).

c) Chaffey Island.

Several allochthonous blocks within the Bog Hole Formation on an island in the Chaffey Dam, 34 km SE of Tamworth (Mawson & Talent, 1998), yielded unidentifiable foraminiferal linings. Conodonts recovered from these blocks indicate an Emsian age, *serotinus* conodont Zone.

d) Loomberah Heights.

Spot samples from basal Silver Gully Formation, in Norman Close at Loomberah Heights (Mawson *et al.*, 1995) yielded unidentifiable foraminiferal linings. Mawson & Talent (1998) dated this horizon as possibly early *patulus* or *serotinus* conodont zones. (See Mawson *et al.*, 1995 for a detailed map of sample location.)

3. **Queensland.**

Martins Well.

A section through the Martins Well Limestone member of the Shield Creek Formation (MW) from the Broken River area of northern Queensland has been dated as spanning the *pesavis-sulcatus* conodont zones (Benson & Bear *in* Mawson *et al.* 1988); all foraminiferal linings were recovered from horizons dated as *sulcatus* Zone. This limestone is a shallow marine bioclastic calcarenite deposited on a broad, stable shelf (for further details see Winchester-Seeto, 1993; Wyatt & Jell, 1980).

4. **Tasmania.**

Point Hibbs.

Fossiliferous lime packstone characterises the Point Hibbs Limestone, from Sanctuary Bay, southwestern Tasmania (Carey & Berry, 1988). The Sanctuary Bay section spans the *sulcatus-kindlei* conodont zones (Philip & Pedder, 1968; Winchester-Seeto, unpub. data).

5. **Western Australia.**

Canning Basin.

A series of spot samples from the cores through strata in the Canning Basin, Western Australia, were investigated for palynomorphs. One sample from bore-core PD 166, depth 358.4m, from the Pillara Limestone, Unit 1 (BHP log units), yielded one species of foramininferal lining. The age is inferred to be middle Givetian, ?*varcus* conodont Zone (Colbath, 1990; Winchester-Seeto & Paris, 1995).

6. **Russia**.

Shanda (MSh).

The Shanda horizons occur on the southwestern margin of the Kuznetsk Basin in southern Siberia. Samples of the Middle Shanda beds (MSh) were collected from the southeastern wall of the Akaratchkino Quarry (section B-8313 of Yolkin *et al.*, 1988). The Middle Shanda strata are massive, light coloured limestones interbedded with minor shales and lie within the *serotinus* conodont Zone.

7. **Pakistan.**

Kuragh.

Situated within the Hindu Kush, the Kuragh spur is located in the Chitral region of northwest Pakistan. The Shogram Formation outcrops along the spur as 100m of limestones, sandstones and calcareous shales. Two samples from a section through this formation yielded palynomorphs; KG sample 1 is dated as ?Late *hermanni* conodont Zone, i.e. Late Givetian, and KG sample 17 is from the ?Late *falsiovalis* conodont Zone, i.e. Early Frasnian (Molloy, 1979; Molloy *et al.* 1997; Winchester-Seeto & Paris, 1995).

8. **France.**

La Serre.

Extensive biostratigraphic work has been carried out on two sections from the Serre Formation in the Montagne Noire, southern France (e.g. Klapper & Feist, 1985; Klapper, 1988; Winchester-Seeto & Paris, 1995). The oldest segment of the formation is represented by a trench through the lower part of the Serre Formation

(La Serre trench A; LSA) and has been dated as spanning the Middle-Late Devonian interval, i.e. *norrisi-falsiovalis* conodont Zone to *falsiovalis* conodont Zone. Trench C (LSC) extends across the Frasnian-Famennian boundary (?*linguiformis-triangularis* conodont zones).

3. STRATIGRAPHIC PALAEONTOLOGY

3.1 *Middle Palaeozoic Foraminiferal Faunas – A brief survey.*

The antecedents of known foraminifera appear to have belonged to Allogromiidae, regarded as the most primitive foraminiferal group (Hohenneger 1995). This group has a soft organic test (variously referred to as chitinous, pseudochitinous, mucropolysaccaride or glycosamminoglycan); members of the Allogromiidae exist in the present day oceans from shallow waters to abyssal depths (Gooday 1986a, b; Gooday & Haynes 1983; Burnett 1979).

Foraminifera with a mineralized test *i.e.* an agglutinated protective layer over the sarcode, first appeared as simple tubular forms in the type section for the Precambrian-Cambrian boundary (the Chapel Island Formation in South East Newfoundland (McIlroy *et al.* 1994) and forms similar to *Psammosphaera* sp. occur in the Atdabanian strata of Wales and Baltica (McIlroy *et al.* 1994). By the Middle Cambrian, foraminiferans had evolved significantly; Cherchi & Schroeder (1985) and Culver (1994) have described more complex forms from Sardinia (Cabitza Formation) and West Africa (Nandoumari Formation), respectively.

By the Ordovician and into the Silurian the agglutinated foraminiferans had diversified into some 30 genera (Loeblich & Tappan 1988a) consisting of taxa with varying shapes (*e.g.* discoidal, linear, spherical) and with uni-, bi- and multi-thalamous tests. The evolutionary trends shown in this period include

(i) changes from globular or irregular tests of finite growth to a tubular test for extended growth (*e.g. Hyperammina, Tolypammina*),

(ii) coiling of tubular tests with later growth (*e.g. Ammodiscus, Ammovertella*),

(iii) formation of multithalamous tests (*e.g. Webbinelloidea, Reophax, Reophanus*),

(iv) apertural modifications, including lips and necks (*e.g. Saccammina, Lagenammina, Thurammina*).

Loeblich & Tappan (1988a) have shown that the number of families increased from 10 in the Ordovician to 24 in the Middle Devonian and to 40 at the base of the Carboniferous but that there was comparatively little change in the number of genera from 30 in the Middle Silurian to 50 at the top of the Devonian. By Late Silurian there were about 30 genera in 20 families, all with agglutinated tests, and this number persisted with only minor changes (± 10 genera) through the early Devonian until the late Middle Devonian (Givetian) when there was a sudden jump to about 50 genera, incorporating eight new families due almost entirely to a great increase in genera belonging to the Fusulinina (Eifelian – 15 genera, Givetian – 37 genera; Loeblich & Tappan 1988a). This pulse of radiation was based on the ability acquired by foraminiferans to:

(i) develop septa *i.e.* form multichambered tests and so periodic growth, and

(ii) the evolution of new wall types *i.e.* calcareous microgranular wall (Parathuramminiidae and Endothyracea) and calcareous fibrous wall (Miliolina). This radiation of calcareous forms could well be due to increases in available carbonate content in the oceans due to loss of phosphates which are carbonate inhibitors (Martin 1995, 1996; Simkiss 1964, 1977).

In the Devonian we first see good evidence for two faunal types of foraminiferans – a shallow water limestone fauna and a deeper muddy fauna (Boesma 1978). It is considered that during the first part of the Palaeozoic, testate foraminiferans inhabited shallow marine seas (?epicontinental) as there is little record of deeper water Palaeozoic sediments and foraminifera are not common in deeper water sediments until the Jurassic (Boersma 1978). Ecologically little is known about the faunas of the Cambrian, Ordovician or Silurian due to the paucity of faunas and lack of studies based on these time periods. McClellan (1966, 1973) made what is probably the first attempt to address the problem in a study of the Silurian Waldron Shale fauna. He suggested that thick test, attached forms were indicative of areas of stronger wave action and the free forms with tubular or discoidal tests indicated more protected areas. Little advance on this simple senario has been made. Worthy of consideration is the premise that simple globular forms (*e.g. Sorosphaera, Psammosphaera*) could have been pelagic as these forms are often frequently found when other attached forms are not present. By the Devonian both shallow, carbonate facies and deeper basinal facies foraminiferan faunas are known, each with its own restricted fauna (Bell 1996; Boersma 1978; McClellan 1973). This development may be due to the increased salinity and the well aerated nutrient rich environment on platforms (Kaźmierczak *et al.* 1985; Kalvoda 1986) compared to the deeper basins which contained a significant volume of dysoxic to anoxic waters in the lower surface non-wind mixed layers (Berry & Wilde 1978; Berry *et al.* 1990).

It is generally accepted that the placement of early Palaeozoic foraminiferans into genera is based entirely on external morphological similarities with present day (or post – Palaeozoic) genera. This may be totally misleading and could lead to difficulties in palaeo-environmental interpretation when based on the foraminiferan fauna compared with other faunal entities. For example, in Summerson's (1958) study of the agglutinated foraminifera of the Middle Devonian of Ohio, a discrepancy between foraminiferal and other faunal elements was identified; Summerson suggested that these interpretative differences could be due to:

(i) too broad a taxonomy and the need to separate the Devonian and Recent foraminifera,

(ii) changes in the environmental conditions required by agglutinated foraminifera since Devonian times, and

(iii) a greater tolerance in living foraminiferans.

To these can be added a refugia factor: for example, present day deep water Astrorhizidae faunas are a refugia fauna displaced from shallower water by more ecologically suited calcareous forms.

Restricting ourselves to a survey of Siluro-Devonian researches on agglutinated foraminiferans a brief survey of regional areas is presented. In a series of papers Toomey (1961, 1963, 1965, 1966) and Toomey & Mamet (1967, 1968, 1969, 1970) compiled an annotated bibliography of pre-Carboniferous non-fusilinid foraminiferal literature, the main approach here therefore is to review the post-1970 literature.

Africa: There appears to be only one paper concerned with Early Devonian foraminiferans in North Africa. Vanchard & Massa (1989) discuss the occurrence of the calcareous foraminiferan *Nanicella* from the ?Emsian and Frasnian of two bore cores in Southern Tunisia. Their record of *Nanicella* from the ?Emsian is the oldest record of this genus but the dating of the cores is based only on stratigraphic inference (see Systematic Taxonomy section).

Australia: see Introduction.

Austria: Kristan-Tollmann (1971a) has discussed an agglutinated Silurian fauna from the Austrian Alps, detailing the genera *Psammosphaera, Sorosphaera, Hemisphaerammina, Ammodiscus, Lituotuba, Weikkoella* and three new genera *Scyphocodon, Cellonia* and *Nephrosphaera*. She has revised (Kristan-Tollmann 1971b) the early Palaeozoic species within the genus *Sorosphaera.* In this revision, using the arrangement of the chambers (planar or agglomerate) she found that five species occur – *tricella* Moreman, *bicella* Dunn, *confusa* Brady, *subconfusa* Dunn and *papilla* Gutschick & Treckman. However I have found that the distinguishing features she used cannot be easily applied to the eastern Australian faunas (see Systematic Palaeontology).

Baltic: Franzén (1974) has discussed the epizoan malformations on crinoid stems from the Silurian of Gotland and found that attached foraminiferans with agglutinated siliceous tests are associated with the stem pits on the crinoids. She stated that the specimens found resembled the genera *Psammosphaera* and *Saccammina* but made no further comparisions.

Burma: Toomey (1968), in an abstract, has briefly described an Eifelian foraminiferan fauna from Padaukpin, Northern Shan States, Burma. The fauna came from a formic acid residue of limestone and contained *Minammodytes* sp., *Hyperammina?*-like sp., *Hemisphaerammina* sp. cf. *H. bradyi, Metamorphina* sp. cf. *M. tholus, Thurammina*?-like sp., *Nanicella* sp. and *Semitextularia* sp. cf. *S. thomasi.*

China: Literature on the Chinese early Palaeozoic foraminiferan faunas (non-fusulinid) has been difficult to access. A search using GEOREF produced a number of papers but only two were available. Lin & Hao (1982) describe a late Middle Devonian fauna of parathuramminids and *Paratikhinella, Earlandia, Nodosaria* and *Geinitzina* from the Dongganling Formation in central Guangxi and the Qiziqiao Formation in southern Hunan. Wang (1988) has described a varied parathuramminid fauna from the Nanbiancien region, Guilin, which is most likely of Late Devonian to early Carboniferous age. The listed faunas in the various other papers, whilst seemingly abundant, consisted of minor saccamminids (*Lagenammina*) and abundant parathuramminid genera.

England: Silurian organic-walled and agglutinate- walled foraminiferans have been described from the Wenlock Stage near Dudley, Worcestershire (Eisenack 1977, 1978). He described *Archaeochitina tubifera, Archaeochitosa lobosa, A. clausa* and

Blastammina polymorpha. More recently Mabillard & Aldridge (1982) have described an agglutinated fauna from the Llandovery/Wenlock boundary beds in Shropshire, including the genera *Rhabdammina, Hyperammina, Psammosphaera, Lagenammina, Thurammina, Hemisphaerammina, Webbinelloidea, Ammodiscus, Turritellella, Lituotuba* and *?Astrorhiza.*

Germany: Since 1969 a number of papers have appeared describing some of the German Ordovician to Devonian foraminiferans faunas; these deal with small regional areas.

Riegraf & Niemeyer (1996) have described an Ordovician (Llanvirnium) fauna from oxygen-depleted graptolite shales from the Sauerland; this fauna contains the genera *Bathysiphon, Amphitremoida, Thurammina, ?Raibosammina* and *?Thekammina.*

Langer (1969) has described an extensive agglutinated fauna (17 genera, 32 species) from the uppermost ~~Silurian~~ Ordovician (Ashgill), Silurian (Valent-Ludlow) and uppermost Devonian limestones from the Carnic Alps.

Foraminiferans and other microfossils extracted from Devonian limestones of the Eifel Basin (using hydrochloric acid digestion) have been described by Pichler (1971). Foraminiferans were present in the form of organic linings (*Archaeochitosa, Blastammina, Mesammina*), as agglutinated forms (*Psammosphaera, Saccammina, Reophax, Semitextularia*), or as pyrite steinkerns (cf. *Rotalia* cf. *Nodosaria*). The foraminiferan *Semitextularia* sp. indet. is recorded from the Late Emsian, Eifelian and Early Givetian.

Middle Devonian (Givetian) foraminiferans (*Webbinelloidea beuthi, Saccorhina trivirgulina*) from several localities in West Germany have been described by Langer (1991). These were associated with a charophyte f[illegible].

Givetian parathuramminids from the Sauerland have been described from thin sections by Flügel & Hötzl (1971), who found the fauna to be very similar to that of the Late Devonian of Russia.

A large silicified fauna of Fammenian age (upper *costatus* Zone = *expansa-praesulcata* Conodont zones) from the Woklum Formation, obtained using formic acid, has been described by Eickhoff (1970). It contains agglutinated genera *Hyperammina, Psammosphaera, Thurammina, Webbinelloidea, Tolypammina* and calcareous genera *Paratikhinella, Moravammina* and *Septatournayella.*

Poland: There are several recent publications on Polish Devonian foraminiferans faunas. Malec (1984a, b) and Malec & Studencki (1988) have discussed the Early Eifelian faunas from the Góry Świętokrzyski Mountains, western Poland. Malec (1992) described the agglutinated fauna from the same area and distinguished five assemblages from the deposits representing the boundary beds of the *patulus/partitus* conodont zones. These assemblages are diagnosed principally on the different morphotypes (*i.e.* unilocular or multilocular forms) of *Webbinelloidea similis* Stewart & Lampe.

Olempska (1983) described an Late Devonian (Fammenian, *expansa-praesulcata* conodont zones) fauna of principally agglutinated species of the genera *Hyperammina, Psammosphaera* and *Thurammina* but with rare calcareous forms belonging to

Paratikhinella, Septatournayella and *?Moravammina* also from the Góry Świętokrzyskie Mountains.

Kaźmierczak (1976) suggested that some of the parathuramminid foraminiferans could be better referred to the Devonian volvolacean alga *Eovolvox silesiensis*.

Racki & Soboń-Podgórska (1993), working on material from the Góry Świętokrzyski Mts., have shown that sections of irregular objects may be described under several different names and have suggested that some of the Late Devonian Parathuramminiidae, which make up a large section of the described faunas, all described from thin sections, may be better considered as algal rather than foraminiferan. A small calcareous fauna of *Semitextularia thomasi, S. oscoliensis, Nanicella tchernyshevae, N.* sp. A, *N.* sp. B, *N.* sp. C, *Tikhinella fringa, Eonodosaria evlanensis, E. solida, E. stalinogorski, Eogeinitzina rara,* and *E. alta* described by them is indicative of a Givetian to Frasnian age.

Russia: Silurian–Devonian faunas have been extensively documented and an excellent summary is given in Poyarkov (1979) who gives details of stratigraphic ranges of most of the families and genera, and discusses evolutionary trends and speciation within many genera.

Much of the Russian work has been based on thin-section studies so it is difficult to compare their material with complete specimens. Sabirov (1978) and Kotlyar (1982) have described faunas (parathuramminids) from Tadzhikistan and the Ukraine, respectively.

The systematic and phylogenetic positions of the Nodosariida, Hemigordiopsida and the Hormosinida have been discussed by Rauzer-Chernousova (1992), Vdovenko et al. (1993), Pronina (1994) and Rauzer-Chernousova & Reytlinger (1986) respectively.

"Microforaminifera" have been described by Chuvashov & Djupina (1992) in palynological preparations (HF treated samples) of material from the Upper Palaeozoic of the Bisert region west of Ekaterinberg (western Urals). These small (10-20 times smaller than related foraminiferans) had either only an organic wall or what the authors considered to be a secreted primary wall which had been replaced by silica. They considered the "microforaminiferans" to be confined to sediments deposited under unfavourable conditions for other 'normal' foraminiferans.

Sardinia: A Late Silurian-Early Devonian agglutinate fauna has been described by Gnoli & Serpagli (1985) from the Fluminese region of Sardinia. They describe *Psammosphaera cava, Tolypammina devonica, T. bransoni* and *?Webbinelloidea* sp. Numerous phosphatic moulds also recovered were suggested to be foraminiferal in origin but whilst some undoubtedly are, others could more likely be coprolitic in nature.

United States of America: Most of our knowledge of early Palaeozoic foraminiferans and their distributions have come from studies on American faunas. In the 1930's a number of papers appeared, all descriptive, which laid the basis for most later determinations and discussion of their evolution. From 1939 to 1958 a trickle of taxonomic papers appeared, usually just reporting faunas from restricted areas of Silurian and Devonian in Ohio, Indiana and Oklahoma. Little regional stratigraphic correlation was attempted in these papers. However in the 1960's research, whilst still taxonomic, began to use the faunas for stratigraphic correlations on continent-sized areas and to suggest that the foraminiferal faunas could be useful in formulating a biostratigraphic zonation scheme for the Devonian and Early Carboniferous once taxonomic confusions had been overcome (Conkin & Conkin 1960, 1961, 1964a, b, 1967, 1970, 1977, 1979, 1982; Conkin *et al.* 1970,1979; Browne & Schott 1963; Mound 1961, 1968; McClellan 1966, 1972).

3.2 *The Present Study.*

(a) *General remarks.*

In broad terms, the faunas found can be divided into two groups – those from the Silurian to late Early Devonian (Wenlock to late Emsian) comprising agglutinated species with the first calcareous form appearing in the Emsian, and those from stratigraphically younger beds consisting of both agglutinated and calcareous forms with calcareous species predominating. With the establishment of the calcareous foraminiferans in the record, the number of species and of specimens of the agglutinated forms is greatly diminished. Whether this is a facies-caused change or an evolutionary effect caused by better suited calcareous foraminiferans being able to dominate the sedimentary environment is unclear, but it has been proposed that the agglutinated forms are basinal indicators and calcareous faunas are shelf (inner) indicators (Boersma 1978; Kalvoda 1986). However it cannot be as clearcut as this, for the associated faunas in early deposits seem to differ little from later ones so facies variations may not be the only answer.

The stratigraphic distribution of all the species reported in this research is given in Table 4. There are 19 families present represented by 44 genera (36 agglutinated, 8 calcareous), of which four - *Cylindrammina, Cystingarhiza, Patellammina* and *Vermiculammina*, have been proposed as new; and 100 species (88 agglutinated, 12 calcareous) of which 37 are newly erected. The new specific taxa include 6 species described from the inner organic wall linings (see Section 5). There are six species known as both 'normal' and organic linings and 14 species represented only by organic linings (Table 5).

Using the known eastern Australian occurrences and inferred ranges of the species (Table 4) some simple statistics can be derived. The number of species present within Stages varies from 10 in the Wenlock to 54 in the Emsian (Table 6); figures for the Pridoli and Givetian-Frasnian are not significant as sequences within these time ranges were not studied in detail. Of the 15 species occurring in the Silurian only six (36%; Table 7) cross the Silurian – Devonian boundary: *Psammosphaera cava, Sorosphaera tricella, Hemisphaerammina crassa, Thuramminoides sphaeroidalis, Thurammina foersteri* and *Tolypammina anguinea*. The percentage of species not surviving between Stages (Table 6) shows a range of values from a low of 30%, between the Lochkovian to Pragian, to a high of 86%, between the Emsian to Eifelian. There is a very small turn over of species at both the Lochkovian-Pragian and Pragian-Emsian boundaries but a significant faunal change at the Emsian-Eifelian boundary. The low species turn-over from the Lochkovian to Pragian and Pragian to Emsian are the lowest for any Stage-to-Stage and mirrors the known brachiopod generic global turnovers (Talent *et al.* 1993), who regard these values of turnover (about 25 %) as 'normal' but

Table 4. Stratigraphic range chart of the foraminiferan species found in this study.

Table 5

Species known as normal foraminiferans and as organic linings	Species known only as organic linings
Psammosphaera cava *Sorosphaera* sp. cf. *S. confusa* *Pelosina* sp. *Inauris tubulata* *Webbinelloidea similis* *Thuramminoides sphaeroidalis* *Thurammina subsphaerica* *Lagenammina talenti* *Tolypammina anguinea*	*Psammosphaera garraay* *Psammosphaera* sp. A *Psammosphaera* sp. B *Psammosphaera* sp.C *Psammosphaera* sp.D *Saccammina mea* *Saccammina wingarri* *Saccammina* sp. cf. *S. ampullacea* *Hemisphaerammina coolamon* *Thurammina mirka* *Thurammina pustulosa* *Amphitremoidea* sp. cf. *A. citroniformis* *Hyperammina* sp. cf. *H. sappingtonensis* *Reophanus proavitus*

Table 5. Species occurring as either normal foraminiferans and organic linings or as only organic linings.

Stage	Wenlock	Ludlow	Pridoli	Lochkov	Pragian	Emsian	Eifelian
Number of species	10	12	(6)	30	26	54	28
Species surviving to next Stage	6	6	(6)	21	17	10	12
% spp not surviving	40	50	(0)	30	36	**86**	**56**

Table 6: Numbers of species present in each Stage and the percentage change in the foraminiferal faunas across the various Stage boundaries.

	Silurian	Devonian
Number of species present	15	92
Number surviving the Sil-Dev boundary	6	
% species not surviving the Sil-Dev boundary	64	

Table 7: Number of species in each Epoch and the percentage change over the Silurian-Devonian boundary.

rates two to three times as large are considered 'abnormal'. For the Emsian to Eifelian turnover the large number of species restricted to the Emsian (86%) may be a reflection of facies differences in the sampled sequences. Most of the Emsian foraminiferans came from the Taravale Formation at Buchan and Bindi, V., which is a more pelagic deposit, as shown by its cephalopod and ammonite faunas (Teichert 1948, Teichert & Talent 1958), than the sequences sampled in the Eifelian time range which were mainly shallow water limestones from the Tamworth district. On the above criterion though, the turnover value at the Emsian to Eifelian may be quite significant. It is in the Eifelian that the calcareous foraminiferans become dominant in the fauna and the large change in faunal composition at this boundary may reflect different ecological parameters existing. Kalvoda (1986) has proposed that radiations (and extinctions) of calcareous foraminiferans are closely linked to global changes in carbonate sedimentation which are linked to aridity/humidity oscillations and Walker & Diehl (1985) have theorized that early Palaeozoic carbonate shelf communities are better preserved than in other environments because the fossils were more readily incorporated into the sediment by early-forming cements. Increase in calcareous foraminiferans can be explained by the ease of test construction as carbonate saturation of the seas increased and the proportion of phosphate ions (PO_4^{3-}) present decreased (Martin 1996) as it is known that high levels of phosphate ions inhibit calcification (Simkiss 1964, 1977).

(b) *Normal foraminiferans*:

Silurian Faunas.

Wenlock –Ludlow; *ranuliformis – crispa* zones.

Two sections were studied in this time zone – Borenore (WERR, DSC, ERC) and Cowombat (COW). The fauna consisted of 16 species (Tables 8, 9) with only two species common to both the Wenlock and Ludlow sites (*Stomasphaera globosa, Psammosphaera cava*). Distinctive forms in the Borenore samples include *Sorosphaera tricella, Hyperammina leptalea* n. sp., *'Lituotuba' exserta*, *Rhabdammina* sp.A and *Rhabdammina* sp.B. At Cowombat distinctive species are *Hyperammina teres, Saccammina cyclops* and *Trepeilopsis recurvidens.* Other faunal components are either rare or long ranging (*e.g. Psammosphaera cava*) and found throughout almost all the samples studied.

Late Silurian –Early Devonian.

(a) Pridoli – Lochkovian; *eosteinhornensis –delta* zones.

From the Windellama Limestone sections 15 species were found (Table 10). Restricted to these samples were *Hemisphaerammina crassa, Psammosphaera aspera, Ammovolumina bostryx* n. sp., *Serpenulina uralica* , *S. aulax* n. sp. and *Bathysiphon* sp. The two genera, *Ammovolummina* and *Serpenulina*, have previously been reported only from Russia (Upper Ludlow, *marginalis* horizon, eastern slopes of the northern Urals).

(b)Early Devonian.

(i)Lochkovian – Pragian boundary; *pesavis – sulcatus* zones.

Five localities from within this time zone (MUNG, RUN, GCR, MW and DDH 1) yielded a large fauna of organic linings (20 species) but from only two were normal

Table 8

	DSC	ERC		WERR		
	230	6	7	13	16.2	18.3
Rhabdammina sp.A				x		
Rhabdammina sp. B				x		
Sorosphaera tricella	x	x			x	
Stomasphaera globosa						x
Psammosphaera cava	x					
Hemisphaerammina crassa	x					
Hyperammina leptalea	x					
Lituotuba exserta			x		x	
Thurammina foersteri	x					
Thuramminoides sphaeroidalis						x

Table 8. Distribution of foraminiferan species in samples from Borenore, NSW.

Table 9

Hyperammina teres	*Stomasphaera globosa*
Rhizammina sp.	*Sagenina filiformis*
Psammosphaera cava	*Tolypammina anguinea*
Saccammina cyclops	*Trepeilopsis recurvidens*

Table 9. Foraminiferan species found in COW samples.

Table 10

	S 4	Q 7	QU 23	QU 166/7	QU 209	QU 212	QU 214	QU 217	QU 228	QU 233
Astrorhiza triquetra					x					
Rhabdammina sp.						x	x			
Bathysiphon sp.				x						
Psammosphaera cava				x		x				x
P. aspera										x
Sorosphaera confusa	x		x	x	x	x	x		x	x
S. tricella										x
Stegnammina cylindrica					x					x
Stomasphaera cyclops					x					x
Hemisphaerammina crassa			x							x
Tolypammina anguinea				x				x	x	
Ammovertella sp.				x						
Ammovolummina bostryx		x								
Serpenulina aulax		x								
S. uralica		x		x						x

Table 10. Distribution of foraminiferan species in samples from Windellama, NSW.

foraminiferans recovered (MUNG, RUN) (6 species). The organic linings include the new species *Hemisphaerammina coolamon, Psammosphaera garray, Reophanus proavitus, Saccammina mea, Saccammina wingarri* and *Thurammina mirrka.* The normal foraminiferans present were long ranging forms.

(ii) Pragian, *sulcatus – kindlei* zones.

Three sections were sampled in this time zone - BOO, Tyers, and Point Hibbs, and only organic linings were recovered. Three species were present: *Psammosphaera cava, Saccammina* sp. and *Hyperammina* sp. cf. *H. sappingtonensis.*

(iii)Emsian, *dehiscens – serotinus* zones.

Sections studied in this time range were from Buchan-Bindi, Victoria (OTRC, BON) (Table 11), Pigna Barney (PIG) (Table 12), Sulcor Limestone (SULC) (Table 13), Gelantipy Road (GEL) and Siberia (MSh, Middle Shanda beds). Normal foraminiferans were recovered from the first four localities and only organic linings from the last two sites.

The most prolific Early Devonian fauna is found in the Buchan Caves Limestone and Taravale Formation at Buchan and Bindi, Victoria (*dehiscens* to *serotinus* zones) and comprises 45 species in 26 genera (Bell 1996). There is evidence for facies dependence of some of the species as 2 species, *Cystingarhiza mawsonae* and *Lagenammina stilla,* were only found in the muddy facies species, 28 species were restricted to the limestone facies and 15 species had a cosmopolitan distribution (Bell 1996). Nevertheless certain species, common to OTRC and BON localities in Victoria

Table 11

	OTRC			BON								ORCQ	Ma	SALC		
	2	5	7	13-15	29-35	36-39	39-44	56-60.5	60.5-65	206	220-240	10-15	13	9	7	4
Astrorhiza triquetra			x										x	x		
A. constans				x								x		x	x	
A. sinus												x			x	
Cystingarhiza mawsonae													x	x		
C. tribracchia												x		x		
C. corona												x	x	x	x	
C. furca												x		x	x	x
Cylindrammina stolonifera						x						x		x	x	
Rhabdammina linearis				x									x		x	
R. proavita			x													
Saccorhiza surculus												x				
Hyperammina proboscis												x	x			
H. reflua		x	x			x						x				
H. sp.												x				
Psammosphaera cava	x		x													
Sorosphaera sp.cf. *confusa*	x	x	x													

	OTRC			BON								ORCQ	Ma	SALC		
	2	5	7	13-15	29-35	36-39	39-44	56-60.5	60.5-65	206	220/240	10-15	13	9	7	4
Stegnammina cylindrica	x															
Saccammina biosculata													x			
S. cumberlandiae						x										
Lagenammina spharica				x									x	x	x	
L. stilla													x			
L. talenti												x	x		x	
L. laxacolla						x							x	x	x	
L. ovata												x		x		
Stomasphaera cyclops											x					
Ordovicina eisenacki				x								x				
Pelosphaera grandaeva												x	x			
Thurammina echinata		x	x			x						x				
T. subsphaerica		x	x	x								x				
T. tributa							x	x								
T. foerstei												x				
T. zaramama									x							
Hemisphaerammina sp.			x													
Webbinelloidea crassus										x	x					
Metamorphina tholus				x												
Patellammina prona											x					
Keriammina prolata			x									x				
Tolypammina anguinea		x	x	x	x	x						x	x			
T. tantula				x	x	x						x				
Ammovertella calyx				x								x				
Lituotuba torquata			x	x												
L. helix		x														
Hormosina divitiae											x					
Reophax troca			x													
Thuramminoides sphaeroidalis	x	x	x									x	x		x	x

Table 11. Distribution of foraminiferan species from samples at Buchan and Bindi, V.

Table 12

	7	11	13	13.2	14	18	25	29	45	49
Psammosphaera cava	x		x	x	x	x	x			x
Sorosphaera sp. cf. *S confusa*		x						x		x
Stegnammina cylindrica						x			x	x
Thurammina subsphaerica						x				
Lagenammina stilla									x	x
Toylpammina anguinea	x	x	x	x	x	x	x			
Saccammina sp.							x			
Metamorphina tholus									x	
Webbinelloidea sp.									x	

Table 12. Distribution of foraminiferan species in samples fromEUR section, Eurimbla, N.S.W.

Table 14

	277	289.7	294	308	399
Bathysiphon sp.	x	x	x		
Stegnammina cylindrica	x		x	x	
Hyperammina sp.	x		x	x	?
Tikhinella forma A					x

Table 14. Distribution of foraminiferan species in samples from SULC section.

Table 13

	10.3	13.8	14.2	15.3	16.1
Cystingarhiza corona	x	x			
C. furca		x	x		
Cylindrammina sp.		x			
Rhabdammina linearis	x	x	x		
R. proavita		x			
Saccorhiza sp.	x				
Sorosphaera confusa			x		x
Stegnammina cylindrica	x	x		x	x
Hyperammina sp.		x			
Thurammina foersteri					x
Pelosphaera grandaeva			x		
Metamorphina tholus			x		
Lagenammina laxacolla	x			x	
Tolypammina sp.		x			

Table 13. Distribution of foraminiferan species in samples from PIG section, Pigna Barney, NSW.

and in samples from PIG in N.S.W., suggest a usefulness in correlation over many hundreds of kilometers; these include *Cystingarhiza corona, C. furca*, *Lagenammina laxacolla*, *Pelosina grandaeva*, *Rhabdammina proavita, R. linearis* and *Thurammina foersteri*.

In the topmost Sulcor Limestone (SULC 399.3; *serotinus* Zone) rare specimens of the genus *Tikhinella* (*Tikhinella* forma A) appear. This is the first documented occurrence of the calcareous walled foraminiferans previously thought to have originated in the Middle Devonian (Givetian).

(c) Middle Devonian. (Eifelian – Givetian; *?partitus –norrisi/falsiovalis* zones).

Although the first calcareous foraminiferan, *Tikhinella* forma A, occurs in the uppermost *serotinus* Zone, faunas from all the horizons in the Middle Devonian time range are dominated by calcareous walled species, often with no agglutinated species present. *Tikhinella* spp. are the first to appear and *Nanicella* and *Semitextularia thomasi* come in slightly higher in the sequence (TIM section, see fig. 20; Table 14). Also *Subbdelloidina spathula* n. sp., *Moravammina segmentata, Vermiculammina isis* n. gen. n. sp.and *Trochammina* sp. make their first appearances in the *costatus* conodont Zone. Accurate dating of this part of the lower horizons in the Timor section is difficult because diagnostic conodonts were absent, but *Nanicella* and *Semitextularia* are definitely dated to the *costatus* Zone (see Stratigraphy chapter).

The Eifelian – lower Givetian faunas are dominated by specimens of *Nanicella* and *Tikhinella* with smaller numbers of *Semitextularia* and *Vermiculammina* n. gen. *Tikhinella* is particularly common with five species species found in ISIS, YAR6, TIM sections and from the David & Pitman B locality (Tables 15, 16, 17). Agglutinated species are quite uncommon in these sections and consist in the main of long ranging species of genera such as *Sorosphaera, Stegnammina, Psammosphaera* and *Rhabdammina*.

(c) *Foraminiferal organic linings* (see also Section 5 of thesis):

Twenty-nine species of foraminiferal linings have been described from the Early-Late Devonian in Australia (Winchester-Seeto & Bell 1994, 1998 submitted; Bell & Winchester-Seeto 1998). Of these, six species are also present as normal foraminiferans. Thus by studing the linings, the number of known forms present is increased by about one-quarter overall. The majority of the foraminiferal linings were recovered from the Early Devonian sequences spanning the Lochkovian-Pragian boundary (*pesavis-sulcatus* Conodont zones) and from the Emsian-Frasnian (*serotinus*-linguiformis Conodont zones) sequences in the Tamworth area, NSW.

Our studies (TW-S, KNB) indicate that the organic linings of agglutinate foraminiferans are quite widespread both geographically and chronologically. Diverse faunas have been recovered from shallow marine environments such as limestones, marls and shales and in localities on three continents (see locality data). Thirteen known genera are present of which only two (*Hemisphaerammina* and *Tolypammina*) are of attached genera (the others having free tests) and 29 species – 10 of established species, 6 compared with known species, 7 new species and 6 left in open nomenclature because of lack of specimens. Tubular linings with thin and thick walls are present in many samples from a variety of localities, and may represent broken parts of various genera

Table 15

Sample numbers	0.8	4.2	14.1	18.9	20.1	22.7	29.2	36.6	48.7	50	52.3	57	63.7	68.6	78.3	83.9	91.2
Sorosphaera sp. cf. *S. confusa*								x	x			x					
Saccorhina trivirgulina	x		x	x		x		x					x		x		
Moravammina segmentata								x					x	x			
Tikhinella forma A		x			x		x		x		x	x	x		x	x	x
Tikhinella forma B		x		x		x	x	x	x	x	x	x	x	x	x	x	
Tikhinella forma C				x	x	x	x	x				x	x	x	x		x
Tikhinella forma D					x			x	x							x	
Lunucammina sp.		x					x	x	x	x		x	x	x		x	
Semitextularia thomasi				x								x	x	x			
Nanicella sp.			x	x		x		x	x	x		x	x	x		x	

Table 15. Distribution of foraminiferan species in samples from TIM section.

Table 16

	1.7	2.2	3.3	3.5	11.2
Moravammina segmentata		x		x	x
Vermiculammina isis		x			
Tikhinella forma A	x	x		x	x
Tikhinella forma B	x	x	x		
Tikhinella forma C		x	x	x	x
Tikhinella forma D	x	x		x	
Lunucammina sp.		x		x	x
Semitextularia thomasi		x		x	
Nanicella sp.		x	x	x	

Table 16. Distribution of foraminiferan species in samples from ISIS section.

Table 17

	63.4	64.4	72.5	75.5	78.7	84
Psammosphaera cava						x
Sorosphaera sp. cf. *S. confusa*				x		x
Hyperammina sp. cf. *H. devonica*	x	x	x			
Pelosina sp.					x	

Table 17. Distribution of foraminiferan species in samples from OKE section.

Table 18

Hyperammina sp. cf. *H. devonica*	*Tikhinella* forma C
Saccorhina trivirgulina	*Tikhinella* forma E
Paracaligella sp.	*Lunucammina* sp.
Tikhinella forma A	*Semitextularia thomasi*

Table 18. Foraminiferan species found in sample from David & Pitman B section (= THQ section).

such as *Hyperammina, Rhabdammina* or *Saccorhiza* or may even be Allogromiidae such as *Shepherdella*, but cannot be further determined and thus have been omitted from the faunal lists.

Most of the specimens are black indicating they are highly thermally mature, many are broken or compressed; this may have affected our recovery rates and introduced bias in the types of genera and species preserved. Comparable work in other parts of the world when undertaken on a wider suite of sediment types, will enable further analysis.

The surface of the organic wall is either smooth or shows varying degrees of reticulation *i.e.* raised ridges outlining smaller or larger smooth areas. These ridges, we believe, are indications of the outlines of the agglutinate material used in an outer wall but subsequently lost by either diagenesis or treatment. Specimens with smooth, unridged surfaces probably had either no agglutinated outer wall or one in which the various grains were sparse and perhaps only very weakly attached.

The predominance of sites with only foraminiferal linings is marked. This may be due to (a) possible procedural artefacts *i.e.* it may be easier to extract the linings than intact foraminiferans; (b) foraminiferal linings were more common than "normal" foraminiferans in the Palaeozoic and/or in some areas; (c) foraminiferal linings may be more easily preserved than intact forms. It should be considered that in Recent agglutinated foraminiferal species, the grains forming the outer test wall are held together by some type of cement: organic, calcareous or siliceous (Bender 1995). There is no reason to suppose that similar cements were not used in the Palaeozoic. As nothing is known about the lifetimes of these cements or the effects of diagenesis on them, it is possible that "normal" foraminiferans disintegrate over time. If this were so, the predominance of linings could be explained.

Genera can be subdivided into morphological groups (*i.e.* into species) based on characters such as shape, surface structure/s, wall thickness, number of apertures etc. – all of which have previously been accepted as specific characters for normal-sized foraminiferans. Table 19 lists the features used for specific separation.

(d) *Biostratigraphy of organic wall linings.*

Many of the species described herein, have a wide geographic spread, both as "normal" foraminiferans and as organic linings. Those found on two or more continents include *Inauris tubulata* (Kentucky, USA; Siberia andAustralia), *Saccammina mea* (Australia, Siberia and Kentucky, USA), *Thurammina pustulosa* (northern NSW and Texas, USA), *T.* sp. cf. *T. subsphaerica* (Australia and USA), *Thuramminoides sphaeroidalis* (Australia, USA and Germany), *Saccammina wingarri* (Canning Basin,Western Australia; northern NSW and France), *Psammosphaera cava* Moreman (Australia, North America, Great Britain, Austria and Sardinia), *Psammosphaera* sp. (Australia and Siberia), *Amphitremoidea* sp. cf. *A. citroniforma* Eisenack (Australia and Pakistan), *Lagenammina ovata* Bell (Australia and Pakistan), *Saccammina mea* n. sp. (Australia and Siberia), *Saccammina wingarri* n. sp. (Western Australia and southern France), *Webbinelloidea similis* Stewart & Lampe (Australia, Poland and the United States), and *Hyperammina* sp. cf. *H. sappingtonensis* (Australia and Siberia).

Some species, though found so far only in eastern Australia, occur in localities separated by up to1400 kilometers. These include: *Saccammina* sp. cf. *S. ampullacea*

Table 19

Genus	Criteria for species determination
Psammosphaera	size of test wall texture (smooth or reticulate)
Thurammina	number of apertures whether apertures are raised or flush with the surface
Saccammina	wall texture (smooth or reticulate) whether apertures are raised or flush with the surface
Hemisphaerammina	wall texture (smooth or reticulate) presence/absence of basal flange

Table 19. Criteria used in the determination of species within some genera of organic foraminiferal linings.

(central and northern NSW), *T. mirrka* (central and northern NSW), *Sorosphaera* sp. cf. *S. confusa* Brady, *Tolypammina tantula* Bell and *Saccammina* sp. found in central New South Wales and in Victoria; *Psammosphaera garraay* n. sp., *Saccammina mea* n. sp., *Thurammina* sp. cf. *T. subspherica* Moreman and *Hemisphaerammina collamon* n. sp. found in central New South Wales and in north Queensland; *Hyperammina devoniana* Crespin in central New South Wales, north Queensland and Western Australia; and *Hyperammina* sp. cf. *H. sappingtonensis* Gutschick from central New South Wales, north Queensland and Tasmania.

Five species may have biostratigraphic utility globally, namely: *Inauris tubulata* Conkin & Conkin (late Emsian to middle Eifelian, *serotinus – costatus* conodont zones), *Saccammina mea* n. sp. (*pesavis – serotinus* conodont zones), *Saccammina wingarri* n. sp. (*varcus - falsiovalus* conodont zones), *Thurammina pustulosa* ranges from the *linguiformis* conodont Zone into the Kinderhookian of Texas (late Frasnian to early Carboniferous), and *Pelosina* sp. which ranges from *costatus* to Middle *varcus* conodont zones (middle Eifelian to middle Givetian).

Within Australia *Sorosphaera* sp. cf. *S. confusa*, *Hemisphaerammina coolamon* n. sp., *Psammosphaera garraay* n. sp. and *Thurammina* sp. cf. *T. subspherica* Moreman appear to be restricted to the *pesavis-sulcatus* conodont zones, while *Hyperammina* sp. cf. *H. sappingtonensis* ranges through the *pesavis-serotinus* conodont zones, and *Tolypammina tantula* spans the *pesavis-perbonus* conodont zones. Further studies are needed to confirm the full ranges of these species. Useful, but somewhat longer ranges are associated with *Thurammina mirrka* which spans the *pesavis* to *australis* conodont zones (Lochkovian to Middle Eifelian), *Sacammina mea* which ranges from *pesavis –*

australis (Lochkovian to Middle Eifelian), and *Sacammina* sp. cf. *S. ampullacea* which extends from *pesavis* to *costatus* (Lochkovian to Middle Eifelian).

As in any fossil group, there are a number of very long ranging species or ones with disjunct, long ranges. These include *Webinellinoidea similis, Hyperammina devoniana, Amphitremoidea* sp. cf. *A. citriniforma, Lagenammina ovata* and *Psammosphaera cava.*

3.3 *Comparison with other known faunas:*

As has been pointed out above, there have been few studies on the Early Palaeozoic foraminiferal faunas on a large regional scale, most previous studies being confined to only one sequence or to relatively close sample sites. The influences of differing environments represented by the sediments (*i.e.* facies dependence of foraminiferal faunas) is very poorly known for these early faunas.The taxonomic identification and separation of the variously described species of some of the very simple foraminiferal forms (*e.g.* within the genera *Psammosphaera, Rhabdammina* and *Sorosphaera*) is difficult and uncertain, and no doubt many of the described species are synonymic. Also for many of the studies carried out elsewhere in the world only broad ages of the sampled sediments and sequences are given. Nevertheless an attempt is made here to quantify the possible endemism of the eastern Australian faunas reported in this research.

In the Silurian Wenlock-Ludlow faunas the presence of *Psammosphaera cava, 'Lituotuba' exserta, Thuramminoides sphaeroidalis, Sorosphaera tricella, Thurammina foersteri*, *Stegnammina cylindrica* and similar species of *Rhabdammina, Rhizammina,* *Hyperammina, Hemisphaerammina* and *Stomasphaera* from England (Eisenack 1977, 1978; Mabillard & Aldridge 1982), U.S.A (Browne & Schott 1963, Dunn 1942; McCellan 1963, 1973; Millar 1956, Moreman 1930, 1933; Mound 1968; Stewart & Priddy 1941), Russia (Poyarkov 1979, Tschernich 1967), the Baltic region (mainly organic linings, Eisenack 1930, 1931, 1932, 1934, 1954), Austria (Kristan-Tollmann 1971a), Germany (Blumenstengal 1963), Sardinia (Gnoli & Serpagli 1985) and in the Australian fauna indicate a quite similar fauna worldwide but one with regional differences on the specific level. As shown in Table 20 in Australia there is between 50-60% endemism.

The Lochkovian fauna shows about 40% endemic species as does the Pragian fauna, again indicating a possible worldwide fauna in this time range but one with regional but not significant endemism.

However, in the Emsian we find a much higher degree of endemism in the foraminiferal fauna, at least 60% (Table 20). This is despite the large number of studies made on the Middle Devonian foraminiferal faunas (*e.g.* U.S.A.: Cushman & Stainbrook 1944, Ireland 1939, Stewart & Lampe 1947, Summerson 1958; Poland: Malec 1992; Germany: Bartenstein 1937, Langer 1969, 1970), although most of these dealt with only isolated sequences.

In the Eifelian the Australian fauna shows 50% endemism (Table 20) although many studies have been undertaken on the faunas in this time range (*e.g.* Blumenstengal 1961; Bykova 1955; Duzynska 1956, 1959; Eickhoff 1968, 1970; Malec 1984a, b; Malec & Studencki 1988; Pichler 1971; Sobat 1966; Toomey 1968; Zadorosniy 1987).

Stage	Wen.	Lud.	Prid.	Lochk.	Prag.	Emsian	Eifel.
No species	10	12	(6)	30	26	54	28
No. known from elsewhere	5	5	-	17	16	21	14
% new species	50	**58**	-	40	40	**61**	50

Table 20: The percent endemism of the foraminiferal faunas in the various Stages.

The Givetian and Frasnian faunas reported here are not representative of the probable total fauna as mainly only chitinozoan preparations were studied for the organic linings.

3.4 ZONATION OF THE SILURIAN-MIDDLE DEVONIAN AND SIGNIFICANT FORAMINIFERAL FAUNAL EVENTS

> "It has been assumed by many foraminiferologists ...that arenaceous Foraminifera in general are so conservative, slowly evolving, and of such simple makeup, that they would be of little use in stratigraphic paleontology and correlation. It was thought that their usefulness lay primarily in their being indices for types of depositional environment; or in essence, they were strongly controlled by facies. ...It is quite true that arenaceous Foraminifera in general are conservative and slowly evolving forms, and that they are of value in the recognition of facies and interpretation of environment of deposition; however, it is possible to demonstrate change within arenaceous Foraminifera ... and to recognize species, genera, and faunas which are restricted to certain parts of the system, surely not by facies alone." (Conkin 1961, p. 228-229.)

This statement,made concerning Mississippian foraminiferal faunas, to some extent appears to holds true for the present study.

This present study, being the first to describe regional faunas or assemblages using both 'normal' and organic wall linings from the middle Palaeozoic in eastern Australia, indicates possible stratigraphically important foraminiferal faunas and events. Faunal differences due to facies variations within time zones have not been investigated as most faunas were recovered from limestone residues. Where this was possible (e.g. Buchan-Bindi, Bell 1996) the agglutinated faunas were not significantly different. The marked change in faunal composition with the incoming of the calcareous forms, does not appear to be due to facies differences as these, too, were recovered from limestone residues.

Important stratigraphical foraminiferal events in eastern Australia, based on both normal foraminiferan species and organic foraminiferal linings, have been correlated against the conodont zonation for this period (Table 21). Further research may lead to the establishment of a foraminiferal bizonation for the Silurian and the Devonian.

	STAGE	Conodont Zone	Characteristic fauna
DEVONIAN	Frasnian	*linguiformis*	*Thurammina pustulosa, T. quadritubulata.*
		gigas	
		triangularis	
		asymmetricus	
	Givetian	*falsiovalis*	
		disparilis	
		hermanni	
		varcus	
		hemiansatus	
		ensensis	
	Eifelian	*kockelianus*	
		australis	
		costatus	*Inauris tubulata, Subbdelloidina spathula, Moravammina segmentata, Vermiculammina isis, Semitextularia thomasi,* **entry** of *Nanicella.*
		partitus	
	Emsian	*patulus*	
		serotinus	**Entry** of *Tikhinella.* *Astrorhiza* spp., *Cystingarhiza* spp., *Pelosina grandaeva, Rhabdammina proavita, Thurammina echinata, Hyperammina reflua*
		inversus	
		perbonus	
		dehiscens	
	Pragian	*pireneae*	
		kindlei	
		sulcatus	*Psammosphaera garraay, Reophanus proavitus, Hemisphaerammina coolamon, Webbinelloidea similis*
	Lochkovian	*pesavis*	
		delta	*Psammosphaera aspera, Ammovolummina bostryx, Serpenulina aulax, S. uralica.*
		eurekaensis	
		hesperius	
SILURIAN	Pridoli	*eosteinhornensis*	
	Ludlow	*unzoned*	
		crispa	*Hyperammina teres, Saccammina cyclops.*
		unzoned	
		siluricus	
		ploeckensis	
		unzoned	
	Wenlock	*amsdeni*	
		ranuliformis	*Hyperammina leptalea, Lituotuba exserta, Sorosphaera tricella.*

Table 21: Stratigraphically important foraminiferans from eastern Australia.

SYSTEMATIC PALAEONTOLOGY

Note:

(i) The classification followed is that of Loeblich & Tappan (1988b).

(ii) Specimens prefixed NMV P refer to registered specimens deposited in the Palaeontological Collection of the Museum of Victoria.

Specimens prefixed AMF refer to registered specimens in the Australian Museum, Sydney.

(iii) Use of the term *proloculum*: In recent years there has been a tendency to call the initial chamber of a foraminiferan test the proloculus (e.g. Loeblich & Tappan 1988b, 1994). However as Cushman (1905, p. 538) defined the initial chamber as the proloculum it must, by priority, still stand.

(iv) The term 'normal foraminiferans' refers to normal sized foraminiferans that have a complete agglutinated wall as distinguished from those specimens that only have an organic wall.

(v) Unless otherwise stated, descriptions and comments refer to normal sized foraminiferans.

Order FORAMINIFERIDA Eichwald, 1830

Suborder TEXTULARIINA Delarge & Hérouard, 1896

Family ASTRORHIZIDAE Brady, 1881

Subfamily ASTRORHIZINAE Brady, 1881

Genus **Astrorhiza** Sandahl, 1858

Type species. Astrorhiza limicola Sandahl, 1858.

Diagnosis. Test free; compressed hollow central disc from which numerous tubular arms radiate; wall agglutinate, aperture terminal.

Astrorhiza constans Bell, 1996

Plate 2, figs C, D.

Astrorhiza constans Bell 1996: 80, Figs 5C, D.

Diagnosis. A species of *Astrorhiza* with six short, coplanar, regularly arranged about the body chamber.

Description. Test free; large, slightly inflated body chamber, with six coplanar stolons issuing more or less regularly about the periphery; the stolons are short and thick, slightly flaring at the apertural end; the aperture is a simple opening at the end of each stolon; the test is formed of small quartz grains, with little cement, and fairly smoothly finished.

Distribution. Buchan Caves Limestone and Taravale Formation; Buchan and Bindi, Victoria, Emsian, *perbonus-inversus* conodont zones.

Holotype. NMV P126953, Plate 2, fig. C.

Type locality and horizon. South arm, Limestone Creek, Bindi; sample 7.

Measurements.

Holotype NMV P126953 – SALC 7, body diameter, 0.4 mm

Paratype NMV P199388 – BON13.5-15, 0.34 mm

Paratype NMV P199389 – SALC 7, 0.3 mm

Paratype NMV P199390 – ORCQ 10-15, 0.6 mm

Remarks. This species varies from *A. triquetra* in the number of arms and the shape of the body chamber, and from *A. sinus* by the shape and number of the stolons and their arrangement.

Specimens from BON 13.5 and SALC 9 often have one or more stolons stouter than the others and the placement of the arms is then not as regular about the periphery.

Derivation of Name. constans (L.): consistent; referring to the regular arrangement of the stolons.

Astrorhiza sinus Bell, 1996

Plate 2, figs E-G.

Astrorhiza sinus Bell 1996: 81, figs 5E-G.

Diagnosis. A species of *Astrorhiza* with five, long narrow stolons emanating from one side of the discoidal body chamber.

Description. Test free; chamber discoidal, with five stolons issuing from one side of the chamber; the stolons are long, narrow and may be curved; a simple aperture at the end of each stolon; test wall formed of fine quartz grains with little cement, fairly smoothly finished surface.

Distribution. Buchan Caves Limestone and Taravale Formation; Buchan and Bindi, Victoria, Emsian, *perbonus-inversus* conodont zones.

Holotype. NMV P126954, Plate 2, fig. E.

Type locality and horizon. South arm, Limestone Creek, Bindi; sample 7.

Measurements.

Holotype. NMV P126954 – SALC 7, body diameter, 0.38 mm

Paratype NMV P199391 – ORCQ 10-15, 0.48 mm

Remarks. In the holotype there is only one long, sinuous stolon, the others are short due to breakages, but in specimen NMV P126955 from ORCQ 10-15 two stolons are long and curved, one being somewhat flattened. It is possible that all the stolons were originally long and sinuous.

A. sinus differs from *A. constans* in the arrangement of the stolons about the body chamber and in the shape and number of stolons. It can be separated from *A. triquetra* by having a discoidal rather than triangular, inflated body chamber.

Derivation of Name. sinus (L.): winding; referring to the shape of the stolons.

Astrorhiza triquetra Bell, 1996

Plate 2, figs A, B.

Astrorhiza triquetra Bell,1996: 80, figs 5A, B.

Diagnosis. A species of *Astrorhiza* having a triangular, inflated body chamber with a stolon emanating from each of the corners.

Description. Test free; central body chamber is triangular and slightly inflated, the sides are of equal length; an arm issues from each corner of the central chamber, these stolons lie in one plane and are short, less than half side length; aperture a simple opening at the end of each stolon; test wall formed of small quartz grains, with little cement, smoothly finished.

Distribution. Windellama Limestone, Windellama, NSW, Lochkovian, *eurekaensis* conodont zone; Buchan Caves Limestone and Taravale Formation, Buchan and Bindi, Victoria, Emsian, *dehiscens –inversus* conodont zones.

Holotype. NMV P126952, Plate 2, fig.A.

Type locality and horizon. Gelantipy Road, Buchan, sample Ma 13.

Measurements.

Holotype NMV P126952 , from Ma 13, body diameter 0.3 mm

Paratype NMV P199385 , from Ma 13, body diameter 0.46 mm

Paratype NMV P199386 , from SALC 7, body diameter 0.25 mm

Paratype NMV P199387 , from OTRC 7, body diameter 0.39 mm

Remarks. The stolons are usually short, most likely due to breakages after death, as occasionally they are longer (equal to side length) and slightly curved, indicating that they may have been flexible in life.

A. triquetra is easily distinguished from *A. constans* and *A. sinus* by having a triangular, inflated body chamber.

A. triquetra differs from the Recent *A. triangularis* Earland 1933 from South Georgia in having stout arms, a smaller body chamber with less inflated sides and a much smoother surface.

Derivation of Name. *triquetra* (L.): three cornered; referring to the triangular shaped body chamber.

Genus **Cylindrammina** Bell, 1996

Type species. Cylindrammina stolonifera Bell, 1996

Diagnosis. Test free; inflated tubular chamber from which protrude short, thin stolons.

Description. Test free; consisting of an inflated chamber usually slightly curved, from which protrude several (2-10) thin, short stolons; wall composed of fine sand grains, thin, with a slightly rough exterior but smooth interior; a simple aperture at the end of each stolon.

Remarks. Cylindrammina differs from both *Astrorhiza* and *Cystingarhiza* in the tubular shape of the test which can be quite variable in degree of curvature and amount of inflation. It also differs from *Astrorhizoides* Shchedrina, 1969 which consists of a thick branching tube unlike *Cylindrammina* which is slender, usually curved tube with short, thin stolons. The number of stolons per test is also variable within a population from any one sample, varying from 2 – 10; the stolons appear to be placed at random over the test.

Derivation of Name. referring to the cylindrical body chamber + the agglutinated wall.

Cylindrammina stolonifera Bell, 1996

Plate 3, figs A-C

Cylindrammina stolonifera Bell 1996: 84, figs 6A-C.

Diagnosis. A species of *Cylindrammina* with short, thin stolons.

Description. as for genus.

Distribution. Buchan Caves Limestone and Taravale Formation; Buchan and Bindi, Victoria; Emsian, *dehiscens –inversus* conodont zones; Benny's Top Limestone, Pigna Barney, NSW, Emsian, *dehiscens-perbonus* conodont zones.

Holotype. NMV P126994, Plate 3, fig. B.

Type locality and horizon. South arm, Limestone Creek, Bindi; sample 7.

Measurements (in mm).

	Locality	length	width	No. stolons	diam.
Holotype NMV P126994	SALC 7	0.72	0.3	8	0.06
Paratype NMV P199402	SALC 7	0.72	0.3	2	0.06
Paratype NMV P199403	ORCQ	0.8	0.3	4	0.16
Paratype NMV P199404	SALC 9	0.78	0.21	3	0.1

Remarks. The length of the stolons is variable and the shortness of the majority of them is most likely due to breakages as occasional specimens from BON 36-39 and SALC 9 have longer arms up to three times that normally found.

Genus **Cystingarhiza** Bell, 1996

Type species. Cystingarhiza mawsonae Bell, 1996

Diagnosis. Test free; globular chamber from which radiate tubular extensions; wall agglutinate; aperture terminal.

Description. Test free; small, globular to ovate; consisting of a single spherical to subspherical chamber with a few (2-6) radiating tubular extensions, not all in the one plane; wall agglutinated of small to medium sized sand grains with little cement visible; aperture at open ends of the tubular extensions.

Remarks. This genus is erected to accommodate *Astrammina*-like specimens known only from the Early Devonian of Victoria. The genus *Astrammina* Rhumbler (*in*

Wiesner 1931) was erected to accommodate *Astrorhiza*-like specimens but which had a globular, not flattened, central chamber and with fewer arms. *Astrammina* is only known from the Holocene in the Antarctic, South Atlantic and South Pacific (Loeblich & Tappan 1988b). *Cystingarhiza* differs from *Astrammina* in the much smaller size (about one-quarter to one-tenth diameter) and in having the stolons usually not in the one plane.

Conkin & Conkin (1967) have suggested that *Thurammina triradiata* Gutschick & Treckman emend. Conkin, Conkin & Canis, found in the Mississippian Rockford Limestone of Northern Indiana, U.S.A., may be better referred to *Astrammina* (i.e. the new *Cystingarhiza*) because it has long tubular processes whereas *Thurammina* has small stubby papillae.

Derivation of Name. *kystrix* (Gk.): a cell + *rhiza* (Gk.): a root.

Cystingarhiza corona Bell, 1996

Plate 2, figs K, L.

Cystingarhiza corona Bell 1996: 82, figs 5K, L.

Diagnosis. A species of *Cystingarhiza* with four stolons radiating from one cap of the central chamber.

Description. Test free; moderate size; globular central chamber with four radiating stout stolons which issue from one cap of the central chamber; stolons short, about one-third of central chamber diameter; wall composed of fine grains with little cement, surface coarsely finished; aperture not observed on holotype but is a simple opening at end of each stolon in other specimens.

Distribution. Buchan Caves Limestone and Taravale Formation; Buchan and Bindi, Victoria; Emsian, *perbonus – inversus* conodont zones; Benny's Top Limestone, Pigna Barney ,NSW, Emsian, *dehiscens - perbonus* conodont zones.

Holotype. NMV P126957, Plate 2, fig. L.

Type locality and horizon. South arm, Limestone Creek, Bindi; sample 9.

Measurements (in mm).

	Locality	diam	arms	aperture
Holotype NMV P126957	SALC 9	0.3	0.09	0.05
Paratype NMV P199394	ORCQ10-15	0.6	0.3	0.12
Paratype NMV P199395	Ma 13	0.43	0.12	0.05
Paratype NMV P199396	SALC 7	0.6	0.18	0.1

Remarks. The degree to which the stolons are coplanar varies greatly; in the holotype the arms are almost in one plane whereas in specimens from ORCQ 10-15 the arms are highly angled with respect to the main chamber.

Specimens having only two or three arms are recorded as separate species.

Derivation of Name. corona (L.): crown; referring to the stolons encircling one cap of the chamber.

Cystingarhiza furca Bell, 1996

Plate 2, figs M-O.

Cystingarhiza furca Bell 1996: 84, figs 5M-Q.

Diagnosis. A species of *Cystingarhiza* with two stolons at one end of central chamber.

Description. Test free; body chamber ellipsoidal, slightly compressed at one end from which issues two stolons; stolons straight and narrow; aperture a simple opening at end of each stolon; wall fine grained with little cement, surface smoothly finished.

Distribution. Buchan Caves Limestone and Taravale Formation, Buchan and Bindi, Victoria; Emsian, *dehiscens – serotinus* conodont zones; Benny's Top Limestone, Pigna Barney ,NSW, Emsian, *dehiscens-perbonus* conodont zones.

Holotype. NMV P126959, Plate 2, fig. N.

Type locality and horizon. South arm, Limestone Creek, Bindi; sample 7.

Measurements (in mm).

	Locality	length x width	arm length	aperture
Holotype NMV P 126959	SALC 7	0.39 x 0.26	0.19	0.09
Paratype NMV P199398	SALC 7	0.6 x 0.26	0.15	0.06
Paratype NMV P199399	SALC 7	0.45 x 0.36	0.15	0.09
Paratype NMV P199400	SALC 7	0.32 x 0.31	0.13	0.05
Paratype NMV P199401	ORCQ	0.38 x 0.16	0.07	0.05

Remarks. This species shows much variation both in the shape and inflation of the central chamber and in the divergence angle between the two stolons. The body chamber ranges from quite elongate to almost spherical with quadrate forms also present. These do not seem to be preservational differences but morphological variation within the species. The angle of divergence between the two stolons varies at Buchan/Bindi from 40° to 113°, whilst at Pigna Barney the angle may range as high as145°.

This species differs from *C. corona* and *C. mawsonae* by having only two stolons placed at one end of the central chamber.

Cystingarhiza mawsonae Bell, 1996

Plate 2, figs I, J.

Cystingarhiza mawsonae Bell 1996: 82, figs 5I, J.

Diagnosis. A species of *Cystingarhiza* having five radiating arms.

Description. Test free; moderate size; central chamber globular with five radiating arms which taper slightly aperturally; simple aperture at the end of each stolon; wall of small sand grains with little cement, coarsely finished.

Distribution. Taravale Formation, Buchan and Bindi, Victoria,; *inversus* conodont zone.

Holotype. NMV P126956, Plate 2, fig. I.

Type locality and horizon. South arm, Limestone Creek, Bindi; sample 9.

Measurements .

Holotype NMV P126956 – SALC 9, body chamber diam. 0.3 mm

Paratype NMV P199392 – SALC 9, 0.3 mm

Paratype NMV P199393 – Ma 13, 0.35 mm

Remarks. The stolons are of variable length due to breakage and range up to equal in length to the central chamber diameter. *C. mawsonae* differs from other species of *Cystingarhiza* in having five stolons more or less evenly spaced about the central chamber.

Derivation of Name. For Dr. Ruth Mawson, Macquarie University, for her contributions to the knowledge of Devonian biostratigraphy in Australia.

Cystingarhiza tribracchia Bell, 1996

Plate 2, fig. H.

Cystingarhiza tribracchia Bell 1996: 84, fig. 5H.

Diagnosis. A species of *Cystingarhiza* with three coplanar stolons.

Description. Test free; a small globular chamber from which issues three coplanar stolons; stolons are long, up to twice the body chamber diameter in length, narrow; aperture not observed.

Distribution. Buchan Caves Limestone and Taravale Formation; Buchan and Bindi, Victoria; Emsian, *perbonus – inversus* conodont zones.

Holotype. NMV P126958, Plate 2, fig. H.

Type locality and horizon. Old Rocky Camp Quarry, Buchan, 10-15 paces above the top of the Murrindal Formation.

Measurements (in mm).

	Locality	chamber diam.	arm length	aperture
Holotype NMV P126958	ORCQ 10-15	0.1	0.3	0.05
Paratype NMV P199397	SALC 9	0.09	0.2	0.08

Remarks. Tests are known from internal casts only. This species, which could be placed in the genus *Astrorhiza* because of its coplanar stolons, however appears to form a connecting link between *C. mawsonae* (5 stolons) and *C. furca* (2 stolons). Whether the number of stolons is a sufficient character to differentiate these species must await more and better preserved material. Specimens from SALC 9 show curving stolons.

Derivation of Name. tres (L.): three + *bracchium* (L.); arm-like; referring to the number of stolons.

Genus **Pelosina** Brady, 1879

Type species. Pelosina variabilis Brady, 1879

Diagnosis. Test free; elongate, fusiform, non-septate; wall agglutinate; apertures at ends of tubular extensions.

Pelosina grandaeva Bell, 1996

Plate 5, figs B, C.

Pelosina grandaeva Bell 1996: 94, figs 8B, C.

Diagnosis. A species of *Pelosina* with a thick agglutinated wall.

Description. Test free; a single fusiform chamber, about three times as long as wide, with long, tubular extensions at either end; fine grained test wall but not smoothly finished; simple aperture at ends of tubular extensions.

Distribution. Buchan Caves Limestone and Taravale Formation; Buchan and Bindi, Victoria; Emsian, *perbonus –inversus* conodont zones; Benny's Top Limestone, Pigna Barney, NSW; Emsian, *dehiscens-perbonus* conodont zones.

Holotype. NMV P126976, Plate 5, fig. B.

Type locality and horizon. Old Rocky Camp Quarry, Buchan, 10-15 paces above the top of the Murrindal Formation.

Measurements (in mm).

	Locality	length	width	aperture S1	aperture S2
Holotype NMVP126976	ORCQ	0.38	0.06	0.02	0.02
Paratype NMV P126999	Ma 13	0.64	0.22	0.05	broken

Remarks. The tubular extensions were of unequal length in the type specimen but this is due likely to breakages during preservation as other specimens were of more equal length. The produced ends appear to have been flexible since they are slightly curved.

P. grandaeva differs from *P. variabilis* in the thicker, more rigid, agglutinate wall compared to the Recent species' thin, highly flexible wall with organic extensions.

Pelosina was previously known to range from the Cretaceous to Recent (Loeblich & Tappan 1988).

Derivation of Name. *grandaeva* (L.): very old; referring to its stratigraphical occurrence.

Pelosina sp.

Plate 17, figs D, E.

Diagnosis. A species of *Pelosina* with short, narrow extensions.

Description. Test free; large; somewhat fusiform, about four times as long as broad; the central third of the chamber much wider than the two opposite extensions which narrow quickly and markedly from the body chamber; wall thin (1-2 grains thick), surface smooth; apertures circular at end of each arm.

Organic lining surface smooth, with scattered, round, relatively large punctae; aperture oblique at end of each arm.

Distribution. Normal foraminiferans: YAR6/126, Moore Creek Limestone Member of the Yarrimie Formation, Yarramanbully, NSW; Eifelian, conodont zone uncertain;

organic linings: Isis River, below Timor Limestone, Early Eifelian possibly *costatus* conodont zone

Measurements (in mm).

Normal specimens:

		length		aperture diam	
	total length	arm 1	arm 2	arm 1	arm 2
Figured specimen NM VP208031	0.8	0.2	0.175	0.025	0.037
Figured specimen NMV P208030	0.625	-	-	-	-

Organic linings : Length = 233-250 μm; width (max.) = 50-61 μm; diameter of aperture = 11-12μm; diameter of wall punctae = 11-12 μm.

Remarks. Only three specimens of normal foraminiferans were found, two of which were broken. They differ from *P. grandaeva* from the Emsian (Bell 1996) in total size and in the narrowness of the extensions. Similar but smaller specimens have been found as organic linings from OKE 78.7 and below ISIS clast 2 which localities have Eifelian ages (between *costatus* to mid-*varcus* conodont zones but not well constrained.

Subfamily VANHOFFINELLINAE Saidova, 1981

Genus **Inauris** Conkin, Conkin & Thurman, 1979

Type species. Inauris tubulata Conkin, Conkin & Thurman,1979.

Diagnosis. Test free; single torus-shaped, undivided, tubular chamber with a short, apertural neck in the plane of the torus; wall agglutinate; aperture terminal.

Inauris tubulata Conkin, Conkin & Thurmann, 1979

Plate 11, fig. 1; Plate 15, fig. A.

Inauris tubulata Conkin, Conkin & Thurman 1979: 4, pl. 1, figs 1-10.

Material. Two specimens from MSh (sample 4).

Distribution. Middle Shanda Beds, Siberia, *serotinus* conodont Zone; Jeffersonville Limestone, Kentucky, USA, late Emsian – mid-Eifelian.

Description. Test free; a ring-like, undivided tubular chamber; wall reticulate; aperture rounded produced on a short neck; the inner central area covered by a thin membraneous sheet (after Loeblich & Tappan 1988).

Measurements (in mm).

Length = 125 μm ; Diameter = 80 μm

Remarks. Originally described from Kentucky, USA (Conkin *et al.* 1979), this is the only record of it outside the type locality or as a foraminiferal lining. Loeblich & Tappan (1988) postulated a membraneous central area for *Inauris* and our specimen clearly shows such an inner membrane apparently attached to the outer "ring" by digitate processes.

Known occurrence. late Emsian - early Eifelian (*costatus* conodont Zone), Jeffersonville Limestone, Kentucky, (Conkin *et al.* 1981); *serotinus* conodont Zone, Middle Shanda Beds, Siberia (Bell & Winchester-Seeto 1999).

Size. Diameter (max.) = 95-147 μm; diameter of hole = 10.5 μm

Remarks. Two forms are present - one with a small central hole, the other with a much larger (though damaged) hole; both fit within the variation shown in the original description (Conkin *et al*. 1979). Neither specimen shows any evidence of a central membrane as found in a specimen from the Middle Shanda Beds, Siberia

(Bell & Winchester-Seeto 1999). The neck is broken close to the main body of the test in both specimens.

Family BATHYSIPHONIDAE Avnimelech, 1952

Genus **Bathysiphon** M. Sars *in* G. O. Sars, 1872

Type species. Bathysiphon filiformis M. Sars *in* G. O. Sars, 1872

Diagnosis. Test free; large, elongated, agglutinate tube, may have annular constrictions; aperture at ends of tube.

Bathysiphon sp.

Plate 19, figs C, D.

Description. Tubular pieces; thick wall formed of two layers – an inner layer formed of equiangular grains, closely fitted together with little cement, and which is overlaid by a thin glaze resulting in a smooth exterior; interior smooth; surface may show wrinkles.

Distribution. QU 166, Windellama Limestone, Lochkovian, *eurekaensis* conodont Zone.

Measurements (in mm).

Figured specimen NMV P208032 length 3.1

diameter 0.65

wall thickness 0.15

internal diameter 0.3.

diameter of attached epizoan foraminiferan 0.22.

Remarks. The wall varies in thickness from specimen to specimen but is usually about one-sixth of the tube diameter. Apart from the surface glaze, which seems to be original and not a recrystallization artefact of preservation, there is no evidence of the four layered structure found in certain Cretaceous *Bathysiphon* (Miller 1988) and which is not found in Recent forms (Gooday & Claughter 1989). Some specimens show a thickened ring-like zone on the outer wall but which is not expressed internally. There is insufficient material (9 fragmentary specimens) to formally name the present specimens.

Bathysiphon has been recorded from the Ordovician (Riegraf & Niemeyer 1996) and numerous species in the Silurian (Moreman 1930; Stewart & Priddy 1941; Dunn 1942; McClellan 1966) from Oklahoma, Ohio and Indiana. The American forms are described as thin walled, narrow and usually curved; in these characters they closely resemble the distal tubular section of *Hyperammina* spp, a fact also noted by these authors and also Mound (1968). The present specimens differ from these species in size and wall thickness.

Mound (1968) has figured large thick specimens from the Silurian of Indiana as *Jaculella acuta* (Brady). Specimens of this species from Recent sediments are characteristically solid and expanding conical forms with a narrow internal cavity. The Windellama specimens show no tapering of the test and have a relatively wide internal cavity and so cannot be considered in the genus *Jaculella*.

One specimen (pl.19, fig. C, D) of *Bathysiphon* sp. shows a foraminiferan embedded in the wall. Epizoal activity of foraminiferans is well known and, in Recent and Cretaceous sediments, seem restricted to calcareous rotaliid genera (Nyholm 1961; Sliter 1965; Todd 1965; Banner 1971; DeLaca & Lipps 1972; Baumfalk *et al.* 1982; Alexander & DeLaca 1987; Smyth 1988; Collen 1998). Franzen (1974), in discussing epizoans on Silurian-Devonian crinoids from Gotland, found in many pits on the crinoid stems small, flattened, agglutinated vesicles which in all respects resembled the foraminiferan genera *Psammosphaera* and *Saccammina.* In the present case the epizoan foraminiferan is clearly an agglutinated form. It has a bulbous proloculum followed by a coiled second chamber; this type of growth is characteristic of both *Tolypammina* and *Ammodiscus*, but because of the poor preservation, the specimen cannot be further identified.

Family RHABDAMMINIDAE Rhumbler, 1895

Genus **Rhabdammina** M. Sars *in* Carpenter, 1869

Type species. Rhabdammina abyssorum M. Sars *in* Carpenter, 1869

Diagnosis. Test free; tubular arms radiating from a small central chamber; wall agglutinate; apertures terminal.

Rhabdammina linearis Brady, 1879

Plate 3, figs G-I.

Rhabdammina linearis Brady 1879: 37, pl.3, figs 10-11. - Brady 1884: 26, pl. 22, figs 1-6. - Bell 1996: 85, figs 6G-I.

Diagnosis. A species of *Rhabdammina* with only two, diametrically opposed arms.

Description. Test free; large ellipsoidal chamber with two diametrically opposed long, straight, tubular stolons issuing from the narrower ends of the main chamber; aperture a simple opening at the ends of each stolon; wall finely arenaceous, roughly finished.

Distribution. Buchan Caves Limestone and Taravale Formation; Buchan and Bindi, Victoria; Emsian, *dehiscens -inversus* conodont zones.

Measurements (in mm).

	Locality	diameter chamber	tube diameter
Fig. spec. NMVP126960	SALC 7	0.32	0.1
Fig. spec NMVP199405	Ma 13	0.3	0.1
Unfig. spec NMVP199405	BON 13.5-15	0.16	0.09
Fig. spec NMVP199407	BON 13.5-15	0.22	0.07
Unfig. spec NMVP199408	SALC 7	0.26	0.08
Unfig. spec NMVP199409	SALC 7	0.6	0.17

Remarks. There seems to be nothing to distinguish these early Devonian specimens from Brady's Recent species that cannot be assigned to preservational differences *e.g.* shorter stolons due to breakages and the slight compression of some specimens. Some specimens do have a more inflated central chamber than the Recent forms but the amount of inflation is variable, even in Recent forms.

Rhabdammina proavita Bell, 1996

Plate 3, fig. F

Rhabdammina proavita Bell 1996: 85, fig 6F.

Diagnosis. A species of *Rhabdammina* showing branching of the primary arms.

Description. Test free; small globular prolocular chamber from which two arm issue diametrically; the arms are only slightly narrower than the central chamber, and branch a short distance from the chamber; these secondary stolons are usually narrower than the primary ones; aperture is a simple opening at the ends of the stolons; wall formed of very fine quartz grains, with little cement; surface very smoothly finished.

Distribution. Known only from the type locality, OTRC 7; Buchan Caves Limestone, Buchan; *dehiscens* conodont Zone.

Holotype. NMV P126961, Plate 3, fig. F.

Type locality and horizon. Old Taravale Road Cutting, Buchan, sample 7.

Measurements (in mm).

	proloculum diameter	primary arm diameter
Holotype NMV P126961	0.2	0.18
Paratype NMV P199410	0.1	0.07

Remarks. In general shape this species is similar to the Recent species *Rhabdammina cornuta* Brady, but differs in the smooth surface texture and the very fine grains used in the test wall.

R. proavita shows some variation in the size of the central chamber, the length of the primary stolons and the nature of the secondary arms. In some specimens the primary arms may not branch but instead become flaring and flattened, although this may be a preservational artefact in part.

Derivation of Name proavita (L.): ancestral; referring to the stratigraphic occurrence.

Rhabdammina sp. A

Plate 20, fig. I

Diagnosis. A species of *Rhabdammina* without an inflated chamber and narrow arms.

Description. Test free; large, Y-shaped, bifurcating tube, with arms at 120°; no inflation at arm junction; arms thin (narrow), evenly cylindrical; wall, thin, fine grained, surface smoothly finished; apertures simple, circular opening at ends of arms.

Distribution. WERR 13, Boree Creek Limestone, Borenore, NSW; Early Wenlock, *ranuliformis* conodont Zone.

Measurements (in mm).

Figured specimen NMV P208054 average arm diameter 0.2-0.275;
longest arm 1.2;
wall thickness 0.025;
wall thickness/wall diam. = 0.1

Remarks. There appears to be no inflation at the junction of the arms that would indicate a prolocular chamber as is usual in *Rhabdammina*, but this feature is not always apparent in Recent specimens (of *R. linearis*) figured by Brady (1884) or in Silurian forms figured by McClellan (1966).The arms are usually slightly curved and often show increased swelling just after the junction.

Rhabdammina sp. B

Plate 20, fig. J.

Diagnosis. A species of *Rhabdammina* with three arms, not of equal diameter.

Description. Test free; long, Y-shaped, bifurcating tube; arms narrow, but one arm is usually much wider than the other two; angle between the narrower arms greater than 120°; wall thin, coarsely formed and finished; apertures are narrow openings at the ends of the arms.

Distribution. WERR 13, Boree Creek Limestone, Borenore, NSW; Early Wenlock, *ranuliformis* conodont Zone.

Measurements (in mm).

Figured specimen NMV P208055	average arm diameter 0.4-0.5;
	longest arm 1.1;
	wall thickness 0.075
	wall thickness/wall diam. = 0.15

Remarks. A prolocular inflation is only rarely present. This is a much stouter species than *R.* sp A both in overall size and relative arm thicknesses. One arm is usually much wider than the other two. One four-armed specimen was present.

Genus **Rhizammina** Brady, 1879

Type species. Rhizammina algaeformis Brady, 1879

Diagnosis. Test simple or branching tube; wall agglutinate, thin; apertures terminal.

Remarks. Cartwright *et al.* (1989) found that Recent *R. algaeformis* contained stercomata in the test chamber, and suggested that the species should be considered a member of the family Komokidae on this and the cytological properties but recognized that these factors would not be discernible in fossil material.

Rhizammina sp.

Plate 1, fig. K

Rhizammina sp. Bell 1993: 146, , fig. 3K.

Description. Test free; finely arenaceous; a meandering cylindrical tube which bifurcates into short arms; openings (?apertures) at ends of tubes; wall smooth.

Distribution. Cowombat Formation, Cowombat, Victoria; Ludlow, *crispa* conodont Zone.

Measurements.

length 0.5 mm tube diameter 0.07 mm

Remarks. Only fragments are known, none of which shows any prolocular chamber.

Family DRYORHIZOPSIDAE Loeblich & Tappan, 1984

Genus **Sagenina** Chapman, 1900

Type species. *Sagenina frondescens* Brady, 1879

Diagnosis. Test attached; dichotomously or irregularly branched tubes.

Sagenina filiformis Bell, 1993

Plate 1, fig. N

Sagenina filiformis Bell, 1993: 149, fig. 3N

Diagnosis. A species of *Sagenina* with a test of narrow cylindrical tubes formed of very fine agglutinated quartz grains.

Description. Test probably attached when living; fine cylindrical tubes, branching at irregular interval, forming a complex matted surface; openings at the ends of the tubes; wall very finely siliceous with a smooth surface.

Distribution. Cowombat Formation, Cowombat, Victoria; Ludlow, *crispa* conodont zone.

Holotype. NMV P137627, Plate 1, fig. N.

Type locality and horizon. Cowombat, sample 2.

Measurements (in mm).

Holotype NMVP137627 length 1.2, diameter of tubes 0.03.

Remarks. The multiramous branching habit suggests *Sagenina* although that genus, known only from the Recent, usually has a planar test.

Derivation of Name. filum (L.): thread; referring to the lace-like matted surface.

Family PSAMMOSPHAERIDAE Eimer & Fickert, 1899

Subfamily PSAMMOSPHAERINAE Haeckel, 1894

Genus Psammosphaera Schulze, 1875

Type species. Psammosphaera fusca Schulze, 1875

Remarks. The resolution of specimens of *Psammosphaera* into species is difficult. Many authors have used characters such as size of test, grain size, wall thickness and ratio of cement to grains in the wall as differentiators (e.g. Dunn 1942; Mound 1968; Stewart & Lampe 1947; Summerson 1958), although varying wall thickness, test size and grain size used were not considered to be reliable indicators for specific diagnoses of such simple organisms by Browne & Schott, (1963) or McClellan (1966) whereas others have been prepared to accept a wide variability in these characters within any one species (e.g. Gutschick & Treckman 1959; McClellan 1966). Earlier though Mound (1961) found specimens of *P. cava* to vary in size from 0.1 to 0.6 mm and stated that all variations of the above criteria could be expected within any one species. The size of grain used in test construction will depend upon the sediment size available (Loeblich & Tappan 1964) and they further stated that grain size should not be used as a specific character. Gutschick & Treckman (1959, p. 232) concluded that '..there seems to be insignificant phylogenetic difference throughout the Paleozoic for this simple genus'. Conkin *et al.* (1968) go to an extreme in not specifying any species in their material due to the great variation found within 'a simple agglutinate sphere' (p. 151). Here I have taken a middle course and used only the coarseness of the test wall as a differentiating character as it is well known for many other Recent foraminiferans that they can be very selective in the choice of material used in the wall construction.

The smoothness or otherwise of the organic lining surface can be used as a diagnostic feature as an indicator of original wall texture. Loeblich & Tappan (1988b, p. 28) stated that *Psammosphaera* has no inner lining; but Bender (1995) found that *P. fusca* had an inner organic lining; the presence of reticulate ridges on some individuals suggests that originally these specimens had an agglutinated outer test. A number of specimens of each of the species described here (see *P. cava* for example) show equatorial splitting into two equal halves which, although looking like *Hemisphaerammina*, may be differentiated by their very much thinner wall and rough edged sutural boundary.

Psammosphaera cava Moreman, 1930

Plate 3, fig. J; Pl. 8, figs 7,9,14; Pl 11, figs 2,3; Pl. 15 figs. B,C; Pl. 22, fig. H.

Psammosphaera cava Moreman 1930: 48, pl. 6, fig. 12. – Stewart & Priddy 1941: 371, pl. 54, figs 8,9. – Dunn 1942: 322, pl. 42, fig. 6. – Browne & Schott 1963: 208, pl. 49, figs 7-10 (synonymy). – McClellan 1966: 467, pl. 37, figs 12-14; pl. 39, figs 1,2; pl. 41, figs 12-14, (extensive synonymy). – Mound 1968: 74, pl. 5, figs 13-15 (extensive synonymy). – Kristan-Tollmann 1971a: 255, pl. 2, fig. 3 (extensive synonymy). – Gnoli & Serpagli 1985: 214, pl. 1, figs 19, 20. - Winchester-Seeto & Bell 1994: 202, figs 2.7, 2.9. 2.14; non 2.8, 2.10, 2.12.

Description. Test free; a more or less simple spherical chamber; wall smooth to fairly rough, thin; no apparent aperture.

Distribution. Specimens have been found scattered throughout all the sections studied; Lower Silurian – Middle Devonian. DSC 230, Mirrabooka Formation, Borenore, NSW, Early Wenlock, *ranuliformis* conodont Zone; Garra Limestone, Wellington, NSW, *pesavis-sulcatus* conodont zones; Buchan Caves Limestone and Taravale Formation; Buchan and Bindi, Victoria; Emsian, *dehiscens -inversus* conodont zones; Amphitheatre Group, Darling Basin, NSW, *pesavis-sulcatus* conodont zones; Martins Well Limestone, Broken R, Qld, *sulcatus* conodont Zone; Coopers Creek Formation, Victoria, *kindlei* conodont Zone; DDH2 depth 66.2m, DDH7 depth 95m *costatus-australis* conodont zones; TW-T, Isis river below Timor Limestone Early Eifelian, ?*costatus* conodont zone; TIM 18.9, Timor Limestone, *costatus* conodont Zone

Measurements.

Organic linings - Diameter = 69-140 μm (Av. 97 μm for 9 specimens)

normal specimens – Diameter = 0.11- 0.34 mm

Remarks. As pointed out above the variation in size, wall thickness and grain size used in wall construction of *Psammosphaera* is great and doubtless many separate species are, and have been, lumped together under *P. cava* in its reported distribution from the Ordovician to Upper Carboniferous. *P. cava* has a very long stratigraphic range and it may well be that several species are being confused. It is reported from the middle Ordovician (Gutschick, 1986), through the Silurian (Browne & Schott, 1963; Eisenack, 1932; Mabillard & Aldridge, 1982; Kristan-Tollmann, 1971b; McClellan, 1966; Stewart & Priddy, 1941) and into the Devonian (Bell, 1996; Gnoli & Serpagli, 1985) and perhaps into the Upper Carboniferous (Pennsylvanian) as *P. gracilis* Ireland (Toomey, 1974; Kristan-Tollmann (1971b) and Mound (1968) synonymized *gracilis* with *cava*).

Organic linings : *Psammosphaera cava* is a very simple foraminiferan; the shape may vary from globular to slightly ovate, but this is not a preservational effect. The smooth surface of the organic linings suggests that either the living protist did not have any agglutinate coating or that any grains were not strongly attached or that the test wall was made of small grains, as described by Moreman (1930).

P. cava has been recovered from the *pesavis-sulcatus* conodont zones in Victoria (Bell, 1996) and the linings recovered fit into the size ranges previously observed. A range of variation of preservational styles can be observed, including a worn and somewhat "lumpy" surface (Pl. 11, fig. 3) and the slightly pitted surface (Pl. 11, fig. 2).

In the Tamworth area both organic linings and normal foraminiferans occurred together. As noted with *P. cava* from other localities (Bell & Winchester-Seeto 1999) some specimens show an equatorial splitting of the test. Eisenack (1934) described, from the Silurian of the Baltic area, *Bion perforatum*, which he considered to be a cyst and that also displays this equatorial splitting; Eisenack's description appears to be that of an organic lining with a roughened (? reticulated) surface and is very similar to our specimens placed in *P. cava.*

Psammosphaera aspera Summerson, 1958

Plate 22, fig. 1

Psammosphaera aspera Summerson 1958: 550, pl. 81, figs 10, 11.

Description. Test free; a simple, large spherical chamber; wall coarsely constructed with relatively large grains, single grain thick; surface rough; no apparent aperture.

Distribution. QU 233, Windellama Limestone, Lochkovian, *delta* conodont zone.

Measurements (in mm).

Figured specimen NMV P208077 diameter 1.5.

Remarks. P. aspera is distinguished by its large size and coarse construction. Although similar to single chambers of *Sorosphaera tricella* specimens do not show any evidence of remains of formerly attached chambers but do often show vertical narrow attachment scars as if once attached to algal stems.

Mound (1968) places *aspera* into synonomy with the Recent *P. fusca* without comment.

Psammosphaera garraay n. sp.

Plate 8, figs 8,10-13; Pl. 11, figs 4-6,8.

Psammosphaera sp. Winchester-Seeto & Bell 1994: 202, figs 2.8, 2.10, 2.12; non 2.7, 2.9. 2.14.

Description. Test free; globular; organic wall, reticulated; no apparent apertures.

Holotype. AMF87212, Figure 2.8 Winchester-Seeto & Bell (1994: 202).

Type locality and horizon. RUN 44.4, 42.2 m above the base of the RUN section of the Garra Limestone, central New South Wales, Australia.

Material. Organic linings; 13 specimens from RUN (samples 44.4, 76.7), MUNG (samples 24.8, 71.5), GCR (samples 37, 343, 401.8), MW (samples 31, 95.6).

Distribution. Garra Limestone, Wellington, NSW, *pesavis-sulcatus* conodont zones; Martins Well Limestone, Broken River area, Qld, *sulcatus* conodont Zone.

Measurements (in mm).

Diameter = 71-144 μm (Av. 97 μm for 12 specimens).

Remarks. This species is easily separated from *Psammosphaera cava* by its reticulate surface, i.e. numerous raised ribs outlining various sized small areas. These raised ribs possibly represent the boundaries of the various sized sand grains that may have once covered the test and have now been lost by some cause (preservational or procedural) not yet understood. The size ranges of *P. cava* and *Psammosphaera garraay* are the same.

Numerous specimens of *P. garraay* show a partial equatorial "tear". This may be actual splitting or only an attachment scar similar to that seen in the Recent *P. fusca* Schulze.

Derivation of name. From the Australian Aboriginal word *garraay*, meaning sandhill; -referring to the type locality in the Garra Limestone (Wiradjuri language).

Psammosphaera sp. A

Plate 15, figs D, E

Description. Test free; ellipsoidal, with the longest axis about one and a half times as long as the other two subequal axes; cross-section circular; organic wall lining; surface reticulated with sharp raised edges; rare small pores(~ 5 µm diam.) scattered over the surface; no apparent aperture.

Material. Organic linings; 2 specimens.

Distribution. DDH2 depth 63.5m, *costatus-australis* conodont zones; Mostyn Vale Formation, *linguiformis* conodont Zone;

Measurements.

Length = 90-133 µm; Width = 60-107 µm; l/w= 1.3-1.5

Remarks. The ellipsiodal shape and the reticulate surface distinguishes this species from other *Psammosphaera* species which are normally subspherical to spherical. Conkin & Conkin (1964b) recorded a possible ellipsoidal *Psammosphaera* (from the Upper Devonian Louiseville Limestone, Missouri, U.S.A.) which had a thin wall formed of fine grains. This is probably a new species, but has been left in open nomenclature due to a lack of specimens.

Psammosphaera sp B.

Plate 15, figs F, G

Description. Test free; ellipsiodal with longest axis about one and one-third times as long as the other two subequal axes; more or less circular cross-section; organic wall lining; surface smooth; very small (~1 μm) rare pores scattered over surface.

Material. Organic linings; 3 specimens.

Distribution. OKE 0.9m, 112m, *costatus-varcus* conodont zones

Measurements.

Length = 80-101 μm; width = 70-80 μm; l/w = 1.1-1.3

Remarks. *Psammosphaera* sp. B differs from *Psammosphaera* sp A in its smooth wall surface and the fewer, and smaller surface pores. That the test wall was flexible is shown in specimen OKE 0.9 (Fig.) which has partially collapsed and which may even show an attachment scar.

?Psammosphaera sp. C

Plate 15, figs H-J

Description. Test free; globular; organic wall lining; surface with many strongly rimmed, subcircular craters; no obvious aperture; possible small pores (1-2 μm) in the rims of the craters.

Material. Organic linings, 5 specimens.

Distribution. TW-T Isis River, below Timor Limestone, Early Eifelian ?*costatus* conodont Zone; Isis section, base Timor Limestone, *costatus* conodont Zone; TIM 17.5m, Timor Limestone, *costatus* conodont Zone; DDH2 depth 62.1m, *costatus-australis* conodont zones; Gilwhite Limestone, age unknown – probably Early Eifelian

Measurements.

Diameter = 97-160 μm (Av. 130)

Remarks. The presence of large, sharp-edged craters serves to distinguish this *Psammosphaera* species. It is possible that this surface structure may be a diagenetic feature.

Psammosphaera sp. D

Plate 11, fig. 7

Description. Test free; globular; organic wall lining; surface has a "shaggy" appearance due to relatively high, narrow, rounded ridges; no apparent aperture.

Material. Organic linings; 2 specimens from MUNG (sample 76.2) and MSh (sample).

Distribution. Garra Limestone, Wellington, NSW, *pesavis* conodont Zone; Middle Shanda Beds, Siberia, *serotinus* conodont Zone.

Measurements.

Diameter of chamber = 76-79 μm.

Remarks. Psammosphaera sp. D is easily distinguished from other species of this genus by the unusual surface, which resembles a "shaggy" carpet. This is probably a new species, but has been left in open nomenclature pending the discovery of more specimens.

Genus **Sorosphaera** Brady, 1879

Type species. Sorosphaera confusa Brady, 1879

Diagnosis. Test free; variously arranged globular chambers, with no connection between chambers; no distinct aperture.

Remarks. The determination of species within *Sorosphaera* is difficult. The number of chambers joined together has, in the past, been a character used to distinguish separate species (Dunn 1942; McClellan 1966) even though McClellan (1966) considered that it was highly likely that several species were only various chamber combinations of the one species and he used the number of chambers for convenience. Gutschick & Treckmann (1959) found polythalamous forms in their material and thought it futile to attempt to split these into separate species. Kristan–Tollmann (1971b) revised the early Palaeozoic sorosphaerid foraminiferans and showed that using only the arrangement of chambers (planar or three-dimensional), five species could be distinguished (*S. tricella, S. bicella, S. confusa, S. subconfusa, S. papilla*). This classification is not useful for Australian material; although some samples may only have one form present, in many samples various groupings of chambers can occur and merge from one form to another; only two forms can consistently be separated : *S. tricella* and *S. confusa.*

Single chambered specimens of *Sorosphaera* are distinguished from *Psammosphaera* in having a much thinner test wall and in having one or more flattened surfaces.

Sorosphaera tricella Moreman, 1930

Plate 22, figs F, G

Sorosphaera tricella Moreman 1930: 47, pl. 5, figs 12, 14. – Dunn 1942: 324, pl. 42, fig. 15. – Browne & Schott 1963: 212, pl. 49, fig. 15, - McClellan 1966: 472, pl. 37, fig. 10; pl. 41, fig. 10. – Kristen-Tollmann 1971b: 173, Table 1.

Diagnosis. A species of *Sorosphaera* with a variable number of globular chambers arranged in a plane.

Description. Test free; globular chambers, varying numbers, joined in a plane; moderately loosely combined; wall thickness variable, finely - coarsely arenaceous; no apparent aperture.

Distribution. Early Silurian; WERR 16.2, Boree Creek Limestone, Borenore, NSW; Early Wenlock, *ranuliformis* conodont Zone; DSC 230, Mirrabooka Formation, Borenore, NSW; Early Wenlock, *ranuliformis* conodont Zone; QU 233, Windellama Limestone, Lochkovian, *delta* conodont Zone.

Measurements (in mm).

Figured specimen NMV P208070 chamber diameters 0.7-0.75

Figured specimen NMV P208071 chamber diameters 0.8-0.9.

Remarks. In this taxon I have included specimens with from one to five chambers, loosely arranged in a more or less linear manner. Because various sized chambers are grouped together, the variance between specimens is often marked but only one species is present. Although isolated specimens do have chambers smaller at one end and apparently enlarging in sequence, the variation of the chamber sizes within the specimens taken over the whole population present does not seem to show any apparent growth direction.

The wall thickness is variable even within the one sample. Specimens from WERR 16.2 were much thicker than those from elsewhere, ranging up to 100μm.

Sorosphaera sp. cf. S. confusa Brady, 1879

Plate 3, figs L. M; Pl. 8, Fig. 6; Pl. 11, fig. 9.

?*Sorosphaera* sp. Winchester-Seeto & Bell 1994: 202, fig 2.6.

Description. Test free; subglobular chambers joined together without definite arrangement; no apparent aperture; organic wall, surface reticulate.

Material. Organic linings: 2 specimens, from MUNG (sample 76.2) and Gelantipy Rd., Buchan, V. (sample 11T/81.7).

Normal foraminiferans: 50+ specimens from Windellama; 50+ specimens from Eurimbla; c. 20 specimens from Pigna Barney; c. 10 specimens from Timor and c. 10 specimens from the Moore Creek Limestone at Attunga.

Distribution. Garra Limestone, Wellington, NSW, *pesavis* conodont Zone; Taravale Formation, Victoria, *perbonus* conodont Zone; Windellama Limestone, NSW, *eosteinhornensis* to *delta* conodont Zone; Benneys Top Limestone, Pigna Barney, NSW, *dehiscens* to *perbonus* conodont Zone; Timor Limestone, NSW, *costatus* conodont Zone; Moor Creek Limestone, Attunga, NSW, *australis* to *kockelianus* conodont Zone.

Measurements.

Diameter of chamber 1 = 84.4 μm; Diameter of chamber 2 = 80-89 μm.

Remarks. Prior to the Kristann-Tollmann (1971a) revision of the early Palaeozoic sorosphaerid foraminifera, many species had been erected based only on the number of chambers in the attached masses. Kristan-Tollmann showed that using only the arrangement of chambers (planar or three-dimensional), five species could be distinguished. However, in the studies of normal-sized agglutinate foraminiferans in Devonian sediments from eastern Australia, the classification proposed by Kristan-Tollmann is not useful; within any one sample, various groupings of chambers can occur and merge from one form to another and to suggest that these are different species cannot be substantiated. Until there is more information on this simple organism from Recent sediments, we prefer to place the specimens figured herein with *S.* sp. cf. *S. confusa* Brady.

Both McClellan (1966) and Kristan-Tollmann (1971a) record this species from the Silurian.

Genus **Thuramminoides** Plummer, 1945 *emend.* Conkin, 1961.

Type species. Thuramminoides sphaeroidalis Plummer, 1945

Thuramminoides sphaeroidalis Plummer, 1945

Plate 7, fig. L; Pl. 17, figs A-C.

Thuramminoides sphaeroidalis Plummer 1945: 218, pl.15, figs 4-10.- Conkin & Conkin 1964: 71, pl. 12, figs 36-38 (with synonymy). - Conkin *et al.* 1981: 344, pl. 1, figs 4-7 (with extensive synonymy). - Bell 1996: 103, fig. 10 L. - Riegraf & Niemeyer 1996: 26, figs 4-6, 8-11, 14-15, 17, 20-23, 25-31, 45, 58-60, 63.

Trochammina bursaria Chapman 1933: 246, pl. 11, fig. 3.

Material. Normal foraminifera: many tens of specimens; organic wall linings: 15 specimens.

Distribution. Buchan Caves Limestone and Taravale Formation; Buchan and Bindi, Victoria; Emsian*, dehiscens –inversus* conodont zones. DDH2 depths 55.9m, 63.5m, 73m, *costatus-australis* conodont zones; 0217, Glenrock, ?late Emsian-early Eifelian; OKE sample 0.9, *costatus* conodont Zone; Yarrimie below Jacksons Quarry, *costatus-australis* conodont zones; TIM 18.9, *costatus* conodont Zone

Measurements .

Normal foraminiferan – figured spec. diameter 0.56 mm

organic linings – diameter (max.) 20 -120µm (av. 95 µm).

Remarks. This species is very widespread in the Buchan-Bindi area, Victoria, and was found in many samples which contained no other foraminiferans. It was more common in the deeper water samples from Old Taravale Road cutting (OTRC) and at south arm, Limestone Creek, Bindi (SALC), but infrequent in the purer shallower water limestones of Bonanza Gully (BON) and Old Rocky Camp Quarry (ORCQ 10-15). Specimens were always compressed and often split.

Trochammina bursaria, which Chapman (1933) described from possible Lower Devonian mudstones near Mitcham, Victoria (registered specimen NMV P26009, Museum of Victoria Palaeontological Collection), is identical to forms placed here in *T. sphaeroidalis*; the supposed 'internal tubular chamber' of Chapman's species is a compressional effect on the edge of the specimen.

This is the first report of an organic lining for this species and lends weight to the placement of *Thuramminoides* within the Foraminifera. Loeblich & Tappan

(1988) have suggested that there were several species included in the original description of this species and they have restricted the concept of *T. sphaeroidalis* Plummer to forms with a smooth exterior and interior.

The actual taxonomic position of this species is not known; it has been referred to as a foraminiferan (Plummer 1945; Loeblich & Tappan 1988b), as having spore-like affinities (Conkin *et al.*,1965) and having radiolarian affinities (Conkin *et al.*, 1968; Conkin *et al.*, 1981), but these differing placements may be due to confusion over what actually constitutes *T. sphaeroidalis*.

This is a very common species in the Australian material. The specimens show a variety of surface styles which may represent, in part, some pyritization of the wall.

Subfamily STEGNAMMININAE Moreman, 1930

Genus **Stegnammina** Moreman, 1930

Type species. Stegnammina cylindrica Moreman, 1930

Diagnosis. Test free; subcylindrical chamber, straight or curved; wall agglutinate, thin; no definite aperture.

Stegnammina cylindrica Moreman, 1930

Plate 3, fig. K

Stegnammina cylindrica Moreman 1930: 49, pl. 7, fig. 12. – Browne & Schott 1963: 210, pl.49, figs 11,12. – McClellan 1966: 475, pl. 36, figs 15, 16; pl. 40, figs 15-16. – Mound 1968: 84, pl. 5, figs 32,33. – Bell 1996: 90, fig. 9K.

Description. Test free; cylindrical, ends slightly rounded; fine grained test with a smooth inner surface and a slightly roughened exterior; no apparent aperture.

Distribution. QU 209, QU 233, Windellama Limestone, Lochkovian, *eurekaensis-delta* conodont zones; OTRC 2, Taravale Formation, Emsian, *serotinus* conodont Zone.

Remarks. Although there is a large age difference between the occurrences of this species, there was little difference between specimens from either locality.

Some rarer specimens show an almost triangular cross-section rather than the round section of the commoner form; they are similar to *S. triangularis* Moreman 1930, but are not considered as a separate species as the shape difference may be a deformation due to preservation.

Family SACCAMMINIDAE Brady, 1884

Subfamily SACCAMMININAE Brady, 1884

Genus **Saccammina** M. Sars *in* Carpenter, 1869

Type species. Saccammina sphaerica Brady, 1871

Diagnosis. Test free; subglobular chamber; wall agglutinate, thin; aperture rounded either flush or may be produced on a short neck.

Saccammina biosculata Moreman, 1933

Plate 3, fig. O

Saccammina biosculata Moreman 1933: 395, pl. 47, fig. 6. - Bell 1996: 90, fig. 6O.

Diagnosis. A species of *Saccammina* with apertural neck divided for most of its length.

Description. Test free; small; main chamber flattened but originally probably spherical; neck short, squat; wall thin composed of fine sand grains with little cement; surface roughly finished; the neck is divided into two smaller necks for most of its length, these being almost perpendicular to each other; a simple aperture at end of each neck.

Distribution. ORCQ 10-15, Buchan Caves Limestone, Buchan, Victoria; Emsian, *perbonus* conodont zone.

Measurements (in mm).

length 0.17; width 0.12.

Remarks. One specimen was found but, although slightly smaller than Moreman's figured type, it does not differ in any other aspect. Moreman's specimen is much older coming from Middle Silurian sediments of Oklahoma, U.S.A.

The twinned apertural neck separates *S. osculata* from all other species of *Saccammina.*

Saccammina cyclops Bell, 1993

Plate 1, figs O, P.

Saccammina cyclops Bell 1993: 146, figs 3O, P.

Diagnosis. A species of *Saccammina* with a small aperture on a short neck.

Description. Test free; spherical; test formed of various sized sand grains fitted together with little cement giving a rough surface; aperture circular, on a small neck one grain high.

Distribution. Cowombat Formation, Cowombat, Victoria; Ludlow, *crispa* conodont Zone.

Measurements (in mm).

diameter of chamber 0.35

Remarks. There is little size variation between specimens. This species is distinguished by its small aperture and very short neck.

Derivation of Name. cyclops(L.): a race of one-eyed giants; referring to the single elevated aperture.

Saccammina cumberlandiae (Conkin, 1961)

Plate 3, fig. N

Proteonina cumberlandiae Conkin 1961: 248-250, pl. 14, figs 1-3; pl. 26, figs 4-5; text-figs 2-3. - Conkin *et al.* 1963: 222, pl. 1, figs 12-14, (with synonymy). – Browne & Schott 1963: 215, pl. 50, figs 11,12. – Conkin & Conkin 1964a: 32, pl. 2, figs 38-41, (with synonymy). – Conkin *et al.* 1965: 346, pl. 1, figs 15-19, (with synonymy).

Lagenammina cumberlandiae. – McClellan 1966: 477, pl. 36, fig. 19, pl. 40, fig. 19.

Saccammina cumberlandiae. – Bell 1996: 90, fig. 6N.

Diagnosis. A species of *Saccammina* with a wide tapering neck.

Description. Test free; consisting of one inflated, slightly tapering chamber with a short, wide, tapering neck; aperture circular at end of neck; wall formed of medium-sized quartz grains, fairly smoothly finished.

Distribution. Bonanza Gully, Bindi, Buchan Caves Limestone; *perbonus* conodont zone.

Measurements (in mm).

Figured specimen, NMV P126982. length 0.28; max. diam. 0.23; chamber length 0.23; neck length 0.05; neck max. diam. 0.11; neck min. diam. 0.05; length/width 1.23.

Remarks. Only rare specimens of this form were recovered. They compare closely with the description of *S. cumberlandiae* from the Lower Carboniferous (Lower Mississippian) of the U.S.A., although being somewhat more rounded (l/w=1.23) but this ratio is quite variable (Conkin *et al.* 1963; Conkin & Conkin 1964a; range 1.19-1.94).

Saccammina mea n. sp.

Plate 9, figs 1,2,4; Pl. 12,fig.6-9; Pl. 16, figs A-F.

Saccammina sp. Winchester-Seeto & Bell 1994: 202, figs 4.1, 4.2, 4.4 *non* 4.3, 4.5, 4.6.

Diagnosis. A species of *Saccammina* being an organic lining with a reticulated wall surface and aperture flush with wall surface.

Description. Test free; globular; organic wall lining, surface reticulate; a single large round aperture, flush with the test surface.

Holotype. AMF102656, Pl. 12, fig. 9.

Type locality and horizon. RUN 44.4, 42.2 m above the base of the RUN section of the Garra Limestone, central New South Wales, Australia.

Material. Organic linings; 11 specimens from MUNG (sample, 24.8, 76.2), RUN (samples 44.4, 70.6, 85.7), GCR (sample 106, 117.3, 412.2), MW (sample 24.6) and MSh (sample 1); 9 specimens from Tamworth area.

Distribution. Garra Limestone, Wellington, NSW, *pesavis-sulcatus* conodont zones; Martins Well Limestone, Broken River, Qld., *sulcatus* conodont Zone; Middle Shanda Beds, Siberia, *serotinus* conodont Zone; OKE sample 0.9, *costatus* conodont Zone; DDH2 depths 55.9m, 59.2m, 62.1m, 68.2m, *costatus-australis* conodont zones; Yarrimie below Jacksons Quarry, *costatus* conodont Zone.

Measurements.

Specimens from Wellington area - Diameter = 70-128 μm (Av. 95 μm); diameter of aperture = 5-9 μm for 9 specimens.

Specimens from Tamworth area - Diameter (max.) = 90-107 μm; diameter of aperture = 3-5 μm (for 3 specimens)

Remarks. Saccammina mea is distinguished from *Saccammina* sp. by its reticulate surface and from *S. ampullacea* (Crespin) and *S. wingarri* n. sp. by the flush aperture.

The linings show a finely reticulated surface, although the size of the reticulated ridges varies from specimen to specimen (compare OKE 0.9 and DDH2/89 55.9; Plate 16 A, B-C); this variation may be due to the presence of small grains in the original test, or degradation of the surface subsequently. Some specimens have an oily residue partially covering the surface (Plate16 D-E); this surface feature has previously been observed on chitinozoans and other organic-walled microfossils.

The surface texture does not vary significantly in the specimens from the Garra Limestone, Martins Well Limestone and Middle Shanda Beds, Siberia (Bell & Winchester-Seeto 1999); the diameter of the test falls within a similar size range, but the diameter of the aperture is slightly smaller. Plate 16 F (DDH2/55.9m) shows a specimen with what appears to be an encrusting, hollow, growth; this may be either foraminiferan or algal in nature.

*Derivation of name***.** From the Australian Aboriginal word *mea,* meaning open mesh, referring to the reticulate wall surface (Aboriginal language from Queensland).

Saccammina wingarri n. sp.

Plate 12, figs 12-14; Pl. 16, figs I-K.

Diagnosis. A species of *Saccammina* being an organic lining with a very short protruding neck, large aperture and a smooth wall.

Description. Test free; globular; organic wall, surface smooth; aperture rounded and raised on a short neck.

Holotype. AMF102669, Pl. 12, fig. 12

Type locality and horizon. PD 166, 388.4m, Pillara Limestone, Pillara Range, Canning Basin, WA, Late Givetian-Early Frasnian, ?*varcus* conodont Zone.

Material. Organic linings; 3 specimens from PD 166/388.4m and from LSA (sample 113), 2 specimens from Tamworth area.

Distribution. Pillara Limestone, Pillara Range, Canning Basin, WA, *disparilis* – *asymmetricus* conodont zones; Serre Formation, Montagne Noire, France, E.

asymmetricus conodont zone; ?TIM 36.6, Timor Limestone, *costatus* conodont Zone; Mostyn Vale Formation, *linguiformis* Condont Zone

Measurements .

Specimens from Canning Basin: diameter (max.) = 90-107 μm; diameter of aperture = 3-5 μm (for 3 specimens);

Diameter of chamber = 80-124 μm; Diameter of neck = 23-40 μm; Length of neck = 6-12 μm; Dneck/Dchamber = 0.3; Lneck/Dchamber = 0.1.

specimen from TIM 36.6, diameter (max.) = 138 μm

specimen from Mostyn Vale, diameter (max.) = 73 μm

Remarks. The very short, protruding neck (less than 10% of test diameter) serves to separate this smooth walled species from *Saccammina* sp. *S. wingarri* differs from *S. ampullacea* in having a smooth wall surface and a smaller apertural neck. The neck appears to be of a different construction to the rest of the test wall and usually shows a blocky surface. The aperture is much larger than in other *Saccammina* species. Although there are only a small number of specimens, this species is distinctive and readily distinguished from any other species of *Saccammina*; furthermore specimens have been observed from Western Australia and from southern France, adding weight to the decision of erecting a new species.

Size and appearance of the specimen from Mostyn Vale closely matches specimens from the Pillara Limestone and Serre Formation (Bell & Winchester-Seeto, 1999); however the specimen from the Timor Limestone shows a more "bumpy" (mogular) surface, and a less defined apertural neck.

The stratigraphic range of this species is confidently extended up to *linguiformis* Condont Zone, and questionably down to *costatus* conodont Zone.

Derivation of name. From the local Australian Aboriginal word, *wingarri,* meaning neck, referring to the prominent neck (Gooniyandi language).

Saccammina sp. cf. S. ampullacea (Crespin 1961)

Plate 12, fig. 15; Pl. 16, fig. H

?Lagenammina ampullacea Crespin 1961: 404, pl. 66, figs 6-8.

Saccammina sp. (in part) Winchester-Seeto & Bell 1994: 202, figs 4.3, 4.5, 4.6 *non* 4.1, 4.2, 4.4.

Description. Test free; a globular chamber with a pronounced neck; wall surface reticulate; aperture rounded, on the end of a produced neck.

Distribution. Garra Limestone, Wellington, NSW, *pesavis-sulcatus* conodont zones; TIM 18.9, Timor Limestone, *costatus* Condont Zone.

Material. Organic linings; 3 specimens from MUNG (sample 8.4) and GCR (samples 50.2, 412.2); 1 broken specimen from TIM 18.4, Tamworth.

Measurements .

Wellington specimens - Diameter of chamber = 112-113 µm; Diameter of neck = 22-23 µm for 2 specimens.

Tamworth specimen - Diameter (max.) = approx. 170 µm; diameter of neck = 36 µm

Remarks. Crespin (1961) placed her Late Devonian forms of this species in the genus *Lagenammina* because of the relatively long neck. Conkin & Conkin (1968) found apparent attachment scars on either the body and/or neck and suggested placement in *Oxinoxis*. Our specimens, although much smaller, show no evidence of an attachment scar, and, as the neck is not excessively long, must be placed in *Saccammina*.

Although the only specimen from the Tamworth area (TIM 18.9) is broken it appears to be the same as S. *ampullacea* previously described. This specimen is, however, significantly larger than the previously described specimens.

Saccammina sp.

Pl. 12, figs 10-11

Description. Test free; globular; organic wall, surface smooth; a single round aperture flush with the surface.

Distribution. Garra Limestone, Wellington, NSW, *pesavis* conodont Zone; Tyers Quarry, Cooper Creek Formation, Victoria, *kindlei* conodont Zone; Boola Quarry, Coopers Creek Formation, Victoria, *kindlei* conodont Zone.

Material. 3 specimens from RUN (sample 207), BOO (sample 13.1), Tyers Q. (sample "Far end").

Measurements.

Diameter = 78-90 μm; Diameter of aperture = (approx.) 4-5 μm.

Remarks. The flush aperture and the smooth wall surface serve to distinguish *Saccammina* sp., from any other known species. It is most probably a new species, but as there are only three specimens, it has been left in open nomenclature, pending the recovery of more individuals.

Genus **Amphitremoida** Eisenack, 1937

Type species. Amphitremoida citroniforma Eisenack, 1937

Diagnosis. Test free; single fusiform chamber, with small aperture at each end of chamber.

Amphitremoida eisenacki Conkin & Conkin, 1964

Plate 5, figs I-K.

Amphitremoida eisenacki Conkin & Conkin 1964b: 73, pl. 12, figs 8-10.

Ordovicina eisenacki. – Bell 1996: 92, figs 8I-K.

Diagnosis. A species of *Amphitremoida* being proportionately more slender and with more extenuated apertural ends.

Description. Test free; a single fusiform chamber with a small aperture at each end; the apertural ends slightly produced; test composed of fine sand grains, slightly roughly finished; the surface of the test shows transverse low ridges.

Distribution. Buchan Caves Limestone and Taravale Formation; Buchan and Bindi, Victoria; Emsian, *dehiscens -inversus* conodont zones.

Measurements (in mm).

	Locality	length	width	aperture 1	aperture 2
Figd spec NMVP199434	ORCQ	0.36	0.2	0.03	0.02
Figd spec NMVP127001	BON13.5-15	0.36	0.12	0.03	broken
Figd spec NMVP127000	BON 36-39	0.6	0.35	0.09	0.05

Remarks. The specimens recovered are larger than those described by Conkin & Conkin (1964b) but appear otherwise to be the same species. All specimens are compressed and the surface transverse ridges may be an artifact of preservation. The apertural ends are deformed and the measurements given are lower values only.

The present specimens differ from the larger form recorded by Conkin & Conkin (1964b) as *Amphitremoida* sp. in lacking the 'collar' surrounding the apertures, and from *A. hauffmani* (Conkin & Conkin 1964b) in their much larger size and different length/width ratios. Malec (1992) described *Ordovicina kielcensis* from the Upper Emsian beds of Góry Świętokrzyskie Mountains of Poland which is similar to *A. eisenacki* but appears from the data given to be more slender; however the varying amounts of compaction (flattening) of specimens could easily account for the small differences between these two species.

Loeblich & Tappan (1988b) have reinstated *Amphitremoida* Eisenack as distinct to *Ordovicina* Eisenack 1937 which they reserve for specimens having little or no agglutinated covering.

Amphitremoida sp. cf. A. citroniforma Eisenack, 1937

Plate 9, figs 14-16; Pl. 11, figs 10,11.

Ordovicina sp. Winchester-Seeto & Bell 1994: 205, figs 3.14, 3.15.

Description. Test free; ovate chamber, widest at the centre and tapering evenly to the ends; test organic wall lining, thin; surface shows grainy impressions; apertures rounded (?) about one-third width of test at the end of the chamber.

Material. Organic linings; 4 specimens from MUNG (sample 24.8), RUN (sample 70.6), GCR (sample 74.3) and Kuragh (sample 1).

Distribution. Garra Limestone, Wellington, NSW, *pesavis-sulcatus* conodont zones; Shogram Formation, Pakistan,?Late *hermanni* conodont Zone.

Measurements .

Maximum diameter = 134-316 μm (Av. 248 μm); Minimum diameter = 68-

200 μm (Av. 125 μm); Dmax/Dmin = 1.6-1.9.

Remarks. The species shows a variable number of grain impressions on the wall, but never any attached grains, and these impressions show a range in size. This species is not as elongate as *A. eisenacki* (Bell 1996, Conkin & Conkin 1964b) or *A. kielcensis* Malec (1992). *Amphitremoida citroniforma* has previously been recorded from the Ordovician (Llanvirnian) of NW Germany (Riegraf & Niemeyer 1996) and from the Lower Silurian of Illinois (Dunn 1942); our species is compared to *A. citroniforma* because of disjunct ranges.

Genus **Lagenammina** Rhumbler, 1911

Type species. Lagenammina laguncula Rhumbler, 1911

Diagnosis. Test free;, single flask-shaped chamber; wall agglutinate, thin; aperture rounded at end of long neck.

Remarks. The difference between the genera *Saccammina* and *Lagenammina* is based upon the relative lengths of the apertural neck – in *Saccammina* the neck is very short or altogether wanting (Holbourn & Kaminski 1995), whilst in *Lagenammina* it is quite long. Mound (1968) implies that a possible distinguishing feature was that *Saccammina* has no inner organic lining whilst *Lagennammina* does; however Bender (1995) has shown the Recent *Saccammina sphaerica* does possess an inner organic lining.

Lagenammina laxacolla Bell, 1996

Plate 4, figs K, M-N; Pl. 5, fig. A.

Lagenammina laxacolla Bell 1996: 91, figs 7K, M,N; 8A.

Diagnosis. A species of Lagenammina with a short wide neck.

Description. Test free; small; a discoidal chamber with a straight, wide neck wall formed of fine grains, smoothly finished; aperture circular at end of neck. Some specimens have an aboral spine.

Distribution. Buchan Caves Limestone and Taravale Formation; Buchan and Bindi, Victoria; Emsian, *perbonus – inversus* zones.

Holotype. NMV P126972, Plate 4, fig. K.

Type locality and horizon. Gelantipy Road, Buchan, sample Ma 13.

Measurements (in mm).

	Locality	length	width	aperture
Holotype NMV P126972	Ma 13	0.5	0.48	0.1
Paratype NMV P199422	SALC 9	0.32	0.28	0.05
Paratype NMV P199423	SALC 7	0.53	0.42	0.06
Paratype NMV P199424	MA 13	0.48	0.32	0.06
Paratype NMV P199425	BON 36-39	0.48	0.26	0.07

Remarks. This small species differs from *L. stilla* in having a short, wide neck.

Some specimens from Bonanza Gully and Gelantipy Road in having an aboral spine present may constitute a separate species. Further sampling will settle this question.

Derivation of Name. *laxus* (L.): wide + *collum* (L.): neck; referring to the characteristic of the species.

Lagenammina ovata Bell, 1996

Plate 4, figs O-P; Pl. 12, figs 1-2.

Lagenammina ovata Bell 1996: 92, figs 7O, P.

Diagnosis. A species of *Lagenammina* with an ovate body chamber and short, narrow neck.

Description. Test free; large, ovate body chamber, with a short, narrow neck; wall formed of uniform grains with little cement; surface slightly rough; aperture circular at end of neck.

Distribution. Buchan Caves Limestone and Taravale Formation; Buchan and Bindi, Victoria; Emsian, *perbonus - inversus* conodont zones; organic wall linings from Shogram Formation, Kuragh, Pakistan, ?Late *falsiovalis* conodont Zone.

Holotype. NMV P126973, Plate 4, fig. O.

Type locality and horizon. South arm, Limestone Creek, Bindi; sample 9.

Measurements (in mm).

Normal foraminiferans:

	Locality	length	width	aperture
Holotype NMV P126973	SALC 9	0.74	0.38	0.06
Paratype NMV P199426	ORCQ	0.48	0.36	0.07

Organic wall lining: Diameter of test = 97 μm; Diameter of neck = 37 μm.

Remarks. L. ovata differs from the other species of *Lagenammina* in its large, ovate body chamber and short, narrow neck. It seems closest to *L. talenti* from which it differs in body/neck proportions and in the smoother test surface.

The organic linings from Kuragh are about one-quarter the size of the intact tests recovered from southeastern Australia . The organic wall is finely reticulate which agrees with the small, uniform grains used in the test of the normal agglutinated specimens.

Derivation of Name. *ovata* (L.): oval-shaped.

Lagenammina sphaerica Moreman, 1930

Plate 4, figs J-L.

Lagenammina sphaerica Moreman 1930: 51, pl. 5, fig 15. – Dunn 1942: 327, pl. 42, fig. 29. – Browne & Schott 1963: 214, pl. 50, fig. 2, - Mound 1968: 90, pl. 6, figs 4,5. – Bell 1996: 91, figs 7J,L.

Diagnosis. A species of *Lagenammina* with a globular body chamber and a long neck.

Description. Test free; a globular chamber with a long, narrow neck; aperture a simple opening at the end of the neck; test formed of fine grains , with a fairly smooth surface.

Distribution. Buchan Caves Limestone and Taravale Formation; Buchan and Bindi, Victoria; Emsian, *perbonus -inversus* zones.

Measurements (in mm).

Figured specimen NMV P126969 length of neck 0.16; width of chamber 0.44; aperture 0.06.

Remarks. Due to compression during preservation most of the specimens were somewhat flattened but the degree of distortion was quite variable even within the one sample. Specimens from ORCQ 10-15 were preserved as casts and show the spherical shape without compression. The neck was often slightly curved, and its diameter varied between localities but, until more and better preserved material is found, these are not considered to be of sufficient importance to differentiate species.

Lagenammina stilla Moreman, 1930

Plate 4, fig. F.

Lagenammina stilla Moreman 1930: 51, pl. 6, fig. 6. – Dunn 1942: 327, pl. 42, figs 30,31. – Browne & Schott 1963: 213, pl. 49, fig. 20, - Mound 1968: 91, pl. 6, figs 6,7. – Bell 1996: 91, fig. 7F.

Diagnosis. A species of *Lagenammina* with a globular body chamber and a short neck.

Description. Test free; small; a globular chamber with a very short neck, about one-sixth the length of the globular chamber; thin walled, about two grains thick; test formed of a mixture of large and small sand grains, surface rough; aperture circular at end of neck.

Distribution. Ma 13, Taravale Formation; Emsian, *inversus* Zone

Figured specimen. NMV P126970, from Ma 13, Gelantipy Road, Buchan; Taravale Formation; Emsian, *inversus* Zone.

Measurements (in mm).

Figured specimen - length 0.3; width 0.24; aperture 0.04.

Remarks. The test is made of a random placement of small and larger sand grains apparently with little cement, giving the test a rough external surface. The interior is smooth suggesting that originally there was an inner organic layer on which the grains were laid.

Lagenammina talenti Bell, 1996

Plate 4, figs G-I.

Lagenammina talenti Bell 196: 91, figs 7G - I.

Diagnosis. A species of *Lagenammina* with an ellipsoidal body chamber and a long neck.

Description. Test free; small; ellipsoidal body chamber followed by a long, wide, slightly curving neck; wall formed of largish grains, surface rough; aperture circular at end of neck.

Distribution. Buchan Caves Limestone and Taravale Formation; Buchan and Bindi, Victoria; Emsian, *perbonus -inversus* zones.

Holotype. NMV P126971, Plate 4, fig. G.

Type locality and horizon. South arm, Limestone Creek, Bindi; sample 7.

Measurements (in mm).

	Locality	length	width	aperture
Holotype NMV P126971	SALC 7	0.5	0.2	0.05
Paratype NMV P199419	SALC 7	0.8	0.26	0.06
Paratype NMV P199420	ORCQ	0.48	0.26	0.09
Paratype NMV P199421	Ma 13	0.51	0.27	0.07

Remarks. The body chamber is usually compressed. The long neck shows different degrees of curvature which suggests that it was flexible when living. The overall shape of this species clearly separates it from other *Lagenammina*. *L. silnica* Malec

1992 has a similar body chamber shape but is a much smaller species and lacks the long, produced neck of *L. talenti*.

Derivation of Name. For Professor J. A. Talent, Macquarie University, for his contributions to the biostratigraphy of the Devonian of Australia.

Lagenammina sp.

Plate 12, figs 3-5.

Description. Test free; a flattened, rounded chamber (broken), followed by a short neck; aperture rounded at the end of a neck; organic wall lining, surface coarsely reticulate, with larger and smaller defined areas, but the neck is relatively smooth.

Material. Organic linings; 3 broken specimens from MUNG (samples 8.4, 24.8) and GCR (sample 262).

Distribution. Garra Limestone, Wellington NSW, *pesavis - sulcatus* conodont zones.

Measurements .

Diameter of neck = 42-50 μm.

Remarks. As the specimens have broken body chambers, it is not clear what the original shape may have been. Apart from size, *Lagenammina* sp. is close to *L. talenti* Bell 1996, but shows a more constricted neck. It is also similar to *L. silnica* Malec 1992 in having a short neck, but most of the body is missing and so cannot be accurately compared.

Genus **Stomasphaera** Mound, 1961, *emend.* Bell, 1993

Type species. Stomasphaera brassfieldensis Mound, 1961.

Diagnosis. Test free; single or multithalamous; globular chamber-subglobular chambers irregularly attached together; wall agglutinate; aperture a single rounded opening in each chamber.

Remarks. In erecting *Stomasphaera* from the Indiana Lower Silurian, Mound (1961) mentioned single chambers occurring. McClellan (1966) erected *Sorostomasphaera* for multilocular forms otherwise similar to *Stomasphaera*; he stated (McCellan 1966: 479) '…the differentiation of single chambers [of *Sorostomasphaera*] from *Stomasphaera* is highly subjective'. For this reason it seems better to extend the diagnosis of *Stomasphaera* to include multilocular tests and synonymize *Sorostomasphaera* with it. The genus *Stomasphaera* differs from *Saccaminoides* Geroch, 1955 which shows a sharp change in direction of coiling after the first 2-3 chambers (Loeblich & Tappan 1988b).

Stomasphaera cyclops Bell, 1996

Plate 6, figs A-D.

Stomasphaera cyclops Bell 1996: 91, figs 9A - D.

Diagnosis. A species of *Stomasphaera* with subglobular chambers arranged in an arcuate series.

Description. Test free; subglobular to ovate chambers joined to form a linear to arcuate series; chamber size variable but not necessarily increasing in size along the series; test wall coarsely agglutinate with a smooth to rough surface; aperture rounded to elongate, may be depressed slightly and is surrounded by an area of finer grains.

Distribution. Samples QU 209, QU 233 Windellama Limestone, NSW; Lochkovian, *eurekaensis-delta* zones; BON 220-240, Buchan Caves Limestone, Bindi, V.; Emsian, *perbonus* conodont zone.

Holotype. NMV P126977, Plate 6, fig. A.

Type locality and horizon. Bonanza Gully, Bindi, sample 220-240.

Measurements (in mm).

(largest chamber only measured)

	Locality	length	width	aperture
Holotype NMVP126977	BON 220-240	0.35	0.23	0.09x0.06
Paratype NMV P199432	BON 220-240	0.4	-	0.08
Paratype NMV P199433	BON220-240	0.4	-	0.12

Remarks. S. cyclops differs from the Victorian Late Silurian form *S. globosa* in having a larger aperture, in the chamber shape being not as globular but more elongate, and in having a wide band of finer grains about the aperture. The aperture remains open in early chambers. There is apparently no connection between successive chambers. Both single and multithalamous tests were present.

Derivation of Name. cyclops (L.): a race of one-eyed giants; referring to the large aperture.

Stomasphaera globosa Bell, 1993

Plate 1, fig. I.

Stomasphaera globosa Bell 1993: 146, fig. 3I.

Diagnosis. A species of *Stomasphaera* with globular chambers and a small arcuate aperture.

Description. Test free; finely arenaceous; three globular chambers arranged roughly rectilinearly; chambers firmly attached to each other but with no apparent openings between them; sutures may or may not be clearly defined; aperture a small arcuate to oval opening in each chamber; wall smooth.

Distribution. Cowombat Formation, Cowombat, Victoria; Ludlow, *crispa* conodont zone.

Holotype. NMV P137621, Plate 1, fig. I.

Type locality and horizon. Cowombat, sample 2.

Measurements (in mm).

Holotype length 1.7; maximum chamber diam 0.75.

Remarks. Single, double and triple chambered specimens present indicate that this species has a monothalamous test which may aggregate into multiform shapes. The apertural shape varies depending upon the amount that the wall grains protrude into the aperture so giving variations from almost slit-like to subcircular. Some specimens have a finer rim of grains surrounding the aperture but this is easily broken away. *S. globosa* differs from *S. cyclops* in the spherical chambers and in the small arcuate aperture with no rim of finer particles.

Subfamily THURAMMININAE Miklukho-Maklay, 1963

Genus **Thurammina** Brady, 1879

Type species. Thurammina papillata Brady, 1879.

Diagnosis. Test free; single globular chamber; wall agglutinate, thin; apertures many, usually raised on small mamellate protrubances.

Thurammina echinata Dunn, 1942

Plate 5, figs D-E.

Thurammina echinata Dunn 1942: 331, pl. 42, figs 20-21, 23. – Mound 1968: 100, pl. 6, figs 23,24. – Bell 1996: 94, figs 8D,E. – Riegraf & Niemeyer 1996: 28, Figs 7,12,13,16,18, 32-34,56,57.

Diagnosis. A species of *Thurammina* with a globular chamber covered with short papillae.

Description. Test free; globular, with many short, pointed papillae on the surface; papillae are hollow with a simple opening at the end of each; test composed of very fine sand grains, smoothly finished.

Distribution. Buchan Caves Limestone and Taravale Formation; Buchan and Bindi, Victoria; Emsian, *dehiscens –perbonus* conodont zones.

Measurements (in mm).

Figured specimen NMVP126978 diameter - 0.48.

Remarks. A widespread and common species. The test is thin and often distorted or compressed but without showing any signs of breakages indicating that the test may have been flexible when the protist was alive.

Thurammina foersteri Dunn, 1942

Plate 5, fig. F.

Thurammina foersteri Dunn 1942: 331, pl. 43, fig. 27. - Browne & Schott 1963: 219, pl. 50, fig. 13. - Bell 1996: 96, fig. 8F.

Diagnosis. A species of *Thurammina* with two, dome-shaped papillae.

Description. Test free; globular, with two low, dome-shaped papillae almost diametrically opposed; test wall made from even sized, very small grains, smoothly finished; aperture a simple opening at the summit of each papilla.

Distribution. ORCQ 10-15, Murrindal Limestone; Emsian, *perbonus* conodont zone.

Measurements (in mm).

Figured specimen NMVP126981 diameter – 0.39.

Remarks. My specimens are larger than Dunn's original (0.29 mm) but otherwise there are no apparent differences.

Thurammina mirrka n. sp.

Plate 13, figs 2-3; Pl. 17, fig. F.

Diagnosis. A species of *Thurammina* being an organic lining with numerous apertures flush with the wall surface.

Description. Test free; originally globular; moderate number of apertures (about

20), evenly distributed over test, and seemingly flush with surface, apertures vary in size; organic wall lining, surface roughened.

Holotype. AMF102664, Pl.13, fig. 3.

Type locality and horizon. GCR 412.2, 410.1m above the base of the GCR section of the Garra Limestone, central New South Wales, Australia.

Material. Organic linings; 4 specimens from RUN (sample 237.6) and GCR (samples 106, 401.8, 412.2); 2 specimens from Glenrock.

Distribution. Garra Limestone, Wellington, NSW, *pesavis-sulcatus* conodont zones ; 0217, Glenrock, ?late Emsian–early Eifelian; Yarrimie, below Jacksons Quarry, *costatus-australis* conodont zones

Measurements .

Specimens from Wellington - Diameter of chamber = 70-110 μm (Av. 92 μm for 4 specimens).

Specimens from Glenrock - Diameter (max.) = 80-150 μm; diameter of pores = 2-3 μm

Remarks. The main feature of *Thurammina* is the presence of the apertures raised on papillae (Loeblich & Tappan, 1988b). This new species is placed in the genus *Thurammina* because of the large number of simple apertures present even though they appear not to be raised above the general wall surface; the numerous apertures preclude placement in the genera *Saccammina* or *Psammosphaera*. This may well represent a new genus but more specimens are required to settle this point.

Derivation of name. From the Australian Aboriginal word *mirrka*, meaning cave, referring to the Wellington Caves near the type locality (Ngiyampaa language).

Thurammina sp. cf. T. arcuata Moreman, 1930

Plate 13, fig. 4.

Description. Test free; globular (most specimens are distorted and compressed); a small number of simple apertures, flush with the surface of the test.

Material. 5 specimens from GCR (samples 37, 55, 285, 412.2).

Distribution. Garra Limestone, Wellington, NSW, *pesavis-sulcatus* conodont zones.

Measurements.

Diameter of chamber = 94-98 μm; Diameter of aperture = 1-2 μm.

Remarks. Both smooth and reticulate surfaces occur on specimens in this species. Moreman's specimens had only four apertures but Browne & Schott (1963) extended the concept of the species to include specimens with more apertures and suggested that, with enough specimens, an ontogenetic sequence would show an array of apertural projections.

All previous records of *T. arcuata* are from the Silurian (Browne & Schott, 1963; see reference list; Dunn, 1942; McClellan, 1966; Stewart & Priddy, 1941).

Thurammina pustulosa Gutschick, Weiner & Young, 1961

Plate 17, figs G-H.

Thurammina pustulosa Gutschick, Weiner & Young. Gutschick, Weiner & Young 1961: 1211, text-fig. 4, 22.

Diagnosis. A species of *Thurammina* with numerous short, pointed protuberances on wall surface.

Description. Test free; subglobular to globular; organic wall lining, surface with many short, pointed, randomly placed protruberances; small rounded apertures at ends of most of these protuberances; larger pores occur between the projections.

Material. Organic linings; 5 specimens.

Distribution. Mostyn Vale, *linguiformis* conodont Zone

Known other occurrence. Tournaisian, Chappel Limestone, Texas,

Measurements .

Diameter (max.) = 92 -144μm; diameter (min) = 80-140;

diameter of apertures = 1-2 μm; diameter of pores = 3-6 μm;

Diameter max./diameter min. = 1-1.2

Remarks. These specimens closely match *T. pustulosa* from the Tournaisian Chappel Limestone of Texas (Gutschick *et al.*1961), and differs from *T. adamsi* Conkin & Conkin 1964 in having a greater number of, and shorter, more pointed papillae.

Thurammina quadritubulata Dunn, 1942

Plate 13, fig. 9.

Thurammina quadritubulata Dunn 1942: 334, Pl. 43, fig. 22. – Blumenstengel 1961: p. 318.

Diagnosis. A species of *Thurammina* with a globular test and four papillae.

Description. Test free; globular chamber; four blunt papillae arranged in opposite pairs, one pair horizontally arranged, the other more or less at right anges to the first; wall thin; apertures at ends of papillae.

Material. Organic lining; 1 specimen from LSC (sample 1.6m below 12b).

Distribution. Serre Formation, Montagne Noire, France, ?*linguiformis* conodont Zone

Measurements .

Diameter = 101 μm

Remarks. The specimen closely resembles Dunn's species from the Bainbridge Formation, Late Silurian, of Missouri. The only other Devonian record is by Blumenstengel (1961), who recorded *T. quadritubulata* from the Late Devonian of Thuringa, Germany, but Conkin *et al*. (1968) suggest that that record may be of *T. triradiata* Gutschick & Treckman; differences between these two species are minor (see Conkin *et al*. 1968).

Thurammina subsphaerica Moreman, 1930

Plate 5, fig. G.

Thurammina subsphaerica Moreman 1930: 52, pl. 5, fig. 16. - Dunn 1942: 331, pl. 43, fig. 31a,b. - Mound 1968: 109, pl. 7, figs 1,2. - Bell 1996: 96, fig. 8G.

Diagnosis. A species of *Thurammina* with a globular chamber covered by about 20 short papillae.

Description. Test free; globular; a small number (about 20) of short papillae more or less evenly distributed over the surface; test wall thin, made of very fine grains with little cement, surface smooth; simple aperture at the end of each papilla.

Distribution. Buchan Caves Limestone and Taravale Formation; Buchan and Bindi, Victoria; Emsian, *dehiscens -perbonus* conodont zones.

Measurements (in mm).

Figured specimen NMVP126979 diameter – 0.53.

Remarks. T. subspjaerica differs from *T. echinata* in the fewer but broader and less pointed papillae. As in the case of *T. echinata*, *T. subsphaerica* was possibly flexible when alive (see discussion of *T. echinata*).

Thurammina tributa Dunn, 1942

Plate 5, fig. H.

Thurammina tributa Dunn 1942: 334, pl. 43, fig. 20 (as *trituba*). – Bell 1996: 96, Fig. 8H.

Diagnosis. A species of *Thurammina* with three equatorially placed papillae.

Description. Test free; small; globular to ellipsoidal; three papillae, short, wide, more or less evenly positioned on the equatorial plane of the globular chamber; test formed of medium sized sand grains with little cement; aperture a simple opening at the end of each papilla.

Distribution. BON 39-44, BON 56-60.5, Buchan Caves Limestone, Bindi; Emsian, *perbonus* conodont zone.

Remarks. The three short, evenly placed papillae make this species easily identifiable.

Thurammina zaramama Bell, 1996

Plate 6, fig. F.

Thurammina zaramama Bell 1996: 96, fig. 9F.

Diagnosis. A species of *Thurammina* with an elongate chamber covered with very numerous short papillae.

Description. Test free; ellipsoidal chamber, covered with many (±100) small, short papillae arranged in rows; test wall thin, very finely agglutinated; interior surface smooth; aperture a small opening at the top of most papillae; specimens were usually red-brown.

Distribution. Buchan Caves Limestone and Taravale Formation; Buchan and Bindi, Victoria; Emsian, *perbonus - inversus* conodont zones.

Holotype. NMV P126974, Plate 6, Fig. F.

Type locality and horizon. Gelantipy Road, Buchan, sample Ma 13.

Measurements (in mm).

Holotype NMVP126974 length – 0.6; width – 0.23.

Remarks. The shape of the test and the large number of papillae are sufficient to distinguish this species from any other *Thurammina.* The shape of the chamber varied with the locality: those from Gelantipy Road had a long ellipsoidal form whilst those from Bonanza Gully were more rounded. As the former is from a pelagic sequence and the later from shallower water limestone this is most likely a reflection of the differing sedimentary facies.

Derivation of Name. zaramama (?Quechua, Peruvian native): for the similarity to the stone imitation maize heads of the Andean Indians (Whymper 1892).

Thurammina sp. cf. T. subsphaerica Moreman, 1930

Plate 10, figs 1-3; Pl. 13, fig. 1; Pl. 17, figs I-K.

Thurammina sp. Winchester-Seeto & Bell 1994: 205, figs 4.1, 4.2, 4.3.

Description. Test free; organic wall lining; globular; numerous "large", simple apertures raised on papillae; many smaller apertures or pores between the papillae.

Material. Organic linings; 3 specimens from MUNG (sample 71.5), GCR (sample 37) and MW (sample 31); 8 specimens from the Tamworth area.

Distribution. Garra Limestone, Wellington, NSW, *pesavis-sulcatus* conodont zones; Martins Well Limestone, Broken River, Qld, *sulcatus* conodont zone; Isis river below Timor Limestone, Early Eifelian, possibly *costatus* conodont zone; TIM 36.6, *costatus* conodont zone; DDH7 95 *costatus-australis* conodont Zones; Kiah Limestone, late Famennian; Gilwhite Limestone, age unknown- probably Early Eifelian.

Measurements .

Wellington specimens - Diameter of chamber = 80-112 μm; Diameter of "large apertures" = 3-10 μm.

Tamworth specimens - Diameter (max.) = 50-146 μm (Av.102); diameter of "large apertures" = 6-12 μm; diameter of pores = 1-3 μm

Known other occurrences. T. subsphaerica is known from the Ordovician and Silurian of Oklahoma (Moreman 1930), Silurian of Mississippi Basin (Dunn 1942), Early Devonian at Buchan and Bindi, Victoria (Emsian, *dehiscens-perbonus* conodont zones; Bell 1996).

Remarks. Most of the specimens are broken, distorted and compressed, suggesting that the organic lining is very thin in this species. This species has been compared to *T. subsphaerica* because the papillae are rounded as in *T. subsphaerica* and there are simple apertures on each papilla, but the presence of small pores between the papillae, ranging down to 0.5μm, has not been observed before.

A widespread and common species in the Tamworth area. One specimen from Isis River, below the Timor Limestone (Fig. 17, figs J-K) shows what appear to be sieve plates in some of the smaller pores.

Thurammina sp.

Plate 13, figs 10-11.

Description. Test free; organic wall lining; "blocky" surface, possibly due to distortion; few apertures of varying size, not raised from the surface.

Material. Organic lining; 1 specimen from MW (sample 25.4).

Distribution. Martins Well Limestone, Broken River, Qld, *sulcatus* conodont Zone.

Measurements.

Diameter of chamber = 69 μm; Diameter of apertures = 0.5-1.5 μm.

Remarks. As this is the only specimen showing this type of "blocky" surface, it is unclear as to whether it is not purely a preservational feature, *e.g.* the impressions of pyrite framboids.

Family HEMISPHAERAMMINIDAE Loeblich & Tappan, 1984

Subfamily HEMISPHAERAMMININAE Loeblich & Tappan, 1961

Genus **Hemisphaerammina** Loeblich & Tappan, 1957

Type species. Hemisphaerammina batalleri Loeblich & Tappan 1957

Diagnosis. Test attached; hemispherical , single chamber; no apparent aperture.

Remarks. It should be noted that the possibility exists that some specimens placed within the genus *Hemisphaerammina* may not belong within the Foraminiferida but actually represent egg-capsules of different species of gastropods (Adegoke *et al.* 1969; Bell & Burn 1979).

Mound (1968) emended Loeblich & Tappan's original description to include forms with a basal flange but these forms were placed in the new genus *Metamorphina* by Browne (Browne & Schott 1963). The diagnosis was further emended by Conkin & Conkin (1981) to include multichambered forms including those with or without a basal flange. McClellan (1966) restricted *Hemisphaerammina* to single hemispherical forms as distinct to the multichambered, flanged *Metamorphima*. Loeblich & Tappan (1988b) synonymized *Hemisphaerammina* and *Metamorphina.* I have used the genus *Hemisphaerammina* for forms without a basal flange but which may at times be two (or very seldom three) joined chambers as it was found that joined specimens were easily broken into separate, single forms, as distinct from *Metamorphina* which has a flange and is a multichambered group.

Hemisphaerammina crassa n. sp.

Plate 5, fig. N.

Hemisphaerammina sp. Bell 1996: 97, fig. 8N.

Diagnosis. A species of *Hemisphaerammina* with a thick , rough wall.

Description. Test attached; hemispherical, with a thick wall; attachment surface flat, smooth with no flanges and no evidence of a basal membrane; wall coarse and roughly finished.

Holotype. NMV P199599, Fig. 8N, Bell, 1996.

Type locality and horizon. Borenore, near Orange, NSW, sample DSC 230.

Distribution. DSC 230, Mirrabooka Formation, Borenore, N.S.W., Early Wenlock, *ranuliformis* conodont Zone; Windellama Limestone,N.S.W., samples QU 23, QU 233, Lochkovian, *eurekaensis - delta* conodont zones; Old Taravale Road cutting, Buchan, V., sample OTRC 7, Taravale Formation, Emsian, *perbonus* conodont Zone.

Measurements (in mm).

diameter of test 0.4 – 0.6; wall thickness - ± 0.075.

Remarks. Only rare specimens were recovered from Buchan but the species was more common at Windellama and Borenore. Whilst the external surface can vary from quite rough to relatively smooth, the thick wall is always characteristic. Double chambered forms were common in the Mirrabooka Formation but were easily separated.

Derivation of Name. crassa (L.) – thick; referring to the wall.

Hemisphaerammina coolamon n. sp.

Plate 10, fig. 7; Pl. 13, figs 6-8.

Hemisphaerammina sp. (in part) Winchester-Seeto & Bell 1994: 205, fig. 4.7 *non* 4.6, 4.8.

Diagnosis. A species of *Hemisphaerammina* being an organic lining with a reticulated wall surface and a basal membrane.

Description. Test apparently formerly attached; hemispherical chamber with a basal membrane; a thick flat attachment surface; organic wall lining, surface reticulate; no apparent aperture.

Holotype. AMF102668, Pl. 13, fig. 7

Type locality and horizon. MUNG 6.3, 6.2 m above the base of the MUNG section of the Garra Limestone, central New South Wales, Australia.

Material. 5 specimens from MUNG (samples 6.3, 24.8) and MW (sample 49).

Distribution. Garra Limestone, Wellington, NSW, *pesavis-sulcatus* conodont zones; Martins Well Limestone, Broken R., Qld, *sulcatus* conodont Zone.

Measurements .

Diameter of chamber = 83-116 μm (Av. 90.5 μm for 5 specimens).

Remarks. The basal attachment surface may show a partial lip or flange surrounding the test; this flange was a diagnostic feature used in the separation of *Metamorphina* (Browne & Schott, 1963) from *Hemisphaerammina*, but Loeblich and Tappan (1988b) have synonymised these two genera. A number of the specimens show a partial basal membrane.

Derivation of name. From the Australian Aboriginal word *coolamon,* meaning water carrier, referring to a water vessel of the same shape (Aboriginal language from Queensland).

Hemisphaerammina sp.

Plate 10, figs 6,8; Plate 13, fig. 5.

Hemisphaerammina sp. (in part) Winchester-Seeto & Bell 1994: 205, fig. 4.6 *non* 4.7, 4.8.

Description. Test apparently initially attached; hemispherical chamber with a smooth, firmly attached basal membrane; wall thick, smooth; no basal flange.

Material. 2 specimens from MUNG (sample 8.4) and GCR (sample 117.3).

Distribution. Garra Limestone, Wellington, NSW, *pesavis-sulcatus* conodont zones.

Measurements .

Diameter of chamber = 86-138 μm.

Remarks. Hemisphaerammina sp. differs from *Hemisphaerammina coolamon* n. sp. in the smooth wall and absence of a basal flange. It is similar to the Recent *H. bradyi* Loeblich & Tappan, but is not as domed and has a thicker wall.

This is probably a new species, but has been left in open nomenclature, pending the recovery of more individuals.

Genus **Metamorphina** Browne, 1963

Type species. Webbinella tholus Moreman 1933

Diagnosis. Test attached; numerous hemispherical chambers attached to each other linearly or in a spreading manner, usually with a basal flange.

Remarks. McClellan (1966) has given a full discussion of the criteria for distinguishing *Metamorphina* Browne, 1963, *Webbinelloidea* Stewart & Lampe, 1947 and *Hemisphaerammina* Loeblich & Tappan, 1957.

Metamorphina tholus (Moreman, 1933)

Plate 6, fig. E

Webbinella tholus Moreman 1933: 395, pl. 47, figs 8, 10.

Webbinella hemispherica Stewart & Lampe 1947. - Eichkoff 1970: 246, pl. 31, figs 11, 12.

Metamorphina tholus. - Browne & Schott 1963: 225, pl. 51, figs 1 - 9. – McClellan 1966: 489, pl. 37, figs, 15-19; pl. 41, figs 15-19, (with synonymy). – Bell 1996: 97, fig. 9E.

Description. Test probably formerly attached; a low dome, sometimes showing a marginal flange; monothalamous but individual chambers may aggregate into pseudomultilocular tests; sutures between the chambers straight; wall of fine grains, smooth surface; no apparent aperture.

Distribution. Bonanza Gully, Bindi, V.; Buchan Caves Limestone, Emsian, *perbonus* conodont Zone; Benny's Top Limestone, Pigna Barney, N.S.W., Emsian, *dehiscens-perbonus* conodont zones.

Measurements (in mm).

Figured specimen NMVP126984 chamber diam. - 0.22.

Remarks. The low-domed test and the absence of a basal wall serve to place the specimens in the genus *Metamorphina*. Although the figure shows a four chambered specimen, single and double chambered forms were more common.

Genus **Patellammina** Bell, 1996

Type species. Patellammina prona Bell, 1996

Diagnosis. Test free; multithalamous, disc-like chambers, joined in an irregular series; wall agglutinate; aperture rounded on concave face.

Description. Test apparently free; multilocular, up to three chambers joined in an irregular series; chambers are flattened, disc-like, with a floor; in section the chambers are meniscus-shaped; aperture an irregular hole, usually subcircular, in the concave (basal?) face; test coarsely agglutinated, with a rough surface.

Remarks. This genus belongs in the Hemisphaeramminae as it has obvious affinities with *Hemisphaerammina, Webbinelloidea, Colonammina* and *Ammopemphix. Patellammina* differs from *Hemisphaerammina* and *Webbinelloidea* in being very flattened and not hemispherical, and from *Hemisphaerammina* and *Colonammina* in the occurrence of not only single chambered but multiple chambered tests; *Colonammina* and *Ammopemphix* have the aperture in the upper, convex surface. It differs from the Recent genus *Causia* Rhumbler which has a chitinous test with only a few attached sand grains and which also possesses a peripheral flange.

It is considered that *Patellammina* was free living as no attached specimens have been found nor is there any evidence of attachment scars on any specimens.

Patellammina prona Bell, 1996

Plate 5, figs L, M.

Patellammina prona Bell 1996: 97, figs 8L, M.

Description. As for the genus.

*Holotype.*NMV P126985, Plate 5. fig.

Type locality and horizon. Bonanza Gully, Bindi, sample 220-240.

Distribution. Buchan Caves Limestone and Taravale Formation; Buchan and Bindi, Victoria; Emsian, *perbonus -inversus* zones.

Measurements (in mm).

	Locality	chamber diam.	aperture
Holotype NMVP126985	BON 220-240	0.6	0.07
Paratype NMV P126998	BON 220-240	ch 1:0.34 ch 2:0.34	ch 1: 0.17 ch 2: 0.1
Paratype NMV P126997	BON 220-240	0.31	0.1
Paratype NMV P126996	Ma 13	0.31	0.09

Remarks. as for the genus.

Genus **Webbinelloidea** Stewart & Lampe, 1947 *emend.* Conkin & Conkin,1970

Type species. Webbinelloidea similis Stewart & Lampe, 1947

Diagnosis. Test attached; numerous hemispherical chambers attached usually linearly, no basal flange; wall agglutinate; aperture a small arcuate opening.

Webbinelloidea crassus Bell, 1996

Plate 7, figs J, K.

Webbinelloidea crassus Bell 1996: 96, figs 10J, K.

Diagnosis. A species of *Webbinelloidea* with walls formed of very coarse sand grains.

Description. Test attached; in the form of a low dome with a circular attachment area; test formed of coarse grains,wall thick, but variable depending on the size of the grains used, surface rough; internal surface smooth; aperture indistinct.

Holotype. NMV P126983, Plate 7, fig. J.

Type locality and horizon. Bonanza Gully, Bindi, sample 206.

Distribution. Bonanza Gully, Bindi, V., Buchan Caves Limestone, Emsian, *perbonus* Zone.

Measurements (in mm).

Holotype NMV P126983, maximum diam. 0.325, aperture diam. 0.1.

Remarks. This is a very robust *Webbinelloidea*, formed from very coarse sand grains. Only single chambered forms were recovered although *Webbinelloidea* may show multichambered tests (Stewart & Lampe 1947). Because of the rough surface and poor preservation I could not distinguish an actual aperture from the small breakages in the test wall.

Derivation of Name. *crassus* (L.): thick, solid; referring to the nature of the wall.

Webbinelloidea similis Stewart & Lampe, 1947

Plate 14, fig. 10.

Webbinelloidea similis Stewart & Lampe 1947: 535, pl. 78, fig. 8. - Conkin & Conkin 1970: 4-14, pl.1, figs 1-31; pl. 2, figs 1-27; pl. 3, figs 1-16; pl. 4, figs 1-35. - Malec 1984: 560-561, pl. 1, figs 1-20; pl.2 figs 1-12. - Malec & Studencki 1988: 84-85, pl. 1, figs 13, 15-18; pl. 2, figs 1-4; pl. 3, figs 1-5. - Malec 1992: 282, pl. 1, fig. 6; pl. 2, figs 6, 10; pl. 3, figs 6, 9; pl. 4, figs 1-9.

?*Webbinelloidea* sp. Stewart and Lampe; Gnoli & Serpagli 1985: 214, pl. 1, fig. 21.

Hemisphaerammina sp. Winchester-Seeto & Bell 1994: 205, fig. 4.8.

For further synonyms see Conkin & Conkin (1970).

Description. Test probably originally attached; domed but flattened; wall surface smooth; no apparent basal membrane; aperture a small everted opening at top of dome.

Material. Organic lining: 1 specimen, from RUN (sample 199.3).

Normal foraminiferans: more than 30 specimens.

Distribution. Garra Limestone, Wellington, NSW, *pesavis* conodont Zone.

Measurements .

Diameter of both chambers = 141 μm.

Remarks. The small domal aperture separates *Webbinelloidea* from *Hemisphaerammina* (Conkin & Conkin, 1970). These authors showed that contrary to the initial description of *W. similis* (Stewart & Lampe, 1947) there is a small aperture present which could be described as '...a single subcentrally located aperture which resembles a pin prick and looks as if a pin had been forced from the exterior into the interior of the test. An apertural protuberance is present on the interior of the shell.'. In this specimen the internal edge of the aperture is quite recurved; in normal sized agglutinated test foraminiferans from this locality the external appearance of the aperture is a very small arcuate opening. *W. similis* ranges from the Middle Devonian to Lower Carboniferous in the U.S.A. (Conkin & Conkin, 1981, with synonymy), and in Poland occurs in the Lower-Middle Devonian (Malec, 1992).

Family DIFFUSILINIDAE Loeblich & Tappan, 1961

Genus **Kerionammina** Moreman, 1933

Type species. Kerionammina favus Moreman, 1933

Diagnosis. Test attached; spreading, labyrinthic interior of small chamberlets; peripheral tubular apertures.

Remarks. The Recent genus *Jullienella* Schlumberger has some features similar to *Kerionammina*: rigid agglutinated walls, flabelliform shape, digitate growth and an interior with weak to strong transverse ridges. However Norvang (1961) did not consider

Jullienella to possess even rudimentary chamberlets as the internal partitions are short and widely scattered, although Buchanan (1960) stated that the internal space was divided into 'intercommunicating canals by longitudinal partitions of cemented sand grains' and Hayward & Gordon (1984) in describing a new species of *Jullienella* from New Zealand stated that the interior surface of the walls was weakly wrinkled. The possibility exists that *Kerionammina* in the Palaeozoic is the ancestor of the Recent *Jullienella* by a change in the form of the interlaminary space but the material available at present does not permit further discussion of this point.

Kerionammina prolata Bell, 1996

Plate 6, figs K-M.

Kerionammina prolata Bell 1996: 98, figs 9K – M.

Diagnosis. A species of *Kerionammina* with a regular, digitate spreading pattern.

Description. Test attached; flattened and spreading in a digitate manner, with once bifurcating arms; early chambers indistinct; wall thin, finely arenaceous – on the upper, unattached side with a roughened surface with transverse ridges, and the attached surface smooth, often translucent to transparent; interior divided into chamberlets which run out to the tips of the arms, the wall between the chamberlets is thin and smooth; aperture not observed.

Holotype. NMV P126986, Plate 6, fig. K.

Type locality and horizon. Old Rocky Camp Quarry, Buchan, 10-15 paces above the top of the Murrindal Formation.

Distribution. Buchan Caves Limestone and Taravale Formation; Buchan and Bindi, Victoria; Emsian, *perbonus -inversus* zones.

Measurements (in mm).

	Locality	basal width	width	length
Holotype NVP126986	ORCQ	0.35	arm 1 0.05	0.2
			arm 2 0.04	0.1
			arm 3 0.04	broken
Paratype NMV P199597	distance between longitudinal partitions 0.008-0.012			
	distance between transverse internal partitions 0.006-0.01			

Remarks. The tests show no obvious places of attachment but the varying shapes of the specimens indicate that they were supported during growth and conformed to the shape of the supporting body. The interior chamberlets, in wider specimens, are arranged in parallel rows but, in narrower specimens and in the narrower arms, the chamberlets were often irregularly placed.

Kerionammina prolata differs from *K. favus* Moreman in having a more regular, digitate spreading pattern, in being finely arenaceous and in having no apparent apertures.

Moreman (1933) erected the genus for specimens from the Middle Ordovician. Conkin & Conkin(1982) assigned *K. favus* to Incertae sedis without giving any reasons but Loeblich & Tappan (1988b) considered it to be a foraminiferan.

Family HIPPOCREPINIDAE

Subfamily HYPERAMMININAE Cushman, 1910

Genus **Hyperammina** Brady, 1878

Type species. Hyperammina elongata Brady, 1878

Diagnosis. Test free; cylindrical; bulbous proloculum followed by a tubular second chamber; wall agglutinate; aperture terminal, rounded, may be constricted.

Hyperammina devoniana Crespin, 1961

Plate 14, figs. 8-9.

Hyperammina devoniana Crespin: 1961; 406, Pl. 64, figs 1-6.

Hyperammina spp. (in part) Winchester-Seeto & Bell 1994: 202, figs 2.1, 2.2.

Description. Test free; organic wall lining; a more or less globular proloculum followed by a tubular chamber; aperture terminal, rounded often preceded by a constriction in the test.

Material. 4 specimens from MUNG (sample 24.8), GCR (sample 38) and MW (sample 39.9).

Distribution. Garra Limestone, Wellington, NSW, *pesavis-sulcatus* conodont zones; Martins Well Limestone, Broken R., Qld, *sulcatus* Conodont Zone; Virgin Hills Formation, Canning Basin, ?*falsiovalis* conodont Zone.

Measurements .

Length = 216-371 µm; (Av. 294 µm); Diameter of proloculum = 71-90 µm (Av. 81 µm); Diameter minimum = 50-79 µm (Av. 61 µm).

Remarks. Conkin & Conkin (1968) place this species in *Tolypammina* as they believe that the specimens show attachment scars which are not found in *Hyperammina*; however, I do not agree with Conkin & Conkin and prefer to leave it in *Hyperammina*. Although the specimens are much smaller than Crespin's (i.e. 250-300 µm compared with 820 µm), the relative length of the tubular section versus the diameter of the proloculum remains the same (about 5:1).

Hyperammina proboscis Bell, 1996

Plate 4, figs A, B.

Hyperammina proboscis Bell 1996: 86, figs 7A, B.

Diagnosis. A species of *Hyperammina* with an ellipsoidal proloculum and a reflexed second chamber.

Description. Test free; large; ellipsoidal proloculum, followed by a long second chamber which tapers directly from the proloculum without any constriction at the proloculum; apertural end of the tube reflexed for about one-third of its length; aperture a simple opening at the end of the tube; wall made of small angular sand grains, surface roughly finished.

Holotype. NMV P126964, Plate 4, fig. B.

Type locality and horizon. Gelantipy Road, Buchan, sample Ma 13.

Distribution. Buchan Caves Limestone, Buchan, Victoria; *perbonus – inversus* zones.

Measurements (in mm).

.	Locality	proloculum diam.	tube diam.	length
Holotype NMV P126964	Ma 13	0.3	0.22	1.0
Paratype NMV P199414	ORCQ	0.16	0.12	0.56
Paratype NMV P199415	Ma 13	0.2	0.13	----

Remarks. H. proboscis differs from *H. reflua* in its ellipsoidal proloculum, no constriction at the base of the tubular chamber and in its rough surface (see also remarks under *H. reflua*).

Derivation of Name. proboscis (L.): elephant trunk; referring to the shape of the test.

Hyperammina reflua Bell, 1996

Plate 4, figs C, D.

Hyperammina reflua Bell 1996: 86, figs 7C, D.

Diagnosis. A species of *Hyperammina* with a subglobular proloculum and a reflexed proximal end.

Description. Test free; globular to subglobular proloculum followed by a long tubular second chamber which is narrower than the proloculum and separated from it by a slight constriction; this tubular chamber is turned back on the proloculum initially for about one-third of a whorl and then becomes more or less linear; near the apertural end, the tubular chamber becomes reflexed for about one-quarter of its length; the second chamber is of more or less uniform diameter until near the aperture when it narrows and then widens to a simple circular aperture; wall formed of fine sand grains,with a smoothly finished surface.

Holotype. NMV P126963, Plate 4, fig. C.

Type locality and horizon. Old Rocky Camp Quarry, Buchan, 10-15 paces above the top of the Murrindal Limestone.

Distribution. Buchan Caves Limestone and Taravale Formation; Buchan and Bindi, Victoria; Emsian, *dehiscens -inversus* zones.

Measurements (in mm).

	Locality	proloculum diam.	tube diam.	length
Holotype NMV P126963	ORCQ	0.12	0.07	1.08
Paratype NMV P199412	ORCQ	0.08	0.18	1.02
Paratype NMV P199413	BON 36-39	0.14	0.14	1.26

Remarks. The placement of *H. reflua* and *H. proboscis* in the genus *Hyperammina* is based on the globular proloculum and the tubular chamber which suggest placement in *Hyperammina* although the early non-rectilinear growth of *reflua* and the reflexed apertural end of the tube in both species are characters which have not apparently been reported for *Hyperammina* previously; Hofker (1972:45) stated that 'the tubular part [of *Hyperammina*] is nearly always straight'.

The somewhat contorted growth of these two species is similar to that of the genera *Tolypammina* and *Ammovertella*, but as these are attached genera (see remarks under *Tolypammina*) then the two species cannot be placed therein.

The apparently flexible nature of the tubular section is reminiscent of the genus *Pelosina* but the test shape, proportions of proloculum to tubular section and the wall structure and composition all preclude placement in that genus. The genus *Saccorhiza* often shows irregular growth (Hofker 1972) but that genus also has sponge spicules characteristically in the wall of the test and has a bifurcating tubular chamber, neither of which characters are present in *reflua* or *proboscis*.

Derivation of Name. *reflua* (L.): flowing back; referring to the proximal shape of the test.

Hyperammina teres Bell, 1993

Plate 1, figs A-H.

Hyperammina teres Bell 1993: 145, figs 3A- H.

Diagnosis. A species of *Hyperammina* with a small bulbous proloculum and a glabrous wall.

Description. Test free; prolocular chamber small, bulbous, succeeded by a slightly arcuate cylindrical chamber separated from the proloculum by a distinct constriction; the second chamber increases gradually in diameter; test surface very smooth, almost glabrous, and formed by small slightly overlapping scale-like flakes; aperture terminal, rounded; test rarely shows any constrictions (hourglass figures) in the wall.

Holotype. NMV P137616, Plate 1, fig. A.

Type locality and horizon. Cowombat, sample 2.

Distribution. Cowombat Formation, Cowombat, Victoria; Ludlow, *crispa* conodont Zone.

Measurements (in mm).

Holotype NMV P137616 length 2.0; greatest diameter 0.1; diameter of proloculum 0.1.

Remarks. This is the most common species in the Cowombat fauna and is represented by two forms which occur in roughly equal numbers; one has a smooth glabrous surface formed of scale-like flakes and the other a rough pitted surface. The rough surface could be due to acid processing but no examples were found with partially pitted wall. Most specimens are broken distally, so the nature of the aperture is uncertain.

This species is similar to *H. glabra* Cushman & Waters from the Early Carboniferous of Texas but differs in the more globular proloculum and less flaring test. It differs from *H. harrisi* Ireland in being more slender, having a longer, more curved test and with a surface of platey flakes.

Hyperammina leptalea n. sp

Plate 22, figs B-E.

Diagnosis. A species of *Hyperammina* with a small elliptical proloculum followed by a narrow, very slowly expanding tubular second chamber.

Description. Test free; small; elliptical to subglobular proloculum followed by a relatively long, narrow cylindrical second chamber which only slowly expands from a constriction at the proloculum to the aperture; wall fine grained, smooth; aperture circular, simple, at end of the tubular part.

Holotype. NMV P208072, Plate 22, fig. B.

Type locality and horizon. DSC 230, Borenore, near Orange, N.S.W.

Measurements (in mm).

	Proloculum diameter	Tube diameter		Total length
		at proloculum	at aperture	
Holotype NMV P208072	0.05	0.037	0.050	0.8
Paratype NMV P208073	0.075	0.037	0.65	0.5
Paratype NMV P208074	0.05	0.050	0.75	0.525

Paratype NMV P208075	-	0.050	0.1	1.0

Distribution. Sample DSC 230, Early Silurian, *ranuliformis* conodont Zone.

Remarks. H. leptalea differs from *H. teres* from the Late Silurian at Cowombat (Bell 1993) in the wall structure, shape of the proloculum and overall size (*teres* is much larger). Only very few specimens have a proloculum which apparently is easily fractured away from the tube at the constriction at their junction. Rare specimens show the 'hourglass' constrictions common in many species of *Hyperammina*. The slow rate of increase in the tubular section is clearly apparent from the table.

Derivation of Name. leptaleos (Gk.) – fine, delicate; referring to the narrow test.

Hyperammina sp. cf. H. sappingtonensis Gutschick, 1962

Plate 14, figs 1-5.

Hyperammina spp. (in part) Winchester-Seeto & Bell 1994: 202, figs 2.3, 2.4, 2.5?

Material. Organic linings; 2 microspheric forms from Pt. Hibbs (sample 68669) and MSh (sample 2); 18 megalospheric specimens from RUN (sample 70.6); GCR (samples 38, 53.7); MW (samples 34, 39.9); KE DDH1 (depths 448.51, 511, 805.25, 1026.54 m), MSh (samples 1, 2).

Distribution. Microspheric form: Pt Hibbs Limestone, Tasmania, *kindlei* conodont Zone; Middle Shanda Beds, Siberia, *serotinus* conodont Zone;

megalospheric form: Garra Limestone, Wellington, NSW, *pesavis-sulcatus* conodont zones; Martins Well Limestone, Broken R., Qld, *sulcatus* conodont Zone; Amphitheatre Group, Darling Basin, NSW, *pesavis-sulcatus* conodont zones; Middle

Shanda Beds, Siberia, *serotinus* conodont Zone.

Measurements .

Microspheric forms: Length = 117-173 μm; Diameter of proloculum = 33-53 μm; Megalospheric forms: Length = 186-400 μm (Av. 219.5 μm); Diameter of proloculum = 35-104 μm (Av. 57 μm).

Remarks. This species is characterised by a globular proloculum with a marked constriction between the prolocular chamber and the second chamber. Conkin & Conkin (1964) determined that *H. sappingtonensis* existed as both micro- and megalospheric forms. Specimens observed in this study have prolocular sizes which quite easily fit into the size ranges given for this species. In the megalospheric forms the ratio of prolocular diameter to length of specimen is one to three or four, whilst in the microspheric form this ratio is one to seven or eight. The microspheric form shows a gradual increase in test diameter from the proloculum whereas in the megalospheric form the proloculum is slightly constricted from the tubular chamber which gradually increases in diameter towards the apertural end. The major difference to *H. sappingtonensis* is that the microspheric form is very much shorter than the megalospheric form.

. The linear chamber may either taper towards the apertural end (Pl.14, fig. 5) or become flaring (Pl. 14, fig. 1) and even shows the characteristic 'hourglass' constriction of *Hyperammina* (Pl. 14, fig. 3).

H. sappingtonensis is recorded from the Late Devonian of Louisiana (Conkin & Conkin 1964) and the Early Carboniferous (Kinderhookian) of Missouri and Illinois (Conkin *et al.*1968). Conkin & Conkin (1964) have suggested that *H. sappingtonensis* is almost certainly a junior synonym of *H. kahlleitensis* Blumenstengal 1969 from the

Upper Devonian of Germany but that doubt exists as to the size range given for the German specimens.

Hyperammina sp.

Plate 4, fig. E

Hyperammina sp. Bell 1996: 88, fig. 7E.

Description. Test consists of an inflated proloculum, ellipsoidal and slightly elongated, followed by a tubular chamber constricted at the junction with the proloculum; diameter of the tube about half that of the proloculum; the tube is curved around the proloculum but separated from it; wall of fine particles with very few larger ones imbedded, surface fairly smoothly finished; aperture at end of tube.

Distribution. Taravale Formation, Buchan, Victoria; Emsian, *perbonus* Zone.

Measurements (in mm).

proloculum 0.2 x 0.14; diameter of linear chamber 0.07.

Remarks. This species differs from both *H. reflua* and *H. proboscis* in the shape of the proloculum and the immediately recurved tubular chamber. The maximum size to which it may have grown is not known as all of the several specimens found only have a short tubular section as figured.

Genus **Saccorhiza** Eimer & Fickert, 1899

Type species. Hyperammina ramosa Brady, 1879

Diagnosis. Test free; prolocular chamber followed by a long dichotomously dividing tubular chamber of more or less uniform diameter; wall agglutinate.

Saccorhiza surculus Bell, 1996

Plate 3, figs D, E.

Saccorhiza surculus Bell 1996: 85, figs 6D, E.

Diagnosis. A species of *Saccorhiza* with a large proloculum followed by a bifurcating second chamber.

Description. Test free; a relatively large, flattened proloculum followed by a narrow cylindrical tube of nearly uniform diameter, which bifurcates once; wall finely arenaceous with a fairly smooth surface; aperture is a rounded opening at the end of each branch.

Holotype. NMV P126962, Plate 3, fig. D.

Type locality and horizon. Old Rocky Camp Quarry, Buchan, 10-15 paces above the top of the Murrindal Formation.

Distribution. Known only from the type locality; ORCQ 10-15, Taravale Formation, Buchan, Victoria; Emsian, *perbonus* conodont Zone.

Measurements (in mm).

			arm width	
	Locality	length	primary	secondary
Holotype NMV P126962	ORCQ	0.21	0.02	0.01
Paratype NMV P199411	ORCQ	0.25	0.02	0.02

Remarks. Hofker (1972) has considered *Saccorhiza* to be a subgenus of *Hyperammina* on the basis of the globular proloculum and the presence of rare abnormal ramifying forms of several otherwise typical *Hyperammina*. Here it is considered that although the two genera are closely related, the bifurcation of the test is sufficient to distinguish the two genera. The presence or absence of sponge spicules in the test wall is only of specific character.

None of the recovered specimens showed a typical globular proloculum; in all cases this part of the test was flattened and distorted to varying degrees.

Derivation of Name. *surculus* (L.): a young shoot; referring to the fancied resemblance of the species.

Family AMMODISCIDAE Reuss, 1862

Subfamily Ammovolumininae Tschernich, 1967

Genus **Ammovolummina** Tschernich, 1967

Type species. Ammovolummina saumensis Tschernich, 1967.

Diagnosis. Test free; proloculum followed by a tubular, variously curved chamber, conoidal, rapidly increasing in diameter; wall agglutinate; aperture terminal.

Ammovolummina bostryx n. sp.

Plate 18, figs G, H.

Diagnosis. A species of *Ammovolummina* showing an initial spiral then a rectilinear growth habit.

Description. Test free (?); tubular, non-septate, slightly curved to tightly coiled; rapidly dilating; initially forming a spiral of about one whorl, then more or less straight; wall thin (one grain thick), closely cemented quartz grains, smoothly finished; interior smooth; aperture simple at end of tube; proloculum not known.

Holotype. NMV P208025, Plate 18, fig. G.

Type locality and horizon. Windellama, NSW., sample Q 7.

Material. 26 specimens.

Distribution. Known only from the type locality; Lochkovian, *?hesperius* conodont Zone.

Measurements (in mm).

	maximum length	apertural diameter
Holotype NMV P208025	1.0	0.63
Paratype NMV P208026	2.6	0.7

Remarks. Some specimens show a small attachment scar only on the prolocular end. In all cases the proloculum has been broken away. The variation in shape is great: specimens maybe rectilinear or strongly spiral with the inner margins contiguous or not with one another, but all intermediate forms are present. This species also shows the formation of secondary chambers but only in the more tightly coiled form where after $1\frac{1}{2}$ - 2 whorls a floor forms in the initial tube. The new chambers are interconected with each other and the initial chamber by small pores. There is only a single wall between the chambers. *A. bostryx* is similar to *A. saumensis* Tschernich but differs in showing contiguous margins within the growth pattern, and differs from *A. pseudotuba* Tschernich in not having a reflexed growth pattern.

Derivation of Name. *bostrychos* (Gk.) – curly; referring to the coiling form of the test.

Genus **Serpenulina** Tschernich, 1967

Type species. Serpenulina uralica Tschernich 1967

Diagnosis. Test attached; proloculum followed by an expanding, tubular chamber, curved, attached side flattened; wall agglutinate; aperture terminal.

Serpenulina uralica Tschernich, 1967

Plate 18, figs A-D.

Serpenulina uralica Tschernich 1967: 32, pl. 3, figs 8-11.

Description. Test attached; proloculum oval; second tubular chamber slightly curved, flattened on attached side; second chamber gradually expanding with growth; wall closely cemented quartz grains, only one grain thick, but may be partially destroyed on attached side; aperture terminal, rounded.

Material. 38 specimens.

Distribution. Q 7, QU 166, QU 233, Windellama Limestone, Lochkovian, *?hesperius* – *delta* zones.

Measurements (in mm).

	maximum length	apertural diameter
Figured specimen NMV P208019	1.75	1.0
Figured specimen NMV P208020	2.03	0.5
Figured specimen NMV P208021	2.37	0.35
Figured specimen NMV P208022	1.7	ch 1-0.6; ch 2-0.4; ch 3- 0.3

Remarks. The present specimens differ slightly from the original description in that the surface is smooth and does not show external wall constrictions. The proloculum is normally missing but one specimen shows a fairly large hemispherical chamber which is slightly constricted from the tubular part. The initial end may be slightly coiled, about one-quarter of a revolution, then almost straight growth with no twisting of the test. The attached wall is very flat and wide giving an almost hemitubular look to the test cross-section. One specimen showed the development of two smaller chambers (?tubes); on the attachment side two small chambers form and apparently grow independently giving a splayed shape to the top of the specimen. These chambers are connected by a pore in the wall between them and by a pore to the initial tubular section which has a transverse floor forming at this junction.

The genotype came from the Ludlow (*marginalis* Zone) of the northern Urals.

Serpenulina aulax n. sp.

Plate 18, figs E, F.

Diagnosis. A species of *Serpenulina* with a long narrow attachment scar along the conical test wall.

Description. Test attached; tubular undivided chamber widening rapidly but uniformly with growth; more or less rectilinear; wall thin (one grain), formed of quartz grains closely cemented; proloculum indeterminate; aperture more or less circular at end of tube.

Holotype. NMV P208023, Plate 18, fig. E.

Type locality and horizon. Windellama, NSW., sample Q 7.

Material. 15 specimens.

Distribution. Q 7, Windellama Limestone, Lochkovian, *?hesperius* Zone.

Measurements (in mm).

	maximum length	apertural diameter
Holotype NMV P208023	1.48	0.55
Paratype NMV P208024	2.63	0.65

Remarks. Serpenulina aulax differs from in S. *uralica* in having a narrow, elongate attachment scar along the entire test length not the wide, flat attachment surface and in being more conical and wider. Also it does not show the development of secondary chambers as in S. *uralica.* The test is usually rectilinear but rarely shows a slight open coil near the initial end, as if at the beginning the test coiled partly about the substrate. The initial end is broken in all specimens but in many cases this end is quite narrowly pointed and a proloculum, if at all present, must be very small. The external surface is often wrinkled.

Derivation of Name. aulax (L.) – furrow; referring to the long, narrow attachment scar.

Subfamily AMMOVERTELLININAE Saidova, 1981

Genus **Tolypammina** Rhumbler, 1895

Type species. Hyperammina vagans Brady, 1879

Diagnosis. Test free or attached; globular proloculum, followed by a long, undivided tubular chamber; aperture terminal.

Remarks. The identification of the vermiform Early Palaeozoic foraminiferal genera has caused much confusion and discussion in the literature. In particular the separation of the genera *Tolypammina* Rhumbler, 1895 and *Ammovertella* Cushman, 1928 has given rise to much discussion and varying interpretations of these genera (Barnard 1958; Bermudez & Rivero 1963; Conkin 1961; Conkin & Conkin 1964b; Gutcshick & Treckman 1959; Henbest 1963; Hofker 1972; Ireland 1956).

In an attempt to distinguish these two genera Ireland (1956) proposed that the main distinguishing features were the tube cross-section, coiling or bending in the initial growth stage and the presence or absence of an agglutinate floor to the tubular section wherever it was attached. However he included in his description of the species within each genus forms with and without these characteristic features. Gutschick & Treckmann (1959), in their study of Early Carboniferous foraminiferans followed Ireland but found (p. 241) '...some tolypamminids contradict some of Ireland's criteria for distinguishing between *Tolypammina* and *Ammovertella*'.

Barnard (1958) proposed a simple division of the genera: *Tolypammina* having no initial coiling about the proloculum, and *Ammovertella* with a planispiral initial coiling of the tubular section about the proloculum. He also pointed out that 'In both *Tolypammina* and *Ammovertella* the final tubular portion of the test is similar and without study of the initial part it is impossible to separate the genera' (Barnard 1958: 117).

Conkin (1961) proposed a separation of the genera based on the second chamber; his criteria are similar to those of Ireland.

A third genus of Palaeozoic tolypamminid, *Minammodytes*, was introduced by Henbest (1963), which differed from *Tolypammina* in having the second chamber partly enclosing the proloculum and from *Ammovertella* in not having the second chamber growing in a zigzag manner. However this latter difference would seem to be, at most, only a specific distinguishing character. Henbest (1963) considered *Minammodytes* to be an Early Carboniferous genus, while Conkin & Conkin (1982), in a review of the Palaeozoic North American foraminiferans, placed the first appearance of *Ammovertella* as Early Carboniferous and of *Tolypammina* as Middle Ordovician, but made no mention of *Minammodytes*.

As the degree of attachment of the second chamber and so the presence or absence of a 'floor' are both greatly variable within specimens that otherwise appear identical, and the degree of diagensis of the sediments causes varying amounts of distortion of the tests, the simplest criterion for separating *Tolypammina* and *Ammovertella* is that proposed by Barnard (1958) and is followed here. *Minammodytes* is considered a junior synonym of *Serpulopsis* Girty, 1911 (Loeblich & Tappan 1988b).

The Late Carboniferous *Ammodiscella* Ireland, 1956 and the Recent *Hemidiscella* Bock, 1968 both differ from *Tolypammina* and *Ammovertella* in having a symmetrical, planispirally enrolled second chamber before the coiling becomes irregular.

Tolypammina anguinea Bell, 1996

Plate 1, figs L, M; Pl. 7, figs A, B.

Tolypammina sp. – Bell in Simpson *et al.* 1993: 146, figs 3L, M.

Tolypammina anguinea Bell 1996: 99, figs 10A, B.

Diagnosis. A species of *Tolypammina* with a subspherical proloculum and a hemitubular second chamber.

Description. Test originally attached; subspherical proloculum followed by a long hemi-tubular second chamber which usually winds about in a highly irregular manner; wall formed of fine grains, surface fairly rough; aperture rounded at the end of the second chamber; attached side of the test shows no evidence of a floor of attachment but the edges of the tube may be slightly flared.

Holotype. NMV P126988, Plate 7, fig. A.

Type locality and horizon. Old Rocky Camp Quarry, Buchan, 10-15 paces above the top of the Murrindal Formation.

Distribution. Cowombat Formation, Cowombat, Victoria; Ludlow, *crispa* Zone; Samples QU 167, QU 217, QU 228, Windellama Limestone, Lochkovian, *eurekaensis-delta* conodont Zone; Buchan Caves Limestone and Taravale Formation; Buchan and Bindi, Victoria; Emsian, *dehiscens -inversus* conodont zones.

Measurements (in mm).

	Locality	proloculum diam	aperture
Holotype NMVP126988	ORCQ	0.02	0.03
Paratype NMV P199427	ORCQ	0.03	0.06
Paratype NMV P199428	BON 36-39	0.06	0.12

Remarks. This species is very close to *T. nexuosa* Crespin from the Australian Late Devonian but differs in having a rough, unpolished surface. It appears close to *T. bransoni* Conkin *et al.*, 1968 from the Mississippian of Missouri but differs in showing little or no evidence for a basal floor. Whilst similar to *T. tortuosa* Dunn, 1942 from the Silurian of the Mississippi Basin the present specimens do not have a globular proloculum nor do they show any initial coiling about the proloculum before assuming a tortuous pattern of growth. As is usual with many tolypamminids the shape of the second chamber is highly variable and no two specimens are exactly alike. Kazmierczak (1973) found *Tolypammina* to live within the water channels of sponges and so the constrictions on its mode of growth cause the great variability in morphology shown by this species. Apart from very rare *Receptaculites* no sponges are known from the Buchan Caves Limestone or the Taravale Formation, nor any from the Windellama Limestone.

Only rare specimens were found at Windellama and these occurred as single specimens in each sample; none showed the proloculum but were otherwise identical with the Victorian specimens.

Derivation of Name. *anguinea*(L.): snaky; referring to the growth habit of the species.

Tolypammina tantula Bell, 1996

Plate 7, figs C-E; Pl. 14, fig. 7.

Tolypammina tantula Bell 1996: 99, figs 10C - E.

Diagnosis. A species of *Tolypammina* with an ovate proloculum and a tubular second chamber.

Description. Normal foraminiferans: Test free; a long, cylindrical tube which expands from a small, egg-shaped proloculum; chamber walls usually entire, made of coarse grains, roughly finished; aperture at end of tube.

Organic wall lining – Test probably formerly attached; a small proloculus followed by an undivided tubular chamber; aperture at the end of a second chamber, round; wall smooth.

Holotype. NMV P126995, Plate 7, fig. D.

Distribution. Normal foraminiferans: Buchan Caves Limestone and Taravale Formation; Buchan and Bindi, Victoria; Emsian, *perbonus* conodont Zone; Organic wall linings: 2 specimens from RUN (sample 44.5) and GCR (sample 53.7), Garra Limestone, Wellington, NSW, *pesavis-sulcatus* conodont zones.

Measurements (in mm).

Normal foraminiferans:

	Locality	proloculum diam.	aperture
Holotype NMVP126995	BON 13.5-15	0.036	0.1
Paratype NMV P19903	BON 29-35	0.07	0.09

Organic wall linings: Length = 440-500 μm, Diameter of proloculum = 42-50 μm.

Remarks. This is a more robust species than *T. anguinea* from which it differs in having a completely tubular second chamber with no apparent indication of attachment to a substrate, in the normally non-meandering habit of growth and in the tiny proloculum. Specimens with a proloculum are rare; the early part of the test is thin and fragile compared to the later more robust section. The specimens of organic wall linings have an attached basal floor and, apart from size differences, appear to be identical to *T. tantula* from Buchan.

Derivation of Name. tantula(L.): so small; referring to the proloculum and initial part of the test.

Genus **Trepeilopsis** Cushman & Waters, 1928

Type species. Turritellella grandis Cushman & Waters, 1927

Diagnosis. Test free or attached; tubular undivided chamber in a high trochospiral coil; wall agglutinate; aperture terminal.

Remarks. In the original generic description Cushman & Waters (1928) did not give reasons for distinguishing *Trepeilopsis* from *Turritellella.* Gutschick & Treckman (1959) have suggested that the distinguishing feature between *Trepeilopsis* and the closely similar *Turritellella* is that in the former the second chamber discontinues coiling and apruptly doubles back over the earlier whorls even to the extent of reaching the proloculum; *Turritellella* has also a more tightly wound, narrower test. Conkin *et al.* (1968) reported forms of *Trepeilopsis recurvidens* with apertural ends varying from specimens ending at the end of the coil to others in which the second chamber was reflexed and reached the proloculum and even specimens in which the tube uncoiled for a short straight distance.

Trepeilopsis recurvidens Gutschick & Treckman, 1959 *emend.* Conkin *et al.*, 1968

Plate 1, fig. J.

Trepeilopsis recurvidens Gutschick & Treckman 1959: 244, pl. 35, figs 25-26. – Conkin & Conkin 1964b:39, pl. 1, figs 37,38, (with synonymy). – Conkin *et al.* 1965: 353, pl. 2, figs 27, 28, (with synonymy). - Conkin *et al.* 1968: 166, pl. 2, figs 44, 46-48, (with synonymy). Conkin & Ciesielski 1973: 38, pl. 3, figs 8, 10, (with synonymy). – Poyarkov 1979: 67, pl. 12, fig. 14. - Conkin & Conkin 1981:30, pl. 3, fig. 20, (with synonymy). – Bell 1993: 149, fig. 3J.

Diagnosis. A species of *Trepeilopsis* with a recurved apertural end over the previous whorls.

Description. Test free; small proloculum followed by a gradually enlarging tubular chamber coiled in the form of a regular expanding evolute high trochospiral of six turns, which then uncoils and reverts over the previous whorls; the direction of coiling reverses after two whorls; early whorls cover the proloculum; aperture at open end of tube; wall of fine grains, smooth.

Distribution. Cowombat Formation, Cowombat, Victoria; Ludlow, *crispa* Zone; sample 2.

Measurements (in mm).

Figured specimen NMV P137622 length 0.45; maximum diameter 0.25.

Remarks. These specimens have fewer coils than other described specimens of *T. recurvidens* but this factor is variable (Conkin *et al.* 1968); otherwise they agree with descriptions and figures of this Late Devonian-Early Carboniferous foraminiferan. The degree to which the apertural end extends back over the preceding whorls varies widely. No specimens were found attached to any spines or spicules as seems normal in *Trepeilopsis*.

Genus **Ammovertella** Cushman, 1928

Type species. Ammodiscus (Psammoph is) inversus Schellwien, 1898

Diagnosis. Test attached; proloculum followed by an undivided chamber, initially planispirally coiled about the proloculum then winding randomly.

Ammovertella calyx Bell, 1996

Plate 7, figs F-I.

Ammovertella calyx Bell 1996: 100, figs 4; 10F - I.

Diagnosis. A species of *Ammovertella* with a hemispherical or hemielliptical proloculum and without a basal wall to the entire test.

Description. Test originally attached; small; hemispherical to hemi-ellipsoidal proloculum followed by a hemitubular second chamber which encircles the proloculum for about three-quarters of a turn, and then becomes sinuous and ultimely rectilinear; wall made of small sand grains, several grains in thickness, coarsely finished outside but interior surface smooth; the attached surface is flat, without any floor along its entire length; aperture is a simple opening at the end of the second chamber.

Holotype. NMV P126989, Plate 7, fig. F.

Type locality and horizon. Bonanza Gully, Bindi, sample 13.5-15.

Distribution. Buchan Caves Limestone, Buchan and Bindi, Victoria; Emsian, *perbonus* conodont Zone.

Measurements (in mm).

	Locality	proloculum diam.	length
Holotype NMVP126989	BON 13.5-15	0.02	0.27
Paratype NMV P199429	BON 13.5-15	0.02	0.21
Paratype NMV P199430	BON 13.5-15	0.03	0.4

Remarks. Because of the partially enrolled second chamber this species is placed in the genus *Ammovertella*. In some specimens there was a small flange on the wall edge at the attachment point. There was a large variation in the the degree of coiling, the thickness of chamber walls, in the chamber diameter and, subsequentially, in the shape of the test (Fig. 28 A-F). Very rare specimens were found with a more enrolled early chamber development (Fig. 28 E). These variations possibly only reflect the influence of the attachment surface and the surrounding environmental factors (Atkinson 1969).

Derivation of Name. calyx (L.): limestone; referring to the sediments of the type locality.

Ammovertella sp.

Distribution. QU 166; Windellama Limestone, Lochkovian, *eurekaensis* conodont Zone.

Remarks. One small specimen comprising the proloculum and part of the encircling tubular chamber is tentively placed here. It is very similar to the initial part of the specimen figured in Bell (1996, Fig. 10I) but complete identity with *A. calyx* must await more material.

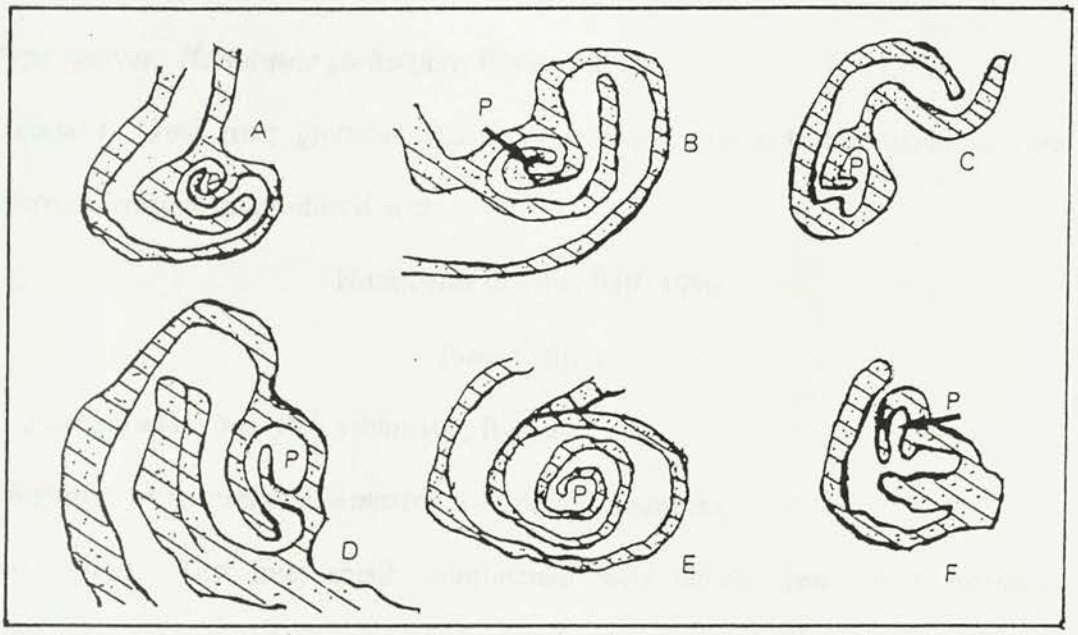


Figure 28. *Ammovertella calyx* Bell. Schematic outlines from SEM photographs showing the variation in growth pattern (viewed from attachment side). P. proloculum. (various magnifications)

Family HORMOSINIDAE Haeckel, 1894

Subfamily HORMOSININAE Haeckel, 1894

Genus **Hormosina** Brady, 1879

Type species. Hormosina globulifera Brady, 1879

Diagnosis. Test free; globular chambers linearly arranged; increasing in size; aperture terminal on produced neck.

Hormosina divitiae Bell, 1996

Plate 6, fig. J.

Hormosina divitiae Bell 1996: 102, fig. 9J.

Diagnosis. A species of *Hormosina* with oblate chambers.

Description. Test free; small; multilocular with oblate, thin-walled chambers gradually increasing in size, arranged linearly; sutures constricted and well marked; wall finely agglutinate and smoothly finished; aperture terminal, rounded, on a slightly protruding neck.

Holotype. NMV P126992, Plate 6, fig. G.

Type locality and horizon. Bonanza Gully, Bindi, sample 220-240.

Distribution. Known only from the type locality, BON 220-240, Buchan Caves Limestone, Bindi, Victoria; Emsian, *perbonus* conodont Zone.

Measurements (in mm).

		length	width	aperture
Holotype NMVP126992	chamber 1	0.11	0.22	
	chamber 2	0.15	0.23	
	chamber 3	0.18	0.23	0.09

Remarks. This species is placed in the genus *Hormosina* because of its rectilinear form, thin-walled chambers and produced apertural neck, even though the chambers are not spherical which has been considered a diagnostic feature of *Hormosina* (Bronnimann & Whittaker 1980). Previously *Hormosina* was only known from the Jurassic to Recent (Loeblich & Tappan 1988b).

Derivation of Name. *divitiae* (L., F., pl.): riches, bonanza; referring to the locality, Bonanza Gully, Bindi, V.

Subfamily REOPHACINAE Cushman, 1910

Genus **Reophax** Montfort, 1808 *emend.* Bronnimann & Whittacker, 1980

Type species. Reophax scorpiurus Montfort, 1808

Diagnosis. Test free; chambers globular, elongate series, nearly straight.

Reophax troca Bell, 1996

Plate 6, fig. G.

Reophax troca Bell 1996: 102, fig. 9G.

Diagnosis. A species of *Reophax* with a globular proloculum and oblate succeeding chambers.

Description. Test free; small; multilocular, uniserial arrangement of chambers in a slightly arcuate chain; initial chamber fairly large, globular, with successive chambers slightly oblate, increasing in size; sutures clearly defined, slightly oblique; aperture terminal, rounded on a very short, wide neck; test formed of moderate sized grains, somewhat roughly finished.

Holotype. NMV P126993, Plate 6, fig. G.

Type locality and horizon. Old Taravale Road Cutting, Buchan, sample 7.

Distribution. Known only from the type locality, Old Taravale Road cutting, Buchan, sample 7; Taravale Formation;Emsian, *dehiscens* Zone.

Measurements (in mm).

	length	width	aperture
Holotype NMV P126993	0.28	ch. 1 0.08	
		ch. 2 0.12	0.03

Remarks. Because of the non-symmetrical chambers and their asymmetrical arrangement this specimen is placed in *Reophax* as emended by Bronnimann & Whittaker (1980) not in *Hormosina* notwithstanding the presence of a short terminal neck.

Although *Reophax* is known from the Ordovician no previous Early Devonian specimens have been reported (Gutschick 1986) but foraminiferal organic linings from the Pragian (*sulcatus* conodont Zone) of New South Wales have been referred to this genus (Winchester-Seeto & Bell 1994) but seem better placed in *Reophanus* (*q.v.*).

Derivation of Name. *troca* : anagram of locality, Old Taravale Road cutting.

Family TELAMMINIDAE Loeblich & Tappan, 1985

Genus **Reophanus** Saidova, 1970

Type species. Hormosina ovicula Brady, 1879

Diagnosis. Uniserial, elongate, ovate chambers separated by relatively long necks.

Reophanus proavitus n. sp.

Plate 9, figs 7,8; Pl. 14, fig. 6.

Reophax sp. Winchester-Seeto and Bell 1994: 206, figs 3.7, 3.8.

Description. Test free; a linear arrangement of chambers; initially a pyriform proloculum followed by a second pyriform chamber of similar size; organic wall lining; surface smooth; aperture rounded, at the end of the neck.

Holotype. AMF102677, Plate 14, fig. 6.

Type locality and horizon. GCR 105, 105 m above the base of the GCR section of the Garra Limestone, Wellington, central New South Wales, Australia.

Material. Organic linings; 3 specimens from RUN (sample 85.7) and GCR (samples 105, 290.9).

Distribution. Garra Limestone, Wellington, NSW, *pesavis-sulcatus* conodont zones,

Measurements .

Length = 135-335 μm; Diameter of proloculum = 40-88 μm; Diameter of final chamber = 43-88 μm.

Remarks. The pyriform chambers and the short interconnecting neck indicate that this species is referable to the genus *Reophanus* and not *Reophax* as emended by Brönnimann & Whittaker (1980). Although only specimens with two chambers are known, in each case the neck is broken so multithalamous specimens may be possible. Because of the time differences (*Reophanus* is only recorded from the Recent [Loeblich & Tappan, 1988b]) and the much smaller size of the specimens from Wellington than the Recent species, a new species is proposed.

Although Loeblich & Tappan (1988b) state that *Reophanus* does not have an inner organic lining, Mendelson (1982) observed the presence of a lining in his

Recent specimens of *R. ovicula* (Brady) from Kainan Bay, Ross Ice Shelf, Antarctica.

Derivation of name. proavitus (L.): ancestor; referring to the early stratigraphic occurrence of the genus.

Family LITUOTUBIDAE Loeblich & Tappan, 1984

Genus **Lituotuba** Rhumbler, 1895

Type species. Serpula filum Schmid, 1867

Diagnosis. Test free; initially a glomospirally coiled tube, followed by an uncoiling rectilinear section; wall agglutinate; aperture terminal.

Remarks. Loeblich & Tappan (1988b: 69) have stated, without giving reasons, that the Palaeozoic forms previously placed in *Lituotuba* are not congeneric with that genus. As I have found no reason for this change, I have retained the genus for Early Devonian species from Eastern Australia but have expressed it as '*Lituotuba*'.

'Lituotuba' exserta Moreman, 1930

Plate 22, fig. J.

Lituotuba exserta Moreman 1930:57, pl. 7, figs 5,6. – Stewart & Priddy 1941: 374, pl. 54, figs 20, 21. – Mound 1968:37, pl. 2, figs 42, 43.

Lituotuba elongata Dunn 1942: 340, pl. 44, fig. 36.

Lituotuba chileana Todd & Kniker 1952 (part): 5, pl. 1, figs 6a,b,

Involutina exserta Conkin 1961 (part):286, pl. 26, fig. 16.

Diagnosis. A species of '*Lituotuba*' with an early plectospiral coiling followed by several planispiral coils and an exert rectilinear section.

Description. Test attached; small globular proloculum followed by a cylindrical tube which makes several complete volutions about the proloculum and then becomes rectilinear in the same plane as the spiral section and more or less at right angles to it; the tubular section has a constant diameter; wall finely agglutinated, thin, surface fairly smooth;aperture circular at end of tube.

Distribution. WERR 13, Boree Creek Limestone, Borenore, NSW; Early Wenlock, *ranuliformis* conodont Zone.

Measurements (in mm).

proloculum diameter: 0.075; tube diameter: 0.15;

total length of test: 1.125.

Remarks. The tube is often flattened on one side which may indicate an attachment scar. In none of the specimens did the rectilinear section show any meanderine growth.

The placement of this species within *'Lituotuba'* is based on the early plectospiral coiling about the proloculum. In the early growth stages '*Lituotuba'* is similar to *Ammodiscus* but in species of that genus the early spiral growth about the proloculum is described as being planispiral (*e.g.* Gutschick & Treckman 1959; Mound 1968; McClellan 1966; Loeblich & Tappan 1964, 1988b). The present Australian specimens cannot be placed in the genus *Tolypammina* as species of this genus have no encirclement of the proloculum (as used here) nor in the genus *Ammovertella* in which species have a meandering growth. As the degree of non-planispirality in the present specimens is small, this would exclude them from being placed in the genus *Glomospira,* species of which show a high degree of irregular to streptospiral initial coiling.

The present specimens are larger than Moreman's figured specimens and those of Mound (1968) and Stewart & Priddy (1941) from the Silurian of Indiana, but otherwise are indistinguishable. Gutschick & Treckman (1959) described *Tolypammina rotula* as having two irregular coils about the proloculum before a straight section and *T. cyclops* with a similar initial coiling but then becoming sinuous; both would seem to be better placed in *'Lituotuba'*. The present specimens do not have the large, prominent proloculum of *'L.' cyclops.*

'Lituotuba' helix Bell, 1996

Plate 6, fig. I.

'Lituotuba' helix Bell 1996: 102, fig. 9I.

Diagnosis. A species of *'Lituotuba'* with helical coiling followed by a rectilinear section.

Description. Test free; initially a small rounded proloculum followed by an unsegmented, cylindrical tube of two and one half whorls helically arranged, then uncoiling and becoming rectilinear; test wall fine grained, surface smoothly finished; aperture a simple opening at the end of the tube.

Holotype. NMV P126991, Plate 6, fig. I.

Type locality and horizon. Old Taravale Road Cutting, Buchan, sample 5.

Distribution. Known from the type locality only; OTRC 5, Taravale formation, Bindi, Victoria; Emsian, *dehiscens* conodont Zone.

Measurements (in mm).

Holotype NMV P126991 length 0.53, width 0.2, aperture 0.08.

Remarks. This species is easily distinguished by the early helix-form of the test.

Derivation of Name. *helix* (L.): referring to the early whorl shape.

'Lituotuba' torquata Bell, 1996

Plate 6, fig. H.

'Lituotuba' torquata Bell 1996: 100, fig. 9H

Diagnosis. A species of '*Lituotuba*' with a helically twisted rectilinear section.

Description. Test free; early stage a bulbous proloculum followed by an almost planispiral coiled, undivided cylindrical tube of more or less one turn; in the later stage the tube becomes an uncoiled, undivided rectilinear segment with an helical twist of two (or more) turns imposed upon it; wall fine grained, fairly smoothly finished; the aperture is a simple opening at the end of the linear segment.

Holotype. NMV P126990, Plate 6, fig. H.

Type locality and horizon. Old Taravale Road Cutting, Buchan, sample 7.

Distribution. Buchan Caves Limestone and Taravale Formation; Bindi, Victoria; Emsian, *dehiscens –inversus* conodont zones.

Measurements (in mm).

	Locality	length	width	neck width
Holotype NMVP126990	OTRC 10-15	0.43	0.26	0.08
Paratype NMV P199431	BON 13.5-15	0.4	0.22	0.08

Remarks. The distinctive twisted neck easily distinguishes this species from other Palaeozoic '*Lituotuba*' species. The degree of twisting is variable but is always present.

Derivation of Name. *torquata* (L.): wearing a twisted collar.

Family PLACOPSILINIDAE Rhumbler, 1913

Subfamily PLACOPSILININAE Rhumbler, 1913

Genus **Subbdelloidina** Frentzen, 1944

Type species. Subbdelloidina hauersleri Frentzen 1944

Diagnosis. Attached, uniserial, rectilinear series of chambers; agglutinate wall.

Subbdelloidina spathula n. sp.

Plate 21, figs A-D.

Diagnosis. A species of *Subbdelloidina* with a very small proloculum and domed chambers.

Description. Test partially attached; uniserial; small; more or less linear arrangement of chambers but usually arched or twisted; proloculum very small, then chambers increasing in size rapidly, becoming subglobular; attached side flattened; sutures depressed; wall calcareous granular, thin (one grain thick), surface smooth and shining; aperture may be a small opening in a depression on the ventral (attached) side.

Holotype. NMV P208056, Plate 21, fig.A.

Type locality and horizon. Yaramanbully, NSW , sample YAR6/126.

Distribution. YAR 6/126, Moore Creek Limestone, Tamworth, NSW; Eifelian, conodont zone uncertain.

Measurements (in mm).

	proloculum diameter	length	width of last chamber	number of chambers
Holotype NMV P208056	0.04	0.74	0.23	10
Paratype NMV P208057	0.05	0.65	0.25	7
Paratype NMV P208058	-	0.75	0.28	10
Paratype NMV P208059	0.5	0.63	0.3	8

Remarks. The test is quite flattened on one side (presumed to be the attachment side) for 4-6 chambers so giving a semicircular cross-section to these early chambers; then apparently the test becomes free as the chambers become more globular. In rare cases the last two chambers are very large and are placed eccentrically and irregularly spreading. In many cases the proloculum is lost but when present is very small and almost pointed. The degree of arching and/or twisting varies greatly as specimens are found from being rectilinear and flat to forms showing twisting of greater than 90° along the test length. The aperture is difficult to discern but several specimens showed a small opening in a depression on the attached side but most showed no apparent aperture.

The genus *Subbdelloidina* is known from the Jurassic but the present specimens seem to be better placed here than in any other genus: the specimens differ from *Placopsilina* in not being planispirally coiled initially, and from *Mooreinella* and *Digitina* in not being trochospiral in the early stages and not having a biserial stage of growth; the rare eccentric and irregularly spreading forms are similar to the Recent *Rudigaudryina* but differ in wall composition, size and having only a uniserial chamber arrangement. They differ from the Early Carboniferous *Oxinoxis* Gutschick in the chambers not having a distinct tubular neck.

Derivation of Name. *spathula* (L.): a small broad blade; referring to the cross-sectional shape of the early chambers.

Subfamily TROCHAMMININAE Schwager, 1877

Genus **Trochammina** Parker & Jones, 1859

Type species. *Nautilus inflatus* Montagu, 1808

Trochammina ? sp

Plate 18, figs I-K.

Description. Test free; small; chambers trochospirally arranged, ovately elongate, slowly increasing in size; umbilicate; four chambers in whorl, all visible on both sides; aperture not distinguished; sutures depressed; wall smooth, very finely granular.

Distribution. Yar 6/126, Moore Creek Limestone Member, Yarrimie Formation; Eifelian, *costatus* – mid-*hemianstus* conodont zones.

Measurements (in mm).

	maximum diameter	minimum diameter	diameter last chamber
Figured specimen NMV P208027	0.3	0.25	0.15
Figured specimen NMV P208028	0.33	0.3	-
Figured specimen NMV P208029	0.3	0.2	-

Remarks. Trochammina has been recorded from the Early Carboniferous (Conkin 1961; Conkin & Conkin 1964b; Cushman & Waters 1927) but not from the Devonian previously.

The present specimens are not well preserved and in none is the aperture visible although it appears to have been on the umbilical side. The chambers are more ovate than the usual globular shape found in *Trochammina*. The present species differs from *T. mehli* Conkin & Conkin in having only one whorl of chambers, even though they are of similar size.

Suborder FUSULININA Wedekind, 1937

Family CALIGELLIDAE Reytlinger, 1959

Genus **Paracaligella** Lipina, 1955

Type species. Paracaligella antropovi Lipina, 1955

Diagnosis. Test irregularly tubular; irregularly and partially divided by incipient septa, commonly alternating from one side to the other and offset; wall calcareous.

Paracaligella sp.

Plate 21, fig. K.

Description. Test free; chambers more or less linear, but placed irregularly; septa partly impressed into chamber but usually from one side only; chambers only slowly increasing in size; wall finely granular, calcareous; aperture not seen.

Distribution. YAR6/126, Moore Creek Limestone, Yarramanbully, Eifelian, *costatus*-mid-*hemianstus* conodont zones; ISIS, below Timor Limestone, Eifelian, *costatus* conodont Zone; David & Pitman sample B, lower-middle Devonian, conodont age uncertain.

Measurements (in mm).

	length	apertural width	initial length
Figured specimen NMV P208066	1.1	0.1	0.05

Remarks. Most specimens found were only internal casts from the dilute acid treatment with only very few complete specimens from the 96% acid treatment. These showed a wide variation in the successive placement of chambers but they could not be divided into discrete groups or 'species'. The detailed nature of the wall characters could not be determined from entire specimens as diagenesis and recrystallization had affected the specimens, but it seemed that the wall was only single layered. No specimens showed any form of initial coiling, the feature used by Bykova (1952) to separate *Evlania* and which is not mentioned by Loeblich & Tappan (1988b).

Family MORAVAMMINIDAE Pokorný, 1951

Genus **Moravammina** Pokorný, 1951

Type species. Moravammina segmentata Pokorný, 1951.

Diagnosis. Test tubular, initially annular due to enrolment about an object, then uncoiled, linear, septate, wall calcareous.

Moravammina segmentata Pokorný, 1951

Plate 20, figs A-C.

Moravammina segmentata Pokorný 1951: 8, pl. 2, figs 4, 5. - Duszyńska 1956:23, pl. 2, figs 4,5. – Poyarkov 1979: 59, pl. 10, fig. 1.

?Lituotuba dubia Miller & Carmer 1933: 430, pl. 50, fig. 11. – Cushman & Stainbrook 1943: 77, pl. 13, figs 18-20.

Description. Test attached; initial section coiled for one whorl about an object so forming a closed ring, this is followed by a rectilinear segment in the plane of the coil; the first part is flattened where it is attached but becomes more tubular with growth; attached periphery sharply angled; the entire test is septate, more or less evenly spaced; wall formed of small agglutinated calcareous grains; aperture terminal, rounded.

Distribution. TIM 36.6, Timor Limestone, Eifelian, *costatus* Zone; ISIS 2.2, below Timor Limestone, basal Eifelian, *?costatus* Zone.

Measurements (in mm).

	total length	maximum diameter	erect length	erect width
Figured specimen NMV P208043	0.73	0.3	0.4	0.1
Figured specimen NMV P208044	0.63	0.25	0.33	0.075
Figured specimen NMV P208045	1.2	0.57	0.63	0.1

Remarks. The present specimens are slightly smaller than the type of the species (maximum diameter: 0.58mm, diameter of erect tube; 0.18mm; Pokorný 1951).

Australian specimens are restricted to the Early Eifelian *costatus* conodont Zone; Loeblich & Tappan (1988b) give the range of *Moravammina* as Givetian to Frasnian but Poyarkov (1979) gives the Russian range as basal Eifelian to upper Frasnian.

Only internal casts are known. The proximal end of specimens is often partially broken leading to a cuphook-like shape (Plate 20, fig. C). The septa are not usually strongly impressed and some specimens appear almost aseptate. More often the attachment substrate is missing and the spiral remains empty.

Racki & Soboń-Podgórska (1993) call the group of moravamminids "dubious sessile microfossils."

Genus **Saccorhina** Bykova, E.V., 1955

Type species. Saccorhina trivirgulina Bykova, 1955.

Diagnosis. Bifurcating cylindrical tube, wall calcareous.

Saccorhina trivirgulina Bykova, 1955

Plate 20, figs D, K, L.

Saccorhina trivirgulina Bykova 1955: 34, pl. 13, figs 5-8. – Poyarkov 1979: 61, pl. 10, fig. 8. – Langer, 1991: 317, pl. 4, figs 12-14.

Description. Test free; small globular proloculum, then a tubular straight section which bifurcates; surface irregular due to constrictions; wall calcareous, aperture terminal, simple opening at end of tube.

Distribution. TIM samples 0.8, 10.4. 14.1, 18.9, 36.6, 78.3, Eifelian, *costatus-australis* zones; David & Pitman sample B, age uncertain (see Stratigraphy).

Measurements (in mm).

	maximum length	arm diameters
Figured specimen NMV P208046	0.68	0.05 – 0.07
Figured specimen NMV P208047	0.57	0.05 – 0.1
Figured specimen NMV P208048	0.38	0.075 – 0.12

Remarks. This species has previously only been reported from Russia (Frasnian; Bykova 1955) and Germany (early Givetian; Langer 1991).

Genus **Vermiculammina** n. gen.

Genotype. Vermiculammina isis n. sp.

Description. Initially test attached, later becoming free; attached section hemicylindrical, free part cylindrical; proloculum very small, followed by a series of opposite chambers, gradually increasing in size; the erect section uniformly cylindrical, uniserial; attached chambers long, narrow, 'free' chambers quadrate in longitudinal section; attachment surface usually curved; wall calcareous, thin; aperture not observed.

Distribution. ISIS sample 2.2, Eifelian, *costatus* Zone.

Measurements (in mm).

Remarks. This new genus is obviously close to *Moravammina* but differs in having only a short (usually less than one-eigth of a circle) attached sector before becoming free and erect. All specimens have more or less the same curvature of attachment and have about seven pairs of chambers in that part. In the erect segment the chambers are more or less the same size and this section uniformly cylindrical. The chambers of both the attached and erect sections of *Vermiculammina* are more clearly marked than in *Moravammina* and in the erect section are more squat than in *Moravammina*.

Vermiculammina isis n. sp.

Plate 20, figs E-H.

Description. as for genus.

Holotype. NMV P 208049, Plate 20, fig. E.

Type locality and horizon. Isis River, Tamworth, NSW., sample 2.2.

Distribution. as for genus.

Measurements (in mm).

	horizontal length	horizontal thickness	erect length	erect diameter
Holotype NMV P208049	0.57	0.15	0.48	0.18
Paratype NMV P208050	0.65	0.1	0.43	0.23
Paratype NMV P208051	0.33	0.075	0.75	0.1
Paratype NMV P208052	0.38	0.1	0.58	0.13

Remarks. Two forms are present: one with a stout erect segment (0.15-0.175 mm diameter), the other with a narrower segment (0.05-0.1 mm diameter), the thinner form is the more common (about 2:1). These forms are not separated into different species as only 30 specimens are known (all from the one sample) and with larger populations graduation between the forms may occur. The length of the erect segment varies between the two forms with the thinner having up-to 12 chambers and the stouter up to 7 chambers. Many specimens give the appearance of having four chambers per whorl on the erect segment but others show only a single discoidal chamber; this is believed to be just a preservational artefact as a similar effect is present on parts of some specimens of *Tikhinella.*

Derivation of Name. isis, for the section from which the specimens were recovered.

Family PARATIKHINELLIDAE Loeblich & Tappan, 1984

Genus **Tikhinella** E. V. Bykova, 1952

Type species. Tikhinella measpis E.V.Bykova, 1952

Diagnosis. Test free; rectilinear, tubular, subdivided into chambers by horizontal septa; calcareous, single layer, microgranular wall.

Remarks. Tikhinella Bykova and *Paratikhinella* Reytlinger have been considered to differ from *Nodosinella* Brady in their wall structure which is a single layered, microgranular calcite and not a double wall with a microgranular outer layer and an inner fibrous layer (Loeblich & Tappan 1988b). In *Tikhinella* the tubular test is divided into chambers which are separated by definite septa whereas in *Paratikhinella* the tubular chamber is only partially subdivided into discrete chambers by incomplete septa. *Earlandinita* Cummings 1955 is here considered a synomym of *Tikhinella* – the septation, chamber enlargement and wall structure are identical, and the two genera appear only to differ in stratigraphic ranges (*Tikhinella* – Upper Devonian; *Earlandinita* – Lower-Upper Carboniferous).

The present specimens are known mainly from internal casts, with very few intact walled specimens. These latter, even within the one species, show a variable test wall, from thin to thick and with a smooth or rough surface; thus I consider that the wall is probably secondary due to diagenesis. So, taxonomically they are treated as *Tikhinella* formae based on the shape and dimensions of the chambers until better preserved material is found.

Tikhinella forma A

Plate 21, fig. G.

Diagnosis. A species of *Tikhinella* with rectangular chambers, evenly spaced.

Description. Test free; long, uniserial, slightly arcuate; chambers longitudinally rectangular (width = 2x height), circular cross-section; chambers well separated; aperture terminal; chambers more or less evenly spaced.

Distribution. SULC 399, Sulcor Limestone, Emsian, *seratinus* Zone; YAR6/126, Moore Creek Limestone, Yarramanbully, Eifelian, *costatus*-mid-*hemianstus* zones; ISIS, below Timor Limestone, Eifelian, *costatus* Zone; David & Pitman sample B, lower-middle Devonian, conodont age uncertain.

Measurements (in mm).

	length	height	width
Figured specimen NMV P208062	0.58	last chamber – 0.05 first chamber – 0.035	last chamber – 0.11 first chamber – 0.75

Remarks. The early 2-3 chambers are more globular and enlarge rapidly in diameter.

The specimens present in sample SULC 399, Emsian, *seratinus* conodont Zone are the earliest occurring examples of calcareous foraminiferans found in eastern Australia and amongst the earliest found in the world (see Section 3).

Tikhinella forma B

Plate 21, figs E, F.

Diagnosis. A species of *Tikhinella* with narrow, elongate chambers.

Description. Test free; long, uniserial, circular section; small globular proloculum followed by narrow, elongate chambers, slightly fusiform, enlarging slowly; chamber length greater than width; aperture terminal.

Distribution. ISIS, below Timor Limestone; Eifelian, *costatus* conodont Zone.

Measurements (in mm).

	length	height	width	number of chambers
Figured specimen NMVP208060	0.65	last chamber – 0.1 second last – 0.1	last chamber - 0.75 second last – 0.07	11
Figured specimen NMV P208061	0.7	last chamber – 0.18 second last – 0.13	last chamber - 0.11 second last – 0.1	8

Remarks. This form seems very close to *T. cannula* Bykova (1952, p. 32, pl. 8, figs 10, 11) and to those figured by Eickhoff [1970, p. 250, pl. 32, figs 6-11; as *Paratikhinella cannula* (Bykova)]. The two entire forms obtained from the strong acid residues have a fusiform outer test outline.

Tikhinella forma C

Plate 21, fig. H-J.

Diagnosis. A species of *Tikhinella* with rectangular chambers and a wide apertural neck joining successive chambers.

Description. Test free; straight, uniserial; chambers wider than high (width about 1½ x height), circular section; early chambers subglobular and closely adpressed; septal indentation not very impressed leaving a wide apertural neck joining successive chambers.

Distribution. YAR6/126, Moore Creek Limestone, Yarramanbully, Eifelian, *costatus* – mid-*hemiansatus* conodont zones; ISIS, below Timor Limestone, *costatus* conodont Zone; David & Pitman sample B.

Measurements (in mm).

	length	proloculum diameter	last chamber height	last chamber width
Figured specimen NMV P208063	0.35	0.04	0.1	0,.13
Figured specimen NMV P208064	0.6	-	0.18	0.1
Figured specimen NMV P208065	0.48	-	0.15	0.1

Remarks. The squarish chambers and the narrow sutural indentations separate this forma from forma A.

Tikhinella forma D

Diagnosis. A species of *Tikhinella* with small globular chambers.

Description. Test free; small; uniserial; proloculum globular, followed by a series of small globular chambers which slowly increase in diameter; sutural impressions quite narrow; aperture simple, terminal.

Distribution. ISIS, below Timor Limestone, Eifelian, *costatus* conodont Zone.

Remarks. This forma is easily separated from the other species of *Tikhinella* by its small size and globular chambers.

Tikhinella forma E

Plate 21, fig. O.

Diagnosis. A species of *Tikhinella* with domed chambers.

Description. Test free; uniserial, may be slightly arcuate; circular section to chambers which overlap slightly; test narrow, chamber width about 1½ x height; chambers domed, wider at base than at apertural end; proloculum globular; test expands slowly; aperture terminal, central.

Distribution. YAR6/126, Moore Creek Limestone, Yarramanbully, Eifelian, *costatus* – mid-*hemiansatus* conodont zones; ISIS, below Timor Limestone, *costatus* conodont Zone; David & Pitman sample B.

Measurements (in mm).

	length	chamber height	chamber width
Figured specimen NMV P208069	0.63	chamber 1 – 0.88 chamber 2 – 0.1 chamber 3 – 0.13	chamber 1 – 0.1 chamber 2 – 0.11 chamber 3 – 0.14

Remarks. The slightly domed chambers, which overlap to some extent, may indicate that this forma may be better placed in the genus *Lugtonia* Cumming 1955, but better material is needed. A few specimens (*e.g.* the figured specimen) show what appears to be short longitudinal grooves on the edges of some of the chambers perhaps indicating that the surface of the test may have been sculptured.

Family GEINITZINIDAE Bozorgnia, 1973

Genus **Lunucammina** Spandel, 1898

Type species. Geinitzella (Lunucammina) permiana Spandel, 1898

Lunucammina sp.

Plate 21, figs L-N.

Description. Test free; uniserial, compressed test, which expands regularly from a small spherical proloculum; chambers ovate in cross-section, narrow but broad (width about 5x height), and ultimately becoming more or less the same size; aperture apparently central, round, terminal.

Distribution. David & Pitman B, conodont Zone uncertain (see stratigraphic section); ISIS section, Eifelian, *costatus* conodont Zone; TIM section, Eifelian, *costatus* conodont Zone; Yar 6/126, Eifelian - Givetian, *costatus-hemiansatus* conodont zones.

Measurements (in mm).

	length	last chamber height	last chamber width
Figured specimen NMV P208067	0.98	0.075	0.29
Figured specimen NMV P208052	0.6	0.75	0.13
Figured specimen NMV P208068	0.53	0.1	0.14

Remarks. Specimens are known as internal casts so the wall structure is unknown; rare specimens were recovered using the 96% acetic acid method (*q.v.* Introduction) but recrystallization of the wall had destroyed all evidence of the original textures. Many specimens gave the appearance of biseriality, especially in the earlier chambers, but this is only due to slight depression along the central line on both sides of the chambers. This early 'biserial' section is usually only 4-6 chambers long and is then followed by a uniserial section up to 11 chambers in length. The later chambers in long specimens may be rotated slightly with respect to the earlier part of the test – the maximum rotation seen is about 90°, but the angle is normally much less than this. In a number of specimens the apertural plug is offset and alternates each side of the centre line between successive chambers.

Family SEMITEXTULARIIDAE Pokorný, 1956

Subfamily SEMITEXTULARIINAE Pokorný, 1956

Genus **Semitextularia** Miller & Carmer, 1933

Type species. *Semitextularia thomasi* Miller & Carmer, 1933

Diagnosis. Test free; palmate; early chambers biserially arranged, then a flabelliform uniserial section; wall finely granular, calcareous; apertures a series of pores in terminal face.

Semitextularia thomasi Miller & Carmer, 1933

Plate 19, figs E-G.

Semitextularia thomasi Miller & Carmer 1933: 423, pl. 50, figs 10 a-e. – Cushman & Stainbrook 1943: 77, pl. 13, figs 24-28. – Copeland & Kesling 1955: 105. - Duszyńska 1956: 25, pl. 1, figs 1-9. - Duszyńska 1959: 78, pl. 2, figs 1-4; - Trifonova 1964: 121. – Sobat 1966: 237, pl. 23, text figs 1-3. – Poyarkov 1979: 71, pl. 13, fig. 11. – Racki & Soboń-Podgońska 1993: 274, fig. 13.

Semitextularia sp. cf. *S. thomasi*. – Toomey 1968: 299.

Semitextularia sp. indet. Pitchler 1971: 32, pl. 2, figs 21-25.

Description. Test of a fan-like shape, flattened, spreading out from an initial biserial section of 2-9 pairs of chambers, then a uniserial part in which the chambers are transversely elongated and vary from rectilinear to arched. The margins of the test may be undulating to serrate. Wall of very fine calcareous grains. The bi- and uni-serial parts are commonly divided into chamberlets by septa perpendicular to the chamber base. Aperture is multiple, consisting of two rows of small pores on the apertural face.

Distribution. TIM section, Eifelian, *costatus* Zone; ISIS section, Eifelian, *?costatus* Zone; David & Pitman B, conodont Zone uncertain (see stratigraphy section).

Measurements (in mm).

	locality	length	Width
Figured specimen NMV P208033	D&P sample B	0.48	0.35
Figured specimen NMV P208034	D&P sample B	0.33	0.3
Figured specimen NMV P208035	D&P sample B	0.45	0.4

Remarks. In the original description Miller & Carmer (1933) stated that the test is initially coiled planispirally. This feature was not seen by Duszyńska (1956) or Copeland & Kesling (1955) but Cushman & Stainbrook (1943, p.78) state 'In the megalospheric form the coiled early stage is much reduced and the biserial stage is taken on very early in the development'. Duszyńska (1959) figured specimens from the Holy Cross Mountains, Poland, showing variation at the adapical end with differing amounts of encirclement of the proloculum by early chambers in the megalospheric form and a microspheric form with no apparent encirclement, but none of which showed true planispiralism. None of the present specimens showed any initial planispiral coiling but did show differing amounts of prolocular enclosure by early chambers.

Poor conodont faunas in both the TIM and ISIS sections make it difficult to date the first occurrence of *S. thomasi* in eastern Australia to one conodont zone. It seems likely that the first appearance is either in the very top of the *partitus* Zone or the lowest *costatus* Zone , that is Early Eifelian.

Outside Australia it has been reported from Poland (Duszyńska 1956, 1959), Germany (Sobat 1966; Pitchler 1971) , Russia (Poyarkov 1979), Bulgaria (Trifonova 1964), Burma (Toomey 1968) and U.S.A. (Miller & Carmer 1933; Cushman & Stainbrook 1943; Copeland & Kesling 1955) within a time range of early Middle Devonian to Frasnian. Pitchler (1971) reported what is apparently the earliest European occurrence from the Heisdorf Beds in the southern German Eifel basin with an age of late Emsian. The earliest U.S.A. occurrence is basal Eifelian; Conkin *et al.* (1981) give the American range as base of Middle Devonian – Late

Devonian (their fig. 15, p. 97) but state (p. 99) that it is found in the *Amphipora ramosa* Zone of the Jeffersonville Limestone the age for which they give as lowest Early Devonian (p. 92) or basal to middle Eifelian (their fig. 20, p. 104). Klug, in a more recent conodont study (1983) of the Jeffersonville Limestone, dates it as the upper part of the *costatus* Zone, and Umio & Lespérance (1997) state that in central Indiana and Kentucky this limestone lies in the *Icriodus angustatus angustatus* Zone and contains the index conodont species *Polygnathus costatus costatus*. In Russia Bykova (1952) has reported numerous species of *Semitextularia* (but not *S. thomasi*), the earliest in the Givetian and many in the Frasnian. Thus it would seem that, as in Australia, *S. thomasi* has an incoming very early in the lower Eifelian globally.

Duszyńska (1956) believed that there are not as many species as Bykova (1952) recorded, and that concern should be more on the great variation found within the species. To this end she used the ratio total length:length to max. width (see Fig.24) and found a unimodal distribution which she took to indicate a single variable population. But Poyarkov (1979, p 9-10, 101-103) disagrees with Duszyńska and suggests that the same resultant histogram could be the result of six different overlapping populations, based on values of the apical angles. Rachi & Soboń-Podgórska (1993) regard the species as having a wide range of variation in test shape and margin outline and follow Duszyńska (1956). Sobat (1966) showed, using uni- to bi- serial chamber ratios and apical angles, there were four morphotypes in his material from Germany. Measurement of the best preserved material from NSW was made (Table 22) and plotted to show various relationships (Figs. 29 - 32). There was no discernable groupings of the species at all. This indicates that there is a single variable population of *S. thomasi* in Australia. The length/width histogram is quite similar to that of Duszyńska (1956) and, whilst using the various outline shapes and vertex angles the specimens could be grouped as done by Sobat (1966), no evidence of any such groupings is evident in the various graphs plotted.

Poyarkov (1972, p. 102, fig. 22), using Bykova's many species and by not assigning Duszyńska's (1995) species to *S. thomasi*, has proposed a phylogeny for *Semitextularia* with suggested origin low in the Eifelian and only one species just entering into the Famennian. Rauzer-Chernousova (1992) gives a suggested classification of the Palaeozoic foraminiferans with *Semitextularia* ranging from the Middle Devonian to the Devonian-Carboniferous boundary. Until the status of Bykova's species is fully accepted by restudy of her material using modern taxonomic philosophy, and/or finding such faunas elsewhere, the phylogenetic tree has little credence.

Family LOEBLICHIIDAE Cummings, 1955

Subfamily NANICELLINAE Fursenko, 1959

Genus **Nanicella** Henbest, 1935

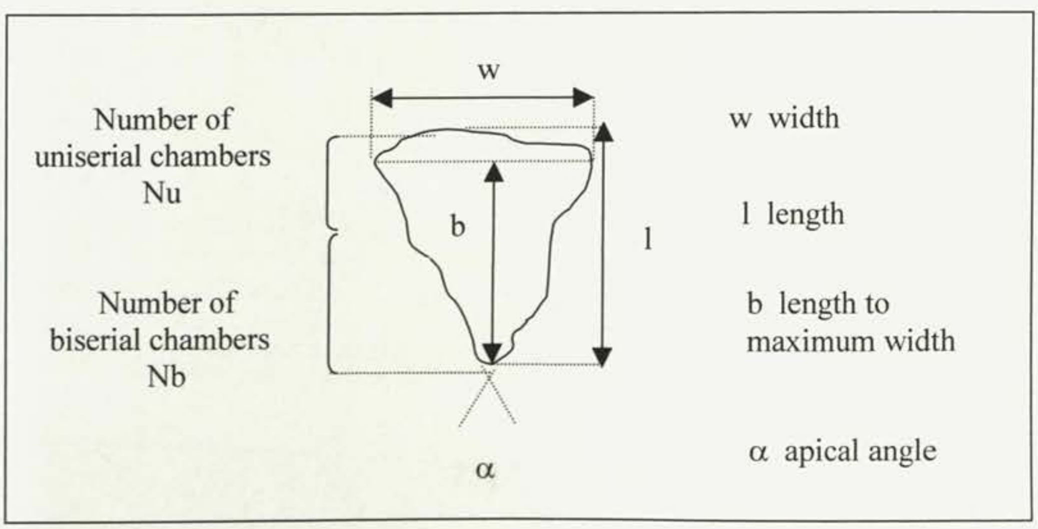
Type species. Endothyra gallowayi Thomas, 1931

Diagnosis. Discoidal, planispiral, evolute, biumbilicate, whorls rapidly enlarging; wall calcareous, granular.

Locality	length l	width w	Nu	Nb	angle α	b	l/w	Nb/Nu	l/b
D&P B	17	12	7	3	50	13	1.42	0.43	1.31
	19	17	6	4	100	7	1.12	0.67	2.71
	18	15	6	5	64	12	1.20	0.83	1.50
	18	14	7	3	56	13	1.29	0.43	1.38
	19	20	9	3	80	12	0.95	0.33	1.58
	22	18	8	5	70	13	1.22	0.63	1.69
	17	18	8	1	120	5	0.94	0.13	3.40
	15	11	5	4	50	12	1.36	0.80	1.25
	17	13	8	3	60	11	1.31	0.38	1.55
	19	13	9	3	56	12	1.46	0.33	1.58
	15	17	8	3	80	10	0.88	0.38	1.50
	19	20	10	3	80	12	0.95	0.30	1.58
	17	15	6	5	74	10	1.13	0.83	1.70
	13	11	5	4	70	8	1.18	0.80	1.63
ISIS	18	13	8	4	60	11	1.38	0.50	1.64
	15	14	6	4	82	8	1.07	0.67	1.88
	17	13	7	5	50	14	1.31	0.71	1.21
	15	15	9	3	74	10	1.00	0.33	1.50
	12	10	7	4	70	7	1.20	0.57	1.71
	8	7	2	4	60	6	1.14	2.00	1.33
	9	9	2	4	74	6	1.00	2.00	1.50
	19	19	11	1	100	8	1.00	0.09	2.38
TIM	23	20	11	5	76	13	1.15	0.45	1.77

Table 22. Semitextularia thomasi. Table of variables measured for specimens from various samples.

Figure 29. Semitextularia thomasi outline showing measurements made.



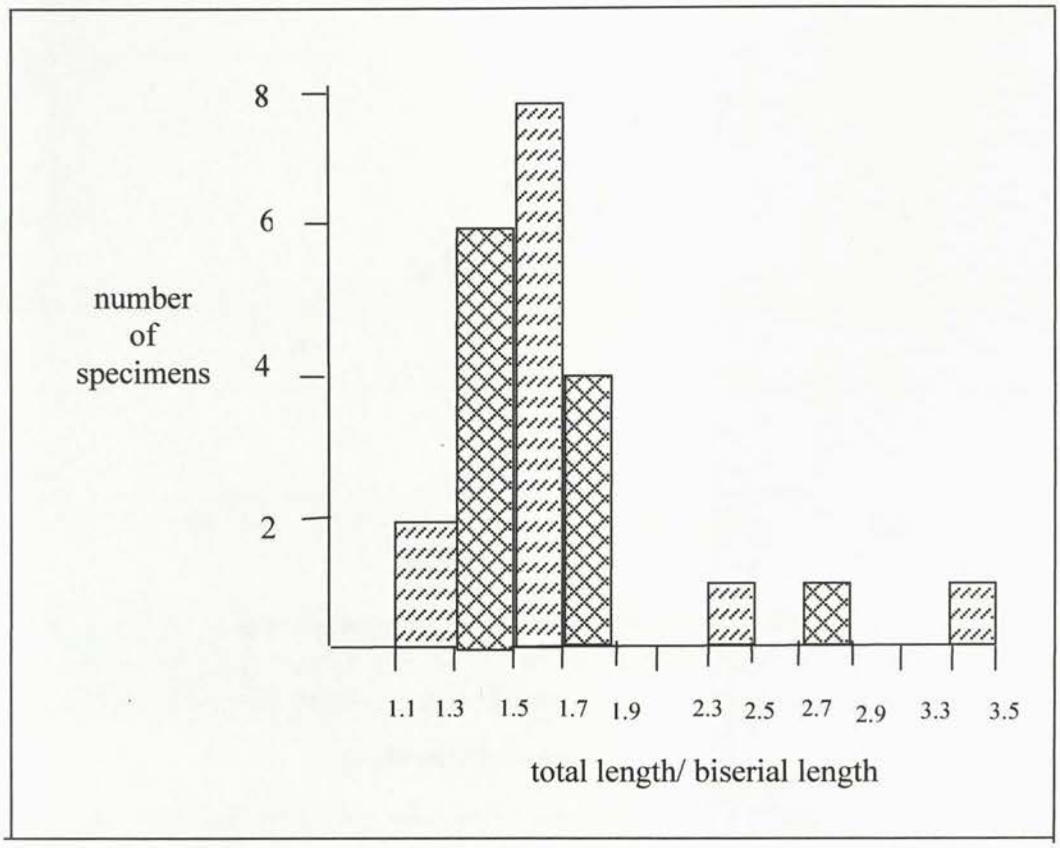


Figure 30. Semitextularia thomasi Miller & Carmer.
Histogram showing the variation of the
total length/biserial length ratio.

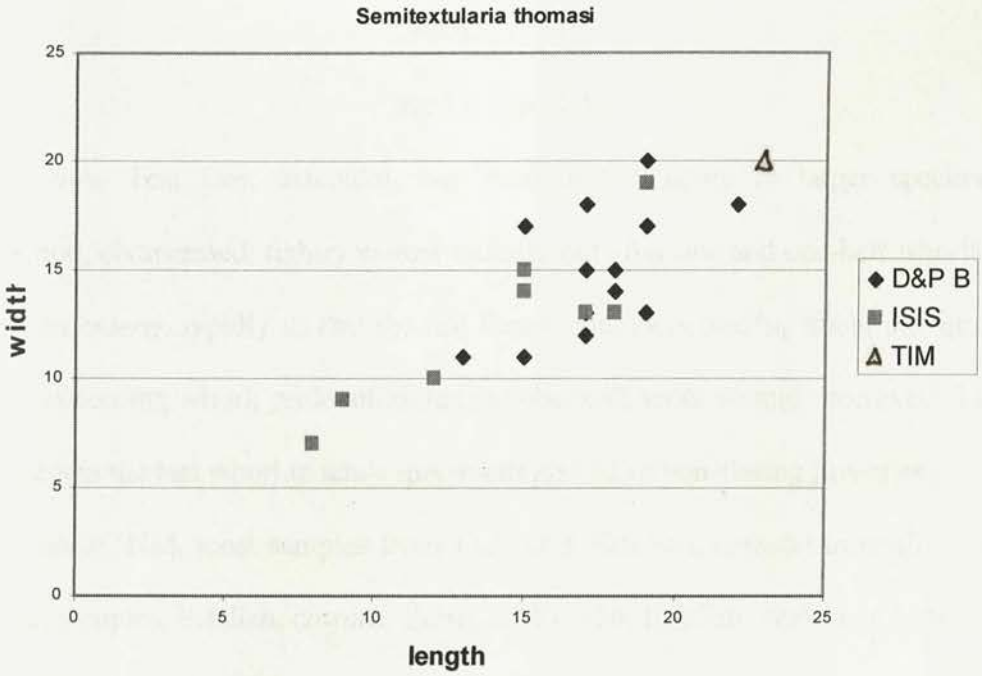


Figure 31. Semitextularia thomasi. Diagram showing the relationship between length and width for specimens from several localities. (Scale: 1 unit =25μm).

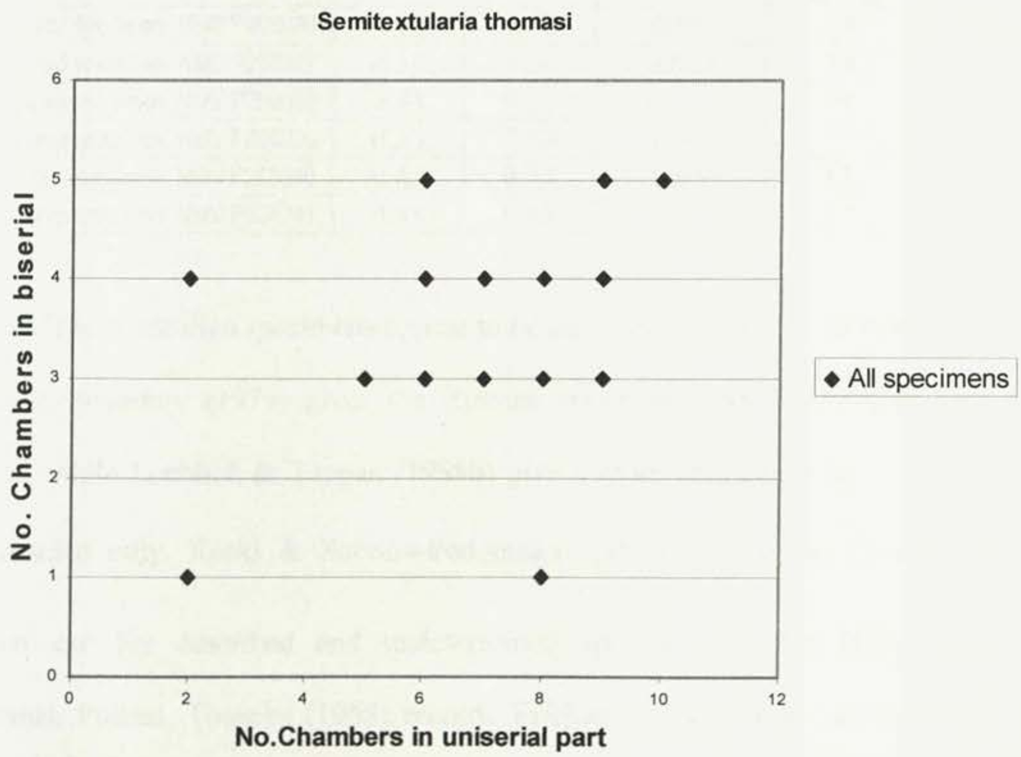


Figure 32. Semitextularia thomasi. Diagram showing the relationship between the number of chambers in the biserial and uniserial sections of specimens from several localities

Nanicella sp.

Plate 19, figs H-N.

Description. Test free; discoidal, but becoming elongate in larger specimens; planispiral, compressed; tightly wound initially but after one and one-half whorls the chambers enlarge rapidly so that the test flares; chambers overlap about one-quarter of the preceeding whorl; proloculum large, spherical; septa strongly recurved; 14-17 chambers in the last whorl in adult specimens and 13 in non-flaring juveniles.

Distribution. TIM, most samples from 14.1-83.9, Eifelian, *costatus-australis* zones; ISIS, all samples, Eifelian, *costatus* Zone; YAR6/126, Eifelian, *?ensensis* Zone.

Measurements (in mm).

	maximum width	minimum width	proloculum diameter	Nunber of chambers in last whorl	Number of whorls
Figured specimen NMV P208036	0.73	0.48	0.05	18	2.5
Figured specimen NMV P208037	0.55	0.4	0.075	14	2
Figured specimen NMV P208038	0.43	0.35	-	14	1.5
Figured specimen NMV P208039	0.33	0.33	0.06	13	2
Figured specimen NMV P208040	0.45	0.33	0.05	12	2
Figured specimen NMV P208041	0.88	0.58	-	18	2.5

Remarks. The Australian specimens appear to be amongst the earliest occurrences of *Nanicella*, Poyarkov (1979) gives the Russian range as early Givetian to early Frasnian, while Loeblich & Tappan (1988b) give a more restricted world range of late Frasnian only. Racki & Soboń-Podgórska (1993) give a late Givetian to Frasnian age for described and undetermined species from the Holy Cross Mountains, Poland. Toomey (1968) records Eifelian pyritized casts of *Nanicella* from Burma. Vachard & Massa (1989) record *N.* ex. gr. *uralica* from two horizons in two different cores in Southern Tunisia – one they give a Lower Devonian (possibly Pragian/Emsian) age and the other a Frasnian age. The ?Pragian/Emsian age is much older than any other suggested age for *Nanicella.*

As most of the present specimens are known only as internal casts recovered from the dilute acid treatment they are left in open nomenclature. After this treatment only occassional specimens were complete – most consisted of either the inner 1-1½ whorls or the outer 1-1½ whorls. The tests are quite fragile and it is more than likely the small and irregular attachment bar between the chambers (and earlier whorls) is easily damaged when the calcareous wall is removed. The tests are, for the early whorls, nearly circular, but when the chambers rapidly increase in radial length they become elongated. The height/width ratio for adult specimes is fairly constant as is the apertural height/test height ratio.

The present specimens differ from *N. gallowayi* (Thomas 1931) as figured by Thomas (1931), Cushman & Stainforth (1943) and Poyarkov (1979) in being more compressed laterally, in the chamber shape, in being more involute in that about one-quarter of the preceeding whorl is covered in each revolution and in the flaring of the test after 1½ - 2 whorls when the chambers greatly increase in radius compared to their breadth which is almost constant. The number of chambers varies from juveniles, assumed to be the non-flaring tests, to adults with flaring tests but this does not indicate different species as the more complete specimens enable the counts to be made on the same specimen.

Poyarkov (1979) lists 10 species within the genus *Nanicella* but there is overlap between some of the defining characters; Racki & Soboń-Podgórska (1993) suggest that differentiation between species based on few specimens is unreliable and this is clearly shown in the frequency distribution of test parameters shown in their histograms. Nevertheless the present specimens seem close to *N. porrecta* Bykova (1952) in general characters but until entire specimens are found this is left open.

FORAMINIFERAL ORGANIC LININGS.

This section is represented by three papers, co-authored with Dr. Theresa Winchester-Seeto of M.U.C.E.P., in which we present evidence for the first time of organic linings of agglutinated foraminifera from the Palaeozoic. The organic linings occurred in Dr. Winchester-Seeto's chitinozoan samples.

The organic linings of rotalid foraminifera from the Permian to the Recent are well documented (Stancliffe, 1989) but only recently have linings of Palaeozoic agglutinated foraminifera been reported (Winchester-Seeto & Bell, 1994). Continuing study of material from Australia, France, Siberia and Pakistan has shown that Ordovician to Upper Devonian agglutinated foraminiferal organic linings are commonly present in shallow marine limestones, marls and shales. In earlier works reporting organic linings they have been referred to as microforaminifera because of their small size (typically <200 μ).We believe that such a term is unwarranted as foraminifera are now known to form part of the sub-63 μ fauna (Gooday, 1986a,b; Pawlowski, 1991) and Burnett (1979) refers to foraminifera of the 10-15 μ range; thus these smaller forms are part of the entire foraminiferan size range (albeit a size range seldom studied) and require no special name.

The first paper (Winchester-Seeto & Bell 1994) shows that organic linings of foraminiferans are present in the Devonian and that they could be readily identified, although of much smaller size, with established agglutinated foraminiferal genera.

Prior to this work organic linings of calcareous rotaliid forams were known only from the Permian to Recent (Stancliffe 1989). There was no record at all of agglutinated foraminiferal linings. These linings are presumed to be the organic sheath which surrounds the living sarcode and on which an agglutinated or calcareous test wall is attached; however it may be that these morphological forms similar to 'normal' (*i.e.* larger sized, with intact agglutinated walls) forms never had a protective hard test (or else a very weakly attached one or one that eventually dissolved). We believe that these represent a size range within foraminiferans that has not been previously studied and so do not require a special name such as 'microforaminifera' that has been used for small-sized rotaliid foraminiferans. They may inhabit a different environment (*e.g.* low oxygen, deeper water, *etc.*) but we can at the moment not comment with certainty on this aspect.

The second and third papers (Bell & Winchester-Seeto 1999, submitted; Winchester-Seeto & Bell, 1999, submitted) show that there is variation present within similar forms of organic lining (*e.g.* smooth walls, reticulated walls) and that the possibility exists of separating several species within some genera *e.g.* *Psammosphaera, Saccammina* and *Thurammina*, and that a number of organic lining species show possible usefulness in local, regional and even continental correlations as their known stratigraphic ranges are short. Some of these species are new and others can be identified with known 'normal' species found in the same aged sediments but not necessarily the same samples. Knowledge of overseas distributions and occurrences are not available (apart from our few samples from France, Pakistan and Siberia) as no work has been done on these oganisms by other workers. Until samples are available and/or other workers elsewhere in the world study these faunal elements, the present suggestions as to ranges are tentative.

This paper has been published as

Winchester-Seeto, T. M. and Bell, K. N. 1994. *Journal of Paleontology* 68:200-207.

The American conventions for spelling, punctuation and formatting is as required by that journal.

I consider that I was responsible for 50% of the contents and structure of this paper.

MICROFORAMINIFERAL LININGS FROM THE EARLY DEVONIAN OF EASTERN AUSTRALIA, AND THEIR GENERIC PLACEMENT

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ABSTRACT

Microforaminiferal linings assigned to 10 known genera have been recovered from Early Devonian (Lochkovian to Upper Emsian) limestones from Victoria, New South Wales and Queensland. These organic linings have been identified by comparison with normal-sized agglutinated foraminiferan genera known to occur in associated sediments. Microforaminiferal linings with smooth walls and reticulate sculptured walls were present and the possible implications of these (diagenetic, relict structure, naked homeomorphs or processing artifact) are discussed. Evidence is presented that *Ordovicina* may have a bilamellar organic lining.

INTRODUCTION

Palynological processing of Early Devonian limestones from New South Wales, Queensland and Victoria yielded many hundreds of small, acid-resistant microforaminiferal linings. Microforaminifera and their linings previously have been recorded from palynological preparations ranging from Late Permian to Recent (Stancliffe, 1989, Tappan and Loeblich, 1965). The term "microforaminifera" as used by Wilson and Hoffmeister (1952) represents the total foraminiferal test for specimens in the range of 30μm to 150μm, whilst Echols and Schaeffer (1960) used it to refer to the organic lining of the foraminiferal test and showed that these linings could reach 770μm. We accept the definition of microforaminiferal linings by Stancliffe (1989, p. 350) as "the acid resistant organic remains found in palynological preparations which are thought to be the inner linings of microforaminiferal tests". Therefore, microforaminifera is restricted to describing the size range of the foraminiferan being discussed.

Little is known of the geographic distribution or stratigraphic significance of these linings. A few palynologists have illustrated isolated specimens from faunas, usually the easily recognizable :rotalid" or coiled forms (Stancliffe, 1989, and references therein). Magloire and Taudourdeau (1973, pl. 1, figs 1-5, 10) figured what appear to be linings from agglutinated foraminiferal genera, recognizing only the rotalid form as foraminiferans (Magloire and Taudourdeau, pl. 1, fig. 10). A number of agglutinated foraminiferan, pyrite casts and uniserial linings have been reported by Pichler (1971) from the Eifelian of West Germany while Eisenack (1978) reported what may be organic linings of the agglutinated *Stegnammina* from basal Wenlock limestone at Dudley, England. Occasionally, complete agglutinated foraminiferal tests and separate acid-resistant linings have been reported from the same preparations, for example Pichler (1971) from West Germany, and Eisenack (1978) from England. These may, however, be the result of low acid concentrations used in sample preparation.

The present study identifies organic linings believed to be remnants of agglutinated microforaminifera assignable to 10 genera.

METHODS

Palynological preparation followed the procedure outlined by Paris (1981). Standardized 50g samples were initially treated in dilute hydrochloric acid (approximately 10 percent), followed by digestion in hydrofluoric acid (70 percent) for 12-48 hours, then washing and screening through a 53μ sieve.

Because on of us (T. W.-S.) was primarily interested in recovering chitinozoans, only the coarse fraction of the separation was inspected. While yields varied from sample to sample, the following fossils could be recognized: chitinozoans, scolecodonts, spores, wood, leiospheres, microforaminiferal linings and algal tetrads. Also present were many specimens of uncertain affinity but which included material similar to that described and figured by Eisenack (1971, 1977, 1978), for example, annulated tubes, tubes in a spiral form, remains of "hydrozoans" and annelids. The microforaminiferal linings were uncommon to rare in most samples i.e. from 1 to 20 or so specimens in a 50g sample.

Thirty randomly selected spot samples from six localities were processed and carefully picked for organic linings. The localities included four from the Garra Limestone at Wellington, New South Wales (MUNG, RUN, GCR, EUR sections), one from the Broken River area of northern Queensland (Shield Creek Formation MW section) and one from northeastern Victoria (Taravale Formation, Gelantipy Road section) (Figure 1). The samples were selected at random to try to establish the geographic range of the microforaminiferal linings, their preferred environment and association with other microfauna, and the suite of morphologies from this time span.

The figured specimens are housed in the collections of the Australian Museum, Sydney, with catalogue numbers prefixed by AMF.

IDENTIFICATION AS AGGLUTINATED MICROFORAMINIFERAL LININGS

The present material has been identified as agglutinated microforaminiferal linings because of their shape, size and similarity to the known foraminiferal fauna in the associated sediments. All reported specimens of microforaminiferal linings to date have been of rotaliform, uniserial or biserial structures most likely belonging to the foraminiferal suborder Rotaliina, although family or generic placement has not been possible. The form recovered in this study are, with one exception, monothalamous tests. Early Devonian foraminiferal faunas of the world are dominated by simple agglutinate forms and are customarily placed in particular genera because of their characteristic shapes (Conkin & Conkin, 1979). In faunal studies of associated sediments only agglutinated foraminiferans have been recovered. Some 24 genera of agglutinated foraminiferans have been recognized, and the microforaminiferal linings can be assigned, on the basis of their shape, to 10 of these genera.

It is known that Recent agglutinated foraminiferans have an inner organic lining (Bender and Hemleben, 1988; Bermudez and de Rivero, 1963; Cartwright et al., 1989; DeLaca, 1986; Galloway, 1933; Goldstein and Barker, 1988; Gooday and Claugher, 1989; Hedley, 1960, 1962; Lipps, 1973; Loeblich and Tappan, 1964). The lining has been referred to as chitin or pseudochitin (an acid mucopolysaccarid; Hedley, 1964), although

Schwab and Plapp (1983) found that in the monthalamous foraminiferan *Allogromia laticollaris* the shell was a proteinaceous carbohydrate. This lining is important as the surface to which the test matrix may be admixed by organic, calcareous, siliceous, or possibly, ferruginous cements (Bender and Hemline, 1988; Gallows, 1933; Goody and Laugher, 1989; Hedley, 1960, 1962; Lipps, 1971; Loeblich and Tappan, 1964, 1989; Murray, 1972; Wood, 1949). This inner lining is usually 1-10μm in thickness (Goody, 1986; Hedley, 1964) but in Recent *Bathysiphon* spp. it is only 0.1-0.5μm thick (Gooday and Claugher, 1989). Hedley (1962) observed that the organic lining of specimens of the genus *Saccammina* was not always present in dried samples. This was due to the contraction of the lining away from the shell during the fixation process and its subsequent loss with the other protoplasmic contents. It is possible that this inner lining may decay rapidly after death of the animal and its absence in dried specimens (i.e. those lacking protoplasm) may have little significance. Thus, the apparently simple concept of dissolving Paleozoic agglutinated foraminiferans to recover their linings for comparison with those found in palynological residues would not necessarily confirm or deny their existence.

Although Echols and Schaeffer (1960) found their material to contain linings ranging from 30μm to 770μm in size, most authors have found that the size range of linings is much smaller (50-300μm). The size of our specimens, 60-300μm, is much less than that of "normal" foraminiferans, falling into the microforaminiferal size range. This may imply that the material observed in these samples are linings of microforaminiferans or, alternatively, the contracted linings of normal-sized foraminiferans. Cohen and Guber (1968) found that organic linings of Recent normal-sized foraminiferans could contract up to 40 percent of the size of the host test.

GEOLOGICAL SETTING

The samples studied were collected from sections measured predominately shallow-water limestone sequences from the Garra Limestone, New South Wales, Taravale Formation, Victoria and the Shield Creek Formation, Queensland (see Figure 1).

Extensive studies on the con0dont faunas from Australia (Mawson, 1987; Mawson et al., 1988; Wilson, 1989) have provided the stratigraphic framework for dating the samples. The conodonts show that the samples examined for foraminiferal linings are of Lochkovian, Pragian and Emsian ages, which is confirmed by the chitozoan faunas (e.g. Winchester-Seeto, 1993).

Eurimbla (EUR) section of the Garra Limestone. – This section consists of 133.5 m of well-bedded carbonates, subordinate shales, and argillaceous limestones from mid-Lochkovian to Pragian in age. The silicified horizons contained brachiopods, sponges and foraminiferans. The section was measured upstream along Loombah Creek, starting at grid reference 6507,7007 on Cumnock 1:50000 topographic map (Sorentino, p. 493, *in* Mawson et al., 1988).

GCR, MUNG and RUN sections of the Garra Limestone. – This is a sequence of over 600 m of shallow-water carbonates containing an extensive biota of trilobites, sponges, foraminifera, brachiopods, rugose and tabulate corals, crinoids, molluscs, dacryoconarids and stromatoporoids (Wilson, 1989). The MUNG and RUN sections are Lochkovian in age and the GCR section spans the Lochkovian-Pragian boundary.

The three sections are documented by Wilson (1989, p. 120-121). The MUNG section concerns a segment of the Garra Limestone cropping out in the Mungalla Creek, 2.2 km south of the Wellington Caves (grid reference FD 817867 on the 8632-I and IV Wellington 1:50000 topographic sheet). The section labeled RUN occurs approximately 500 m southwest of the MUNG section. The third section, GCR, was measured through the Garra Limestone, Wellington Caves Reserve, finishing at the corner of allotments 172 and 180.

Martins Well Limestone Member section (MW). – A 120 m section was measured through the Martins Well Limestone Member of the Shield Creek Formation, Broken River area of northern Queensland, 0.8 km east of Martins Well (Benson and Bear, p.495, *in* Mawson et al., 1988). The shallow-water limestones are Lochkovian in age and contain a fauna dominated by crinoids with complete calyxes, stromatoporoids, bryozoans, corals, rare gastropods and brachiopods.

Taravale Formation section, Gelantipy Road (GEL). – The section, of almost continuous outcrop along the Buchan-Gelantipy Road for 3.5 km, is of Emsian age and includes nodular limestones, shales and impure limestones containing an assemblage of brachiopods, rugose corals, dacryoconarid, foraminifera and goniatites (Mawson, 1987).

SYSTEMATIC PALEONTOLOGY

Order FORAMINIFERIDA Eichwald, 1830

Suborder TEXTULARIINA Delage and Herourd, 1896

Family ASTRORHIZIDAE Brady, 1881

Genus HYPERAMMINA Brady, 1878

Type species. – *Hyperammina elongata* Brady, 1878

HYPERAMMINA spp.

Figure 2.1-2.5

Description. – Specimens with more or less globular proloculus followed by tubular second chamber which often shows a constriction in test just before terminal rounded aperture. Two forms present; one with proloculus of approximately same diameter as second chamber (Figure 2.4), the other with a proloculus about twice the second chamber diameter (Figure 2.1, 2.2, 2.5). Relative proportions of tube and proloculus varies from about 1:1 to 4:1 in larger prolocular forms. This may be a specific character. Size range: 200-300μm.

Material. – Specimens recovered from GCR 38, 53.7; MUNG 24.8; GEL 168.3, 172.1, 172.8, 173.6.

Age.- Lochkovian, *pesavis* conodont Zone; Emsian, *inversus* and *serotinus* conodont Zones.

Family SACCAMMINIDAE Brady, 1884

Genus PSAMMOSPHAERA Schulze, 1875

Type species. – *Psammosphaera fusca* Schulze, 1875

PSAMMOSPHAERA spp.

Figure 2.7-2.14

Description. – Originally spherical forms without any apparent apertures. There may be two separate forms: one with a plain, smooth surface, the other with a granular surface. Diameter from 75 to 120μm.

Material. – Specimens recovered from GCR 50.2, 106, 117.3, 343, 412.2, 479.6; RUN 44.4, 76.7; MUNG 24.8, 76.2; MW 13.7, 31.

Age. – Lochkovian-Pragian, *pesavis* and *sulcatus* conodont Zones.

Genus SOROSPHAERA Brady, 1879

Type species. – *Sorosphaera confusa* Brady, 1879.

?SOROSPHAERA sp.

Figure 2.6

Description. – Two broken specimens are tentatively assigned to this genus. One with a chain of three globular chambers without apparent apertures on or between chambers; the other shows a single chamber and start of a second chamber. Large specimen, total length 180μm, middle chamber 60μm; smaller specimen, 80μm diameter, AMF87237.

Material. – Specimens recovered from MUNG 76.2

Age. – Lochkovian, *pesavis* conodont Zone.

Genus SACCAMMINA Sars *in* Carpenter, 1869

Type species. – *Saccammina sphaerica* Brady, 1871

SACCAMMINA spp.

Figure 3.1-3.6

Description. – Globular test with small circular aperture, sometimes produced on a short neck. Test surface usually coarsely "ribbed".

Remarks. – Several morphological forms can be distinguished on the basis of apertural characteristics: Form A (not figured) has a very small circular aperture about 5μm in diameter; Form B (Figure 3.1, 3.2, 3.4), a more common form, has a larger (about 10μm) diameter aperture on a very short neck; and Form C (Figure 3.3, 3.5) with a wider (greater than 10μm) diameter aperture on a neck about 10-15μm long. One specimen (from RUN 85.7) shows a possible attachment scar (Figure 3.4). Size range: Form A, 70μm; Form B, 75-90μm; Form C, 90-120μm

Material. – Specimens recovered from GCR 50.2, 106, 117.3, 412.2; RUN 44.4, 70.6, 85.7, 207; MUNG 76.2.

Age. – Lochkovian-Pragian, *pesavis* and *sulcatus* conodont Zones.

Genus LAGENAMMINA Rhumbler, 1911

Type species. – *Lagenammina laguncula* Rhumbler, 1911

LAGENAMMINA sp.

Figure 4.4, 4.5

Description. – Specimens have a globular chamber; long narrow neck; a terminal aperture. Size range: 70-120μm

Remarks. – Forms with short stubby necks are placed in *Saccammina.*

Material. – Specimens recovered from GCR 117.3, 262; MUNG 8.4.

Age. – Lochkovian-Pragian, *pesavis* and *sulcatus* conodont Zones.

Genus ORDOVICINA Eisenack, 1938

Type species. – *Ordovicina oligostoma* Eisenack, 1938

ODROVICINA sp.

Figure 3.14-3.16

Description. – Specimens appear to have been originally fusiform in shape, tapering evenly to each end. Size range: greater than 200μm.

Remarks. – The wall, in the specimen from RUN 70.6 (Figure 3.15, 3.16) is double, each part slightly less than 1μm thick and apparently separated by about 1.5μm; this separation may be due to distortion.

Material. – Specimens recovered from RUN 70.6; MUNG 24.8; GCR 74.3.

Age. – Lochkovian-Pragian, *pesavis* and *sulcatus* conodont Zones.

Genus THURAMMINA Brady, 1879

Type species. – *Thurammina papillata* Brady, 1879

THURAMMINA sp.

Figure 4.1-4.3

Description. – Specimens appear to have been originally globular, now flattened or deformed to a greater or lesser extent. Raised nipple-like structures appear over the surface, with a single terminal aperture on each. Test surface may be marked by low "ridges", probably relict impressions of former agglutinated grains or places to which grains were attached by fibrous cement strands. Size range: 100-120μm.

Material. – Specimens recovered from GCR 37, 55, 401.8, 421.2; MUNG 13.7, 25.4, 31.

Age. – Lochkovian-Pragian, *pesavis* and *sulcatus* conodont Zones.

Genus HEMISPHAERAMMINA Loeblich and Tappan, 1957

Type species. – *Hemisphaerammina batalleri* Loeblich and Tappan, 1957

HEMISPHAERAMMINA sp.

Figure 4.6-4.8

Description. – Specimens hemispherical, with or without a basal membrane. Size range: 80-100μm diameter.

Remarks. – As the basal membrane appears to be thin, its presence or absence is, at the present, not taken to be a distinguishing characteristic. Specimens from MUNG 8.4 and 76.2 show that the basal attachment rim was skirted. A two-chambered specimen occurred in RUN 199.3 (Figure 4.8).

Material. – Specimens recovered from GCR 117.3; RUN 199.3; MUNG 6.3, 8.4, 24.8, 76.2.

Age. – Lochkovian-Pragian, *pesavis* and *sulcatus* conodont Zones.

Family AMMODISCIDAE Reuss, 1862

Genus TOLYPAMMINA Rhumbler, 1895

Type species. –*Hyperammina vagans* Brady, 1879

TOLYPAMMINA sp.

Figure 3.12, 3.13.

Description. – One specimen consisting of a long closed , cylindrical tube with a winding growth habit. Prolocular end deformed so that actual shape is unclear. Size: total length 700μm; maximum diameter 30μm.

Material. – Specimen recovered from GCR 53.7

Family HORMOSINIIDAE Haeckel, 1894

Genus REOPHAX Montfort, 1808

Type species. – *Reophax scorpiurus* Montfort, 1808

REOPHAX sp.

Figure 3.7, 3.8

Description. – Specimens have rounded-elliptical proloculus; narrower "neck" expands into another elliptical chamber, larger in size than proloculus. One specimen (from GCR 105, Figure 3.7) suggests presence of a third chamber. Surface generally smooth, small areas of "ribbing" may be present. Size range: 200-300μm.

Material. – Specimens recovered from GCR 105, 290.9.

Age. – Pragian, *sulcatus* conodont Zone.

Miscellaneous tubes

Figure 3.9-3.11

Remarks. – Many tubular fragments have been recovered. They may belong to *Tolypammina, Hyperammina, Rhabdammina* or *Saccorhiza*, but without the prolocular end and more complete specimens they cannot be further identified.

DISCUSSION

Microforaminiferal linings are known to have an extensive geological range (Stancliffe, 1989) and to comprise a large part of the preserved material in Recent sediments (Cross et al., 1966; Gooday, 1986; McKee et al., 1959; Melia, 1984). Nevertheless, very little is known of their biostratigraphy or paleoecology; this is especially so for the agglutinated foraminiferans, which have seldom been reported in the literature (Eisenack, 1978; Pichler, 1971; Magloire and Taugourdeau, 1973) This lack of knowledge is most likely due to the size range of the specimens (50-300μm) and the lack of interest by palynologists untrained in foraminiferal taxonomy (Magloire and Taugourdeau, 1973).

Agglutinated foraminiferal linings may have been overlooked because the texture of the linings is quite different from that of the rotalid microforaminiferans. Rotalid linings appear to be thinner and transparent (Stancliffe, 1989, and references therein), whereas the agglutinated forms have a thicker wall, up to 10μm (Hedley, 1960, 1964), and are opaque. Whether this is an artifact of preservation, such as thermal maturation, or reflects a real difference in the structure or composition of agglutinated organic linings is not yet established.

No microforaminiferans from the palynological residues were observed with agglutinated tests intact, although rare pyrite casts were present. One of us (K.N.B.) has, however, identified normal-sized agglutinated foraminiferans from the same sections but not necessarily from the same stratigraphic samples. The normal-sized tests were recovered from the light fraction residues of limestone samples digested in acetic acid for conodonts. A study is presently being undertaken to establish the statistical association between the linings found in palynological residues and the agglutinated test recovered from the light fractions of conodont processing.

It is usually assumed that the organic lining within an agglutinated foraminiferan is monolamellar, but the presence of a specimen of *Ordovicina* (Figure 3.16) showing an apparently bilamellar wall suggests that this matter needs further investigation. A laminated organic wall has been suggested as occurring in the saccamminid *Pelosphaera cornuta* (Hedley, 1960).

The reticulate sculpture shown by some specimens of *Hyperammina, Thurammina, Reophax* and miscellaneous tubes (e.g. Figures 2.7-2.11, 2.13, 2.14, 3.9-3.11) can be interpreted as a relict impression of the agglutinated sand grains. In Recent *Bathysiphon* spp. the organic lining conformed to the shape of the overlying agglutinated particles (Gooday and Claughter, 1989). The fact that many of the linings show no such patterns has several possible implications. It may be that these microforaminiferans never had any surface coating, i.e. they are naked homeomorphs of the larger normal foraminiferan and then should possibly be placed in the Allogromiina rather than the Textulariina, or that the surface grains were small and only weakly cemented to the organic layer as occurs in the meiofaunal agglutinated foraminiferan in bathyal sediments (Gooday, 1986). However , as Lipps (1973) suggested, the presence or absence of test material may not have significance in foraminiferal classification. A second explanation could be that the loss of any original test material is diagenetic by some, as yet, unknown process. Thirdly, it may be an artifact of the procedure involved in processing the samples. Ongoing studies of the associated macro- and micro-faunal elements may lead to a better understanding of this point.

ACKNOWLEDGMENTS

We gratefully acknowledge the assistance and interest given by John Talent and Ruth Mawson, School of Earth Sciences, Macquarie University, both in this study and in ongoing research on Paleozoic chitinozoans and foraminiferan. We would also like to express our appreciation to Reed Wicander from the Central Michigan University for his constructive comments on the manuscript. We thank the reviewers, H. Tappan-Loeblich and K. Wetmore, for their encouraging and thoughtful suggestions.

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Figure captions

Figure 1. Localities in Eastern Australia from which Early dev microforaminiferal linings have been found.

Figure 2. 1-5, *Hyperammina* spp. 1. GCR 38, x150; 2, MUNG 24.8, x150; 3. GCR 53.7, x200; 4. GCR 38, x200; 5. GCR 38, x200; 6. ?*Sorosphaera* sp., MUNG 76.2, x300. 7-14. *Psammosphaera* spp. 7. MW 13.7, x400; 8. RUN 44.4, x400; 9. GCR 50.2, x300; 10. MUNG 24.8, x400; 11. enlargement of surface and attachment scar of Figure 2.10, x1150; 12. MUNG 24.8, x400; 13. enlargement of surface and attachment scar of Figure 2.12, x800; 14. GCR 479.6, x350.

Figure 3. 1-6, *Saccammina* sp. 1. RUN 70.6, x400; 2. GCR 412.2, x400; 3. GCR 412.2, x300; 4. RUN 85.7, x400, arrow points to apertural pores; 5. GCR 50.2, x300; 6. enlargement of aperture of Figure 2.3, x1100. 7-8. *Reophax* sp. 7. GCR 105, x180; 8. GCR 290.9, x200. 9-11, Miscellaneous tubes. 9. RUN 85.7, x200; 10. MUNG 24.8, x150. 12-13, *Tolypammina* sp. 12. RUN 44.4, x150; 13. GCR 53.7, x120. 14-16, *Ordovicina* sp. 14. GCR 74.3, x200; 15. RUN 70.6, x250; 16, enlargement of wall of Figure 3.15, x1200.

Figure 4. 1-3, *Thurammina* sp. 1. MW 34.4, x400; 2. enlargement of Figure 4.1, x900; 3. gcr 37, x300, arrow points to apertural pores. 4-5, *Lagenammina* sp. 4. GCR 117.3, x300; 5. MUNG 8.4, x300. 6-8 *Hemisphaerammina* sp. 6. MUNG 8.4, x400; &. MUNG 24.8, x400; 8. RUN 199.3, x200.

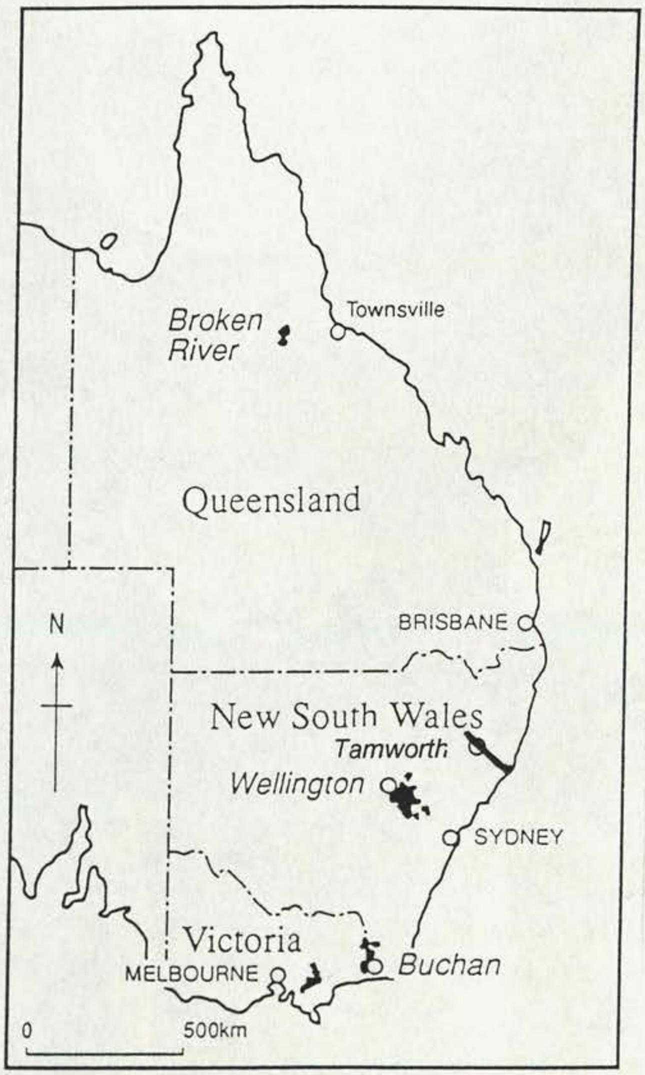
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Fig 1

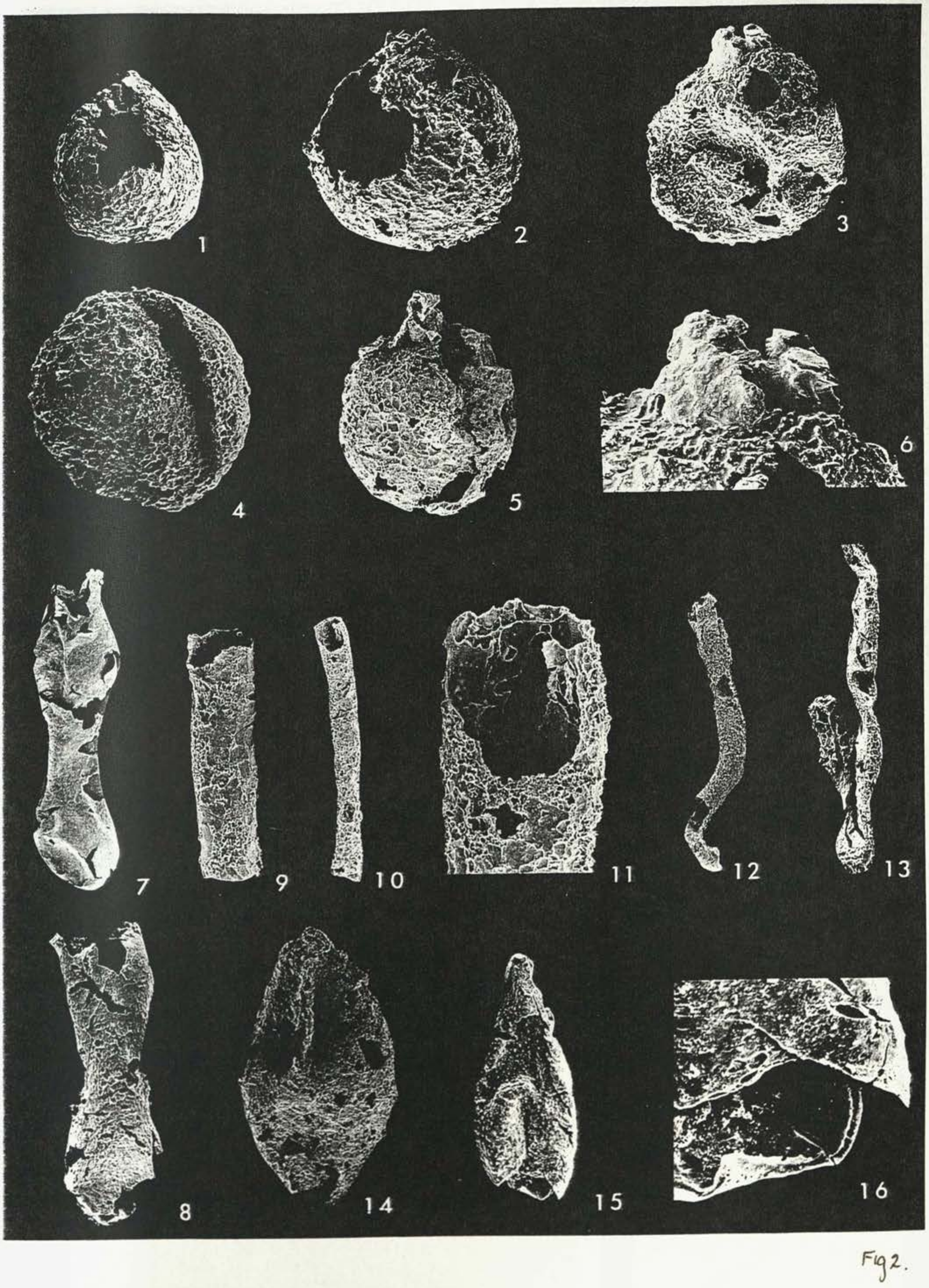

Fig 2.

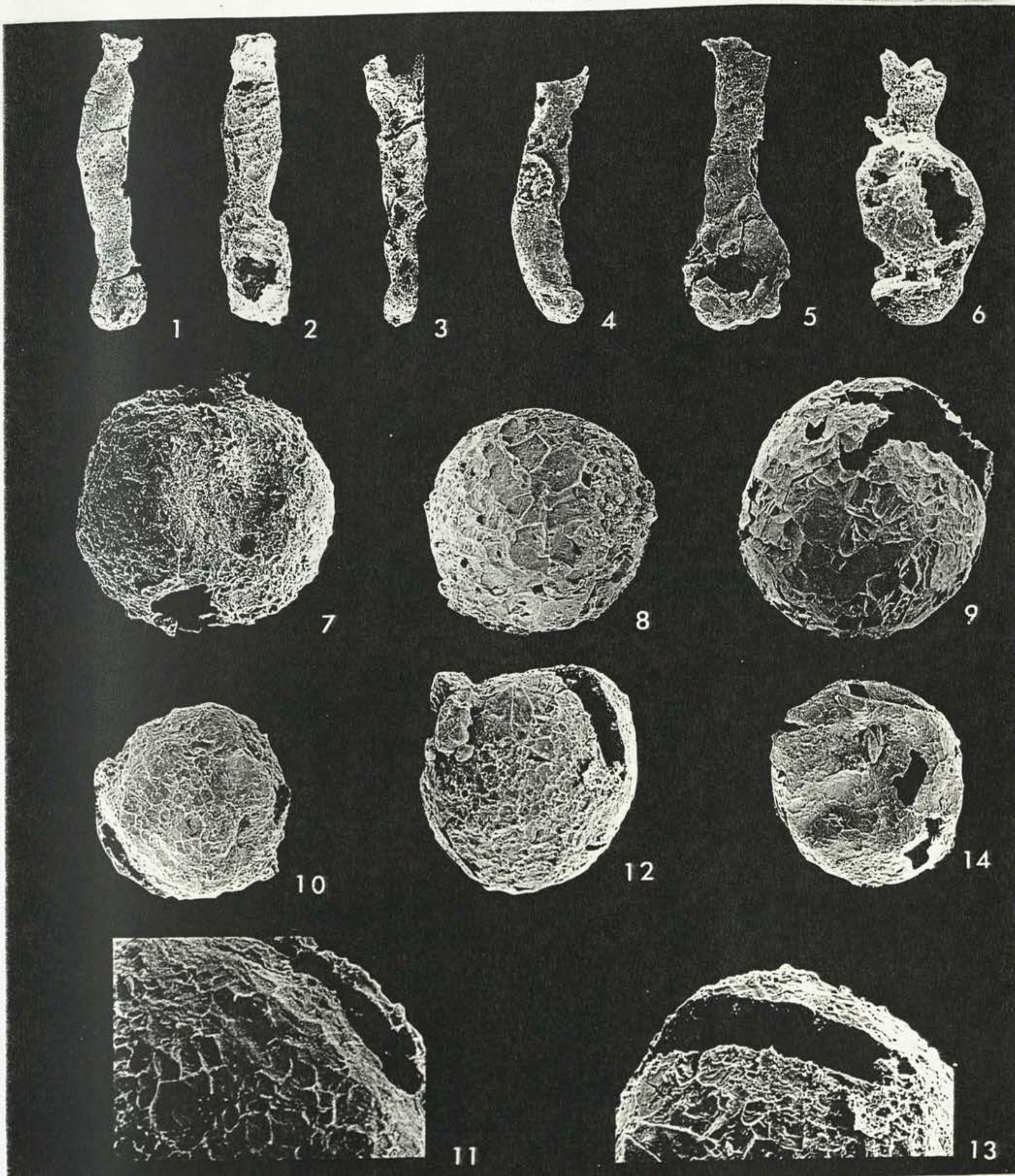

Fig 3

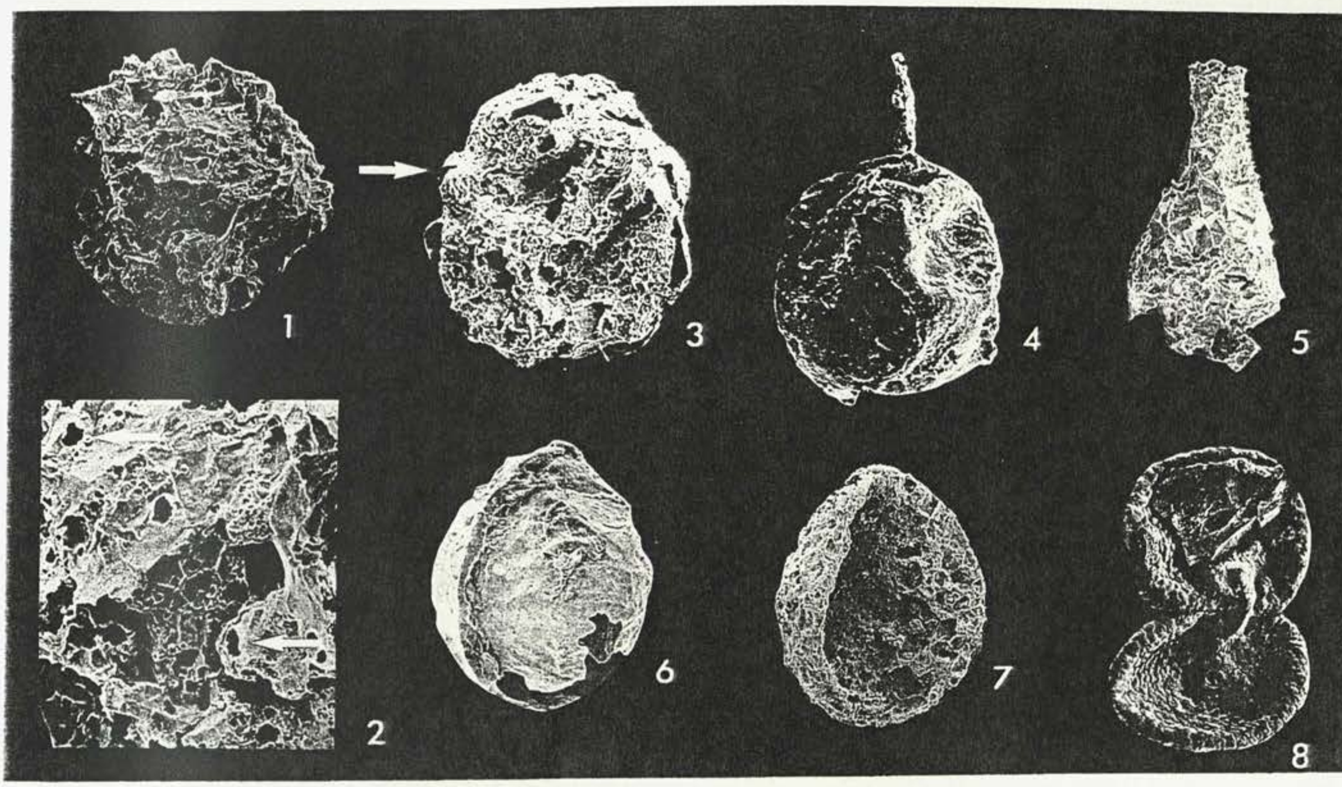

Fig 4

This paper has been submitted to and accepted by *Journal of Micropalaeontology*, and is due for publication in April, 1999.

I consider that I was responsible for 50% of the contents and structure of this paper.

Linings of agglutinated Foraminifera from the Devonian: taxonomic and biostratigraphic implications.

K.N. BELL & T.M. WINCHESTER-SEETO

BELL, K.N AND WINCHESTER-SEETO, T.

Linings of agglutinated Foraminifera from the Devonian: taxonomic and biostratigraphic implications.

The organic linings of agglutinated foraminiferans from the Devonian are documented and described. These linings have been recovered in palynological residues from Australia, France, Pakistan and Siberia and range from the Lochkovian to the Frasnian. Six species are described as new: *Hemisphaerammina coolamon, Psammosphaera garraay*, *Reophanus proavitus*, *Saccammina mea*, *Saccammina wingarri* and *Thurammina mirrka.* Three species, with a wide geographic spread and a relatively limited stratigraphic range, may prove to have some utility in intercontinental correlation: *Inauris tubulata* Conkin & Conkin, *Saccammina mea* n. sp. and *Saccammina wingarri* n. sp.

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Keywords: Foraminiferal linings, Devonian, taxonomy,

biostratigraphy

THE ORGANIC linings of rotalid foraminifera from the Permian to the Recent are well documented (Stancliffe, 1989) but only recently have linings of Palaeozoic agglutinated foraminifera been reported (Winchester-Seeto & Bell, 1994). Continuing study of material from Australia, France, Siberia and Pakistan has shown that Ordovician to Upper Devonian agglutinated foraminiferal organic linings are commonly present in shallow marine limestones, marls and shales. In earlier works reporting organic linings they have been referred to as microforaminifera because of their small size (typically <200 □m).We believe that such a term is unwarranted as foraminifera are now known to form part of the sub-63 □m fauna (Gooday, 1986a,b; Pawlowski, 1991) and Burnett (1979) refers to foraminifera of the 10-15 □m range; thus these smaller forms are part of the entire foraminiferan size range (albeit a size range seldom studied) and require no special name.

Apart from the Allogromiidae, the various foraminiferal genera are defined as either agglutinate or calcareous. Bender (1995) has shown that most agglutinated genera have an inner organic lining and our specimens are obviously congeneric with described agglutinated genera but do not have any agglutinant covering. This absence of outer wall material may be an environmental response, or just a preservational or procedural artefact, at present we cannot differentiate between these possibilities and, so we prefer to use established genera and to ignore the absence of agglutinating wall material. Hohenneger (1990) has suggested that the Allogromiidae and simple Astrorhizidae (in which our specimens are classified) may be more closely related than previously thought and that the amount of agglutinated material present may have little significance and even be environmentally controlled; our studies support this view.

The purpose of this study is to describe and document the inner, organic linings of agglutinated foraminifera, recovered in palynological processing of Devonian material, and to examine their taxonomic and biostratigraphic implications. In particular, we aim to place the species recovered into a more tightly constrained time-frame than most previous studies by referring to the conodont zones from which they were recovered.

Methods

The foraminiferal linings described in this study were recovered from samples processed in the quest for chitinozoans; thus the criterion for selection of sections was the prospectivity for acid-resistant fossils. Many of the sections had also been previously yielded conodonts, and strong, reliable stratigraphic control is already in place. Samples yielding foraminiferal linings so far, are exclusively from marine strata, dominantly shallow marine limestones and shales.

Processing methods followed those outlined by Paris (1981), including initial treatment of 50 g of crushed rock with 10% HCl until all the carbonate had been dissolved, followed by acid digestion by 50-70 % HF for 1-4 days. Nitric acid (concentrated) was used when necessary for surface etching, dissolving of fluorite salts and destruction of amorphous organic matter. The residue was then separated through a 53 µm sieve and picked with a micropipette. Well preserved specimens were selected for examination with a conventional Scanning Electron Microscope (SEM) or with an Environmental electroscan (ESEM); the advantages of the ESEM are outlined by Winchester-Seeto (1993a).

Locality information.

Early Devonian.

The majority of foraminiferal linings were recovered from Early Devonian sequences spanning the Lochkovian-Pragian boundary (i.e. *pesavis-sulcatus* conodont zones), this is primarily due to the more intensive nature of the chitinozoan and conodont work undertaken on these areas.

The Garra Limestone, near Wellington, central New South Wales (figs 1, 2), yielded the most specimens. It is characterised by gray to dark-gray, highly fossiliferous limestones, from a subtidal, shallow shelf. Studies of conodonts (Wilson, 1989) and chitinozoans (Winchester-Seeto, 1993b) provide a detailed biozonation for sections MUNG, RUN (*pesavis* Conodont Zone) and GCR (*pesavis-sulcatus* conodont zones). A section through the Martins Well Limestone member of the Shield Creek Formation (MW) from the Broken River area of northern Queensland has been dated as spanning the *pesavis-sulcatus* conodont zones (Benson & Bear *in* Mawson *et al.,* 1988), although all foraminiferal linings were recovered from the *sulcatus* Zone. This limestone is a shallow marine bioclastic calcarenite deposited on a broad, stable shelf (for further details see Winchester-Seeto, 1993c; Wyatt & Jell, 1980).

The Amphitheatre Group from the Darling Basin, western New South Wales, represented in the Kewell East bore-core (KE DDH1), yielded a moderate diversity of foraminiferal linings. The interbedded gray to dark gray claystones, carbonaceous shales and siltstones represent a marine environment, possibly a transgressive sequence (Bembrick, 1997). Chitinozoan evidence suggests a Late Lochkovian-Early Pragian age (no younger than *sulcatus* Conodont Zone

[Winchester-Seeto, unpub. data]).

Pragian faunas were recovered from the Tyers and Boola quarries (Tyers, BOO) in the limestones of the Coopers Creek Formation, eastern Victoria. Conodonts date the two sections as spanning the *sulcatus-kindlei* conodont zones (Mawson & Talent, 1994), and chitinozoans included *Bulbochitina bulbosa*, an important zone fossil (Winchester-Seeto, 1993c). Palaeoenvironmental interpretation of the area is controversial (see Mawson & Talent, 1994; Rehfisch & Webb, 1993).

Fossiliferous lime packstone characterises the Point Hibbs Limestone, from Sanctuary Bay, southwestern Tasmania (Carey & Berry, 1988). The Sanctuary Bay section spans the *sulcatus-kindlei* conodont zones (Philip & Pedder, 1968; Winchester-Seeto, unpub. data).

The Taravale Formation, Buchan Group, from eastern Victoria, yielded a moderate number of Emsian foraminiferal linings. The section along the Gelantipy Road (Gel. Rd.) extends from the *dehiscens* to the *serotinus* conodont zones (Mawson, 1987; Winchester-Seeto, 1996). The succession consists of nodular limestones, shales and impure limestones, probably deposited on a broad, gently sloping marine shelf (Talent, 1965; 1969).

The Shanda horizons are situated on the southwestern margin of the Kuznetsk Basin in southern Siberia. Samples of the Middle Shanda beds (MSh) were collected from the southeastern wall of the Akaratchkino Quarry (section B-8313 of Yolkin *et al.*, 1988). The Middle Shanda strata are massive, light coloured limestones interbedded with minor shales and lie within the *serotinus* Conodont Zone.

Middle and Late Devonian

A series of spot samples from the cores through strata in the Canning Basin, Western Australia, were investigated for palynomorphs. One sample from bore-core PD 166, depth 358.4m, from the Pillara Limestone, Unit 1 (BHP log units), yielded one species of foramininferal lining. The age is inferred to be middle Givetian, ?*varcus* Conodont Zone (Colbath, 1990; Winchester-Seeto & Paris, 1995).

Situated within the Hindu Kush, the Kuragh spur is located in the Chitral region of northwest Pakistan. The Shogram Formation outcrops along the spur as 100m of limestones, sandstones and calcareous shales. Two samples from a section through this formation yielded palynomorphs; KG sample 1 is dated as ?Late *hermanni* Conodont Zone, i.e. Late Givetian, and KG sample 17 is from the ?Late *falsiovalis* Conodont Zone, i.e. Early Frasnian (Molloy, 1979; Winchester-Seeto & Paris, 1995).

Extensive biostratigraphic work has been carried out on two sections from the Serre Formation in the Montagne Noire, southern France (e.g. Klapper & Feist, 1985; Klapper, 1988; Winchester-Seeto & Paris, 1995). The oldest segment of the formation is represented by a trench through the lower part of the Serre Formation (La Serre trench A; LSA) and has been dated as spanning the Middle-Late Devonian interval, i.e. *norrisi-falsiovalis* Conodont Zone to *falsiovalis* Conodont Zone. Trench C (LSC) extends across the Frasnian-Famennian boundary (?*linguiformis-triangularis* conodont zones).

General Results

Our studies, so far, indicate that the organic linings of agglutinated foraminifera are quite widespread both geographically and chronologically. Diverse faunas have been recovered (by palynological processing) from shallow marine environments such as limestones, marls and shales from Ordovician to Upper Devonian in age and in localities on three continents (see locality data). Although usually not of great abundance (about 10 per 50g rock sample) they are found in about 50% of samples processed. We have found six of the agglutinate families known from this time span, 12 known genera (plus one indeterminate) of which only two (*Hemisphaerammina* and *Tolypammina*) are of attached genera (the others having free tests) and 24 species - 6 of established species, 7 compared with known species, 6 new species and 5 left in open nomenclature because of lack of specimens.

Tubular linings with thin and thick walls are present in many samples from a variety of localities, and may represent broken parts of various genera such as *Hyperammina, Rhabdammina* or *Saccorhiza* or may even be Allogromiidae such as *Shepherdella*, but cannot be further determined and are thus left off faunal lists.

Most of the specimens are highly thermally mature, they are black and many specimens are broken or compressed; this may have affected our recovery rates and introduced bias in the types of genera and species preserved. Until comparable work in other parts of the world is undertaken on a wider suite of sediment types, little can be further deduced.

The surface of the organic wall may be either smooth or show varying degrees of reticulation i.e. raised ridges outlining smaller or larger smooth areas. These ridges, we believe, are indications of the outlines of the agglutinate material used in an outer wall but since lost either by diagenesis or treatment. Those specimens with smooth, unridged surfaces probably had either no agglutinated outer wall or one in which the various grains were sparse and perhaps only very weakly attached.

It is well known that some species of foraminiferans show a high degree of grain size selectivity (Bender 1995; Heron-Allen 1915; Petelin 1970; Scott et al 1998). Thus these species would show fairly uniform reticulations on the outer surface of the organic lining. That the surface of the lining may however show differing sizes of reticulations is also consistent with the results of Allen et al. (1998) who have found that several agglutinate species show fractal (i.e. self-similar) grain distribution in the test wall. The study of these aspects of foraminiferan test structure is just in its infancy and how, or if, they may be applied to fossil assemblages lies in the future.

Thin sections of the sampled limestones and shales have proven of little use; the 'normal' foraminiferans are very rare and seldom found in thin section and those that have been seen have no organic layer present most likely due to the diagenetic changes in the often partly recrystallized sediments. Both Hedley (1962) and Bender (1995) have commented on the rapid shrinkage and decay of the inner organic lining upon death of a foraminiferan.

Discussion

Taxonomic considerations

Many species show a variety of 'holes' in the surface of the lining, these are dominantly apertures or pores, but may also be due to breakages caused by diagenesis or in extraction procedures. The occurrence of the main aperture(s) (of the order of 10 μm) for species such as *Saccammina* and *Thurammina* is easily determined either by size and/or position on a neck or protuberance. Close examination of the test wall, however, shows the presence, quite often, of smaller openings (Pl. 1, fig 6); these holes, usually 1-5 μm in diameter, are termed pores. The smooth walled species do not have such pores present. Within any one species the pores appear to be of relatively constant size and numbers but differences occur between species, and is carried to an extreme case in Gen. et sp. indet. (Pl. 4, fig 12) in which the test is heavily perforated. We are not aware of any previous mention of such pores in the test wall of Allogromiids. It is also possible that the pores are due to some form of chemical degradation of the test during diagenesis or in the processing of the sediments or due to boring by parasites or predators.

The various genera can be subdivided into morphological groups (i.e. into species) based on characters such as shape, surface structure/s, wall thickness, number of apertures etc.,- all of which have previously been accepted as specific characters for normal-sized foraminiferans. Figure 3 lists the features used in this paper for specific separation. *Saccammina,* as defined by Loeblich & Tappan (1988), has a single aperture raised and on either a long or short neck; however, here we follow Hedley (1962) and Holbourn & Kaminski (1995) in including within this genus forms with a single, round aperture, apparently flush with the surface, as well as forms with a raised aperture. Multi-apertured forms, either raised or flush with the test wall are placed in *Thurammina*. It may be that species with apertures raised on necks or papillae could have the opening(s) in the organic lining either raised or flush; studies on recent material do not elucidate this question.

Biostratigraphic implications

There have been few attempts to use Palaeozoic agglutinate foraminiferans for biostratigraphic correlation. This is due to a variety of factors including the small number of studies globally, poor stratigraphic control of the material studied and the problems involved in differentiating species when the forms are simple.

Of the twenty-four species identified in this study, eight, so far, are only known from one region of Australia; a further nine species, however, occur in areas of Australia separated by hundreds of kilometers (e.g. *Sorosphaera* sp. cf. *S. confusa* Brady, *Tolypammina tantula* Bell and *Saccammina* sp. are found in central New South Wales and in Victoria) or separated by thousands of kilometers (e.g. *Psammosphaera garraay* n. sp., *Saccammina mea* n. sp., *Thurammina* sp. cf. *T. subspherica* Moreman and *Hemisphaerammina collamon* n. sp. are found in central New South Wales and in north Queensland; *Hyperammina devoniana* Crespin has been observed from central New South Wales, north Queensland and Western Australia; *Hyperammina* sp. cf. *H. sappingtonensis* Gutschick has been found in central New South Wales, north Queensland and Tasmania). Eight species also occur on two or more continents: *Psammosphaera cava* Moreman, has been found in Australia, North America, Great Britain, Austria and Sardinia; *Psammosphaera* sp. occurs in Australia and Siberia; *Amphitremoidea* sp. cf. *A. citroniforma* Eisenack, has a disjunct range and occurs in Australia and Pakistan; *Lagenammina ovata* Bell has been recovered from Australia and Pakistan; *Saccammina mea* n. sp. is found in Australia and Siberia; *Saccammina wingarri* n. sp. occurs in Western Australia and southern France; *Webbinelloidea similis* Stewart & Lampe is found in Australia, Poland and the United States, and *Hyperammina* sp. cf. *H. sappingtonensis* was recovered from Australia and Siberia.

Three species may have biostratigraphic utility globally, albeit only in a broad sense, namely: *Inauris tubulata* Conkin & Conkin (*serotinus* – *costatus* conodont zones), *Saccammina mea* n. sp. (*pesavis* – *serotinus* conodont zones) and

Saccammina wingarri n. sp. (*varcus* - *falsiovalus* conodont zones).

Within Australia *Sorosphaera* sp. cf. *S. confusa*, *Hemisphaerammina coolamon* n. sp., *Psammosphaera garraay* n. sp. and *Thurammina* sp. cf. *T. subspherica* Moreman appear to be restricted to the *pesavis-sulcatus* conodont zones, while *Hyperammina* sp. cf. *H. sappingtonensis* ranges through the *pesavis-serotinus* conodont zones, and *Tolypammina tantula* spans the *pesavis-perbonus* conodont zones. Further studies are needed to confirm the full ranges of these species.

There are a number of very long ranging species or ones with disjunct, long ranges: *Webinellinoidea similis, Hyperammina devoniana, Amphitremoidea* sp. cf. *A. citriniforma, Lagenammina ovata* and *Psammosphaera cava* (Fig. 4). This list highlights the problems associated with determining species in organisms with a very simple morphology, and may limit the utility of some foraminifera species for biostratigraphy.

Systematic Palaeontology

All figured and type specimens are lodged with the Australian Museum, Sydney, Australia, and are labelled with numbers prefixed with AMF.

Taxonomic conventions used in this study follow Loeblich & Tappan (1988).

Order **Foraminiferida** Eichwald, 1830

Suborder **Textulariina** Delage & Hérouard, 1896

Superfamily **Astrorhizacea** Brady, 1881

Family **Astrorhizidae** Brady, 1881

Inauris Conkin, Conkin & Thurman, 1979

Type species. Inauris tubulata Conkin, Conkin & Thurman, 1979

Inauris tubulata Conkin, Conkin & Thurman, 1979 (Pl. 1, fig. 1)

Inauris tubulata Conkin, Conkin & Thurman 1979, p. 4, pl. 1, figs 1-10.

Material. 1 specimen from MSh (sample 4).

Distribution. Middle Shanda Beds, Siberia, serotinus Conodont Zone; Jeffersonville Limestone, Kentucky, USA, late Emsian – mid-Eifelian.

Description. Test free; a ring-like, undivided tubular chamber; wall reticulate; aperture rounded produced on a short neck; the inner central area covered by a thin membraneous sheet (after Loeblich & Tappan, 1988).

Dimensions. Length = 125 μm ; Diameter = 80 μm

Remarks. Originally described from Kentucky, USA (Conkin et al., 1979), this is the only record of it outside the type locality or as a foraminiferal lining. Loeblich & Tappan (1988) postulated a membraneous central area for Inauris and our specimen clearly shows such an inner membrane apparently attached to the outer "ring" by digitate processes.

Family **Psammosphaeridae** Haeckel, 1894

Psammosphaera Schulze, 1875

Type species. Psammosphaera fusca Schulze, 1875

Remarks. The differentiation of species within *Psammosphaera* has been based on the size and/or the coarseness of the test wall (Dunn, 1942; Moreman, 1930, Mound, 1968), although varying wall thickness, test size and grain size used were not considered to be reliable indicators for specific diagnoses of such simple organisms by Browne & Schott, (1963) or McClellan (1966). We consider that the smoothness or otherwise of the organic lining surface can be used as a diagnostic feature as an indicator of original wall texture. Loeblich & Tappan (1988, p. 28) stated that *Psammosphaera* has no inner lining; but Bender (1995) found that *P. fusca* had an inner organic lining; the presence of reticulate ridges on some individuals suggests that originally these specimens had an agglutinated outer test. A number of specimens of each of the species described here show equatorial splitting into two equal halves which, although, looking like *Hemisphaerammina* may be differentiated by their very much thinner wall and rough edged sutural boundary.

Psammosphaera cava Moreman, 1930 (Pl. 1, figs 2-3)

Psammosphaera cava Moreman 1930, p.48, pl. 6, fig. 12.

Psammosphaera cava Dunn, 1942 p.322, pl. 42, fig. 6.

Psammosphaera cava Gnoli & Serpagli, 1985, p.214, pl. 1, figs. 19, 20.

Psammosphaera spp. Winchester-Seeto & Bell, 1994, p.202, figs 2.7, 2.9. 2.14; non 2.8, 2.10, 2.12.

Psammosphaera cava Bell, 1996, p. 88, fig. 6J.

Material. 15 specimens from GCR (samples 37, 50.2, 117.3, 479.6, 605); RUN (samples 44.4, 199.3), Tyers Q (sample from "Far end"), MW (sample 13.7, 31), KE (samples 511, 669.8, 791.9).

Distribution. Garra Limestone, Wellington, NSW, *pesavis-sulcatus* conodont zones; Amphitheatre Group, Darling Basin, NSW, *pesavis-sulcatus* conodont zones; Martins Well Limestone, Broken R, Qld, *sulcatus* Conodont Zone; Coopers Creek Formation, Victoria, *kindlei* Conodont Zone; Sardinia, Upper Pridolian, *eosteinhornensis* Conodont Zone to Lower Lochkovian; basal Niagaran, Silurian, Missouri, U.S.A.

Dimensions. Diameter = 69-140 μm (Av. 97 μm for 9 specimens)

Remarks. *Psammosphaera cava* is a very simple foraminiferan; the shape may vary from globular to slightly ovate, but this is not a preservational effect. The smooth surface suggests that either the living animal did not have any agglutinate coating or that any grains were not strongly attached or that the test wall was made of small grains, as described by Moreman (1930).

P. cava has been recovered from the *pesavis-sulcatus* conodont zones in Victoria (Bell, 1996) and the specimens recovered in this study fit into the size ranges previously observed. A range of variation of preservational styles can be observed, including a worn and somewhat "lumpy" surface (Pl. 1, fig. 3) and the slightly pitted surface (Pl. 1, fig. 2).

P. cava has a very long stratigraphic range and it may well be that several species are being confused. It is reported from the middle Ordovician (Gutschick, 1986), through the Silurian (Browne & Schott, 1963; Eisenack, 1932; Mabillard & Aldridge, 1982; Kristan-Tollmann, 1971b; McClellan, 1966; Stewart & Priddy, 1941) and into the Devonian (Bell, 1996; Gnoli & Serpagli, 1985) and perhaps into the Upper Carboniferous (Pennsylvanian) as *P. gracilis* Ireland (Toomey, 1974) [Kristan-Tollmann (1971b) and Mound (1968) synonymized *gracilis* with *cava*]. Both Kristan-Tollmann (1971b) and Browne & Schott (1963) give extensive synonymies for this species.

Psammosphaera garraay n. sp. (Pl. 1, figs 4-6, 8)

Psammosphaera spp. Winchester-Seeto & Bell, 1994, p. 202, figs 2.8, 2.10, 2.12; non 2.7, 2.9. 2.14.

Derivation of name. From the Australian Aboriginal word garraay, meaning sandhill; -referring to the type locality in the Garra Limestone (Wiradjuri language).

Diagnosis. Test free; globular; wall reticulated; no apparent apertures.

Holotype. AMF87212, Figure 2.8 Winchester-Seeto & Bell (1994: 202).

Type locality and horizon. RUN 44.4, 42.2 m above the base of the RUN section of the Garra Limestone, central New South Wales, Australia.

Material. 13 specimens from RUN (samples 44.4, 76.7), MUNG (samples 24.8, 71.5), GCR (samples 37, 343, 401.8), MW (samples 31, 95.6).

Distribution. Garra Limestone, Wellington, NSW, *pesavis-sulcatus* conodont zones; Martins Well Limestone, Broken River area, Qld, *sulcatus* Conodont Zone.

Dimensions. Diameter = 71-144 μm (Av. 97 μm for 12 specimens).

Remarks. This species is easily separated from *Psammosphaera cava* by its reticulate surface, i.e. numerous raised ribs outlining various sized small areas. These raised ribs possibly represent the boundaries of the various sized sand grains that may have once covered the test and have now been lost by some cause (preservational or procedural) not yet understood. The size ranges of *P. cava* and *P. garraay* are the same.

Numerous specimens of *P. garraay* show a partial equatorial "tear". This may be actual splitting or only an attachment scar similar to that seen in the *Recent P. fusca* Schulze.

Psammosphaera sp. (Pl. 1, fig. 7)

Material. 2 specimens from MUNG (sample 76.2) and MSh (sample).

Distribution. Garra Limestone, Wellington, NSW, *pesavis* Conodont Zone; Middle Shanda Beds, Siberia, *serotinus* Conodont Zone.

Description. Test free; globular; surface has a "shaggy" appearance due to relatively high, narrow, closest rounded ridges; no apparent aperture.

Dimensions. Diameter of chamber = 76-79 μm.

Remarks. *Psammosphaera* sp. is easily distinguished from other species of this genus by the unusual surface, which resembles a "shaggy" carpet. This is probably a new species, but has been left in open nomenclature pending the discovery of more specimens.

Sorosphaera Brady, 1879

Type species. Sorosphaera confusa Brady, 1879

Sorosphaera sp. cf. **S. confusa** Brady, 1879 (Pl. 1, fig. 9)

?Sorosphaera sp. Winchester-Seeto & Bell, 1994 , p. 202, fig 2.6.

Material. 2 specimens from MUNG (sample 76.2) and Gel. Rd. (sample 11T/81.7).

Distribution. Garra Limestone, Wellington, NSW, *pesavis* Conodont Zone; Taravale Formation, Victoria, *perbonus* Conodont Zone.

Description. Test free; subglobular chambers joined together without definite arrangement; no apparent aperture; wall reticulate.

Dimensions. Diameter of chamber 1 = 84.4 μm; Diameter of chamber 2 = 80-89 μm.

Remarks. Prior to the Kristann-Tollmann (1971a) revision of the early Palaeozoic sorosphaerid foraminifera, many species had been erected based only on the number of chambers in the attached masses. Kristan-Tollmann showed that using only the arrangement of chambers (planar or three-dimensional), five species could be distinguished. However, in the studies of normal-sized agglutinate foraminiferans in Devonian sediments from eastern Australia, the classification proposed by Kristan-Tollmann is not useful; within any one sample, various groupings of chambers can occur and merge from one form to another and to suggest that these are different species cannot be substantiated. Until there is more information on this simple organism from Recent sediments, we prefer to place the specimens figured herein with *S.* sp. cf. *S. confusa* Brady.

Both McClellan (1966) and Kristan-Tollmann (1971b) record this species from the Silurian.

Family **Saccamminidae** Brady, 1884

Amphitremoida Eisenack, 1938

Type species. Amphitremoida citroniform Eisenack, 1938

Amphitremoida sp. cf. **A. citroniforma** Eisenack, 1938 (Pl. 1, figs 10-11)

Ordovicina sp. Winchester-Seeto & Bell, 1994, p.205, figs 3.14, 3.15.

Material. 4 specimens from MUNG (sample 24.8), RUN (sample 70.6), GCR (sample 74.3) and Kuragh (sample 1).

Distribution. Garra Limestone, Wellington, NSW, *pesavis-sulcatus* conodont zones; Shogram Formation, Pakistan,?Late *hermanni* Conodont Zone.

Description. Test free; ovate chamber, widest at the centre and tapering evenly to the ends; test wall thin; surface shows grainy impressions; apertures rounded (?) about one-third width of test at the end of the chamber.

Dimensions. Maximum diameter = 134-316 μm (Av. 248 μm); Minimum diameter = 68-200 μm (Av. 125 μm); Dmax/Dmin = 1.6-1.9.

Remarks. The species shows a variable number of grain impressions on the wall, but never any attached grains, and these impressions show a range in size. This species is not as elongate as *A. eisenacki* (Bell 1996, Conkin & Conkin, 1964) or *A. kielcensis* Malec (1992, p. 280). *Amphitremoida citroniforma* has previously been recorded from the Ordovician (Llanvirnian) of NW Germany (Riegraf & Niemeyer, 1996) and from the lower Silurian of Illinois (Dunn, 1942); our species is only compared *with A. citroniforma* because of disjunct ranges.

Lagenammina Rhumbler, 1911

Type species. Lagenammina laguncula Rhumbler, 1911

Lagenammina ovata Bell, 1996 (Pl. 2, figs 1-2)

Lagenammina ovata Bell, 1996, p. 92, figs 7O, P.

Material. 2 specimens from Kuragh 17.

Distribution. Taravale Formation, Victoria, *perbonus - inversus* conodont zones; Shogram Formation, Kuragh, Pakistan, ?*Late falsiovalis* Conodont Zone.

Dimensions. Diameter of test = 97 μm; Diameter of neck = 37 μm.

Remarks. The specimens from Kuragh are about the same size as the intact tests recovered from southeastern Australia (Bell, 1996). The organic wall is finely reticulate which agrees with the small, uniform grains used in the test of the normal agglutinated specimens.

Lagenammina sp. (Pl. 2, figs 3-5)

Material. 3 broken specimens from MUNG (samples 8.4, 24.8) and GCR (sample 262).

Distribution. Garra Limestone, Wellington NSW, *pesavis-sulcatus* conodont zones.

Description. Test free; a flattened, rounded chamber (broken), followed by a short neck; aperture rounded at the end of a neck; wall of body chamber is coarsely reticulate, with larger and smaller defined areas, but the neck is relatively smooth.

Dimensions. Diameter of neck = 42-50 μm.

Remarks. Our specimens have broken body chambers, and it is not clear what the original shape would have been. Apart from size, *Lagenammina* sp. is close to *L. talenti* Bell 1996, but shows a more constricted neck. It is also similar to *L. silnica* Malec 1992 in having a short neck, but most of the body is missing in our specimens and so cannot be accurately compared. The difference between *L. talenti* and *L. silnica* may only reflect preservations differences.

Saccammina Carpenter, 1869

Type species. Saccammina sphaerica Brady, 1871

Remarks. In addition to the main aperture, most of the species placed in Saccammina also have many small (1-2 μm) pores scattered over the surface (e.g. Pl. 2, fig. 6).

Saccammina mea n. sp. (Pl. 2, figs 6-9)

Saccammina spp. Winchester-Seeto & Bell, 1994, 202, figs 4.1, 4.2, 4.4.

Derivation of name. From the Australian Aboriginal word mea, meaning open mesh, referring to the reticulate wall surface (Aboriginal language from Queensland).

Diagnosis. Test free; globular; wall surface reticulate; a single large round aperture, flush with the test surface.

Holotype. AMF102656, Pl. 2, fig. 9.

Type locality and horizon. RUN 44.4, 42.2 m above the base of the RUN section of the Garra Limestone, central New South Wales, Australia.

Material. 11 specimens from MUNG (sample, 24.8, 76.2), RUN (samples 44.4, 70.6, 85.7) GCR (sample 106, 117.3, 412.2), MW (sample 24.6) and MSh (sample 1).

Distribution. Garra Limestone, Wellington, NSW, *pesavis-sulcatus* conodont zones; Martins Well Limestone, Broken River, Qld., *sulcatus* Conodont Zone; Middle Shanda Beds, Siberia, *serotinus* Conodont Zone.

Dimensions. Diameter = 70-128 μm (Av. 95 μm); Diameter of aperture = 5-9 μm for 9 specimens.

Remarks. *Saccammina mea* is distinguished from *Saccammina* sp. by its reticulate surface and from *S. ampullacea* (Crespin) and *S. wingarri* n. sp. by the flush aperture.

Saccammina wingarri n. sp. (Pl. 2, figs 12-14)

Derivation of name. From the local Australian Aboriginal word, wingarri, meaning neck, referring to the prominent neck (Gooniyandi language).

Diagnosis. Test free; globular; wall surface smooth; aperture rounded and raised on a short neck. Holotype. AMF102669, Pl. 2, fig. 12

Type locality and horizon. PD 166, 388.4m, Pillara Limestone, Pillara Range, Canning Basin, WA, Late Givetian-Early Frasnian, *?varcus* Conodont Zone.

Material. 3 specimens from PD 166/388.4m and from LSA (sample 113).

Distribution. Pillara Limestone, Pillara Range, Canning Basin, WA, *disparilis – asymmetricus* conodont zones; Serre Formation, Montagne Noire, France, E. *asymmetricus* conodont zone.

Dimensions. Diameter of chamber = 80-124 μm; Diameter of neck = 23-40 μm; Length of neck = 6-12 μm; Dneck/Dchamber = 0.3; Lneck/Dchamber = 0.1.

Remarks. The very short, protruding neck (less than 10% of test diameter) serves to separate this smooth walled species from *Saccammina* sp. *S. wingarri* differs from *S. ampullacea* in having a smooth wall surface and a smaller apertural. neck. The neck appears to be of a different construction to the rest of the test wall and usually shows a blocky surface. The aperture is much larger than other *Saccammina* species. Although there are only a small number of specimens, this species is distinctive and readily distinguished from any other species of *Saccammina*; furthermore specimens have been observed from Western Australia and from southern France, adding weight to the decision of erecting a new species.

Saccammina sp. cf. **S. ampullacea** (Crespin)1961 (Pl. 2, fig. 15)

Saccammina spp. Winchester-Seeto & Bell, 1994, p. 202, figs 4.3, 4.5, 4.6.

Material. 3 specimens from MUNG (sample 8.4) and GCR (samples 50.2, 412.2).

Distribution. Garra Limestone, Wellington, NSW, *pesavis-sulcatus* conodont zones.

Description. Test free; a globular chamber with a pronounced neck; wall surface reticulate; aperture rounded, on the end of a produced neck.

Dimensions. Diameter of chamber = 112-113 μm; Diameter of neck = 22-23 μm for 2 specimens.

Remarks. Crespin (1961) placed her Late Devonian forms of this species in the genus *Lagenammina* because of the relatively long neck. Conkin & Conkin (1968) found apparent attachment scars on either the body and/or neck and suggested placement in *Oxinxis*. Our specimens, although much smaller, show no evidence of an attachment scar, and, as the neck is not excessively long, must be placed in *Saccammina*.

Saccammina sp. (Pl. 2, figs 10-11)

Material. 3 specimens from RUN (sample 207), BOO (sample 13.1), Tyers Q. (sample "Far end").

Distribution. Garra Limestone, Wellington, NSW, *pesavis* Conodont Zone; Tyers Quarry, Cooper Creek Formation, Victoria, *kindlei* Conodont Zone; Boola Quarry, Coopers Creek Formation, Victoria, *kindlei* Conodont Zone.

Description. Test free; globular; wall surface smooth; a single round aperture flush with the surface.

Dimensions. Diameter = 78-90 μm; Diameter of aperture = (approx.) 4-5 μm.

Remarks. The flush aperture and the smooth wall surface serve to distinguish *Saccammina* sp. from any other known species. This is most probably a new species, but as there are only three specimens, it has been left in open nomenclature, pending the discovery of more individuals.

Thurammina Brady, 1879

Type species. Thurammina papillata Brady, 1879

Thurammina mirrka n. sp. (Pl. 3, figs 2-3)

Derivation of name. From the Australian Aboriginal word mirrka, meaning cave, referring to the Wellington Caves near the type locality (Ngiyampaa language).

Diagnosis. Test free; originally globular; moderate number of apertures (about 20), evenly distributed over test, and seemingly flush with surface, apertures vary in size; wall roughened.

Holotype. AMF102664, Pl. 3, fig. 3.

Type locality and horizon. GCR 412.2, 410.1m above the base of the GCR section of the Garra Limestone, central New South Wales, Australia.

Material. 4 specimens from RUN (sample 237.6) and GCR (samples 106, 401.8, 412.2).

Distribution. Garra Limestone, Wellington, NSW, *pesavis-sulcatus* conodont zones.

Dimensions. Diameter of chamber = 70-110 μm (Av. 92 μm for 4 specimens).

Remarks. Although the main feature of *Thurammina* is the apertures raised on papillae (Loeblich & Tappan, 1988) we place this new species with the *Thurammina* because of the large number of simple apertures even though they appear not to be raised above the general wall surface; this may well represent a new genus but we await further specimens from elsewhere in the world.

Thurammina quadritubulata Dunn, 1942 (Pl. 3, fig. 9)

Thurammina quadritubulata Dunn, 1942, p. 334, Pl. 43, fig. 22

Thurammina quadritubulata Blumenstengel, 1961 , p. 318

Material. 1 specimen from LSC (sample 1.6m below 12b)

Distribution. Serre Formation, Montagne Noire, France, *?linguiformis* Conodont Zone

Dimensions. Diameter = 101 μm

Remarks. Our specimen closely resembles Dunn's species from the Bainbridge Formation, Upper Silurian, of Missouri. The only other Devonian record is by Blumenstengel (1961), who recorded *T. quadritubulata* from the Upper Devonian of Thuringa, Germany, but Conkin *et al.* (1968) suggest that this may be *T. triradiata* Gutschick & Treckman; differences between these two species are minor (Conkin *et al.*, 1968).

Thurammina sp. cf. **T. arcuata** Moreman, 1930 (Pl. 3, fig. 4)

Material. 5 specimens from GCR (samples 37, 55, 285, 412.2).

Distribution. Garra Limestone, Wellington, NSW, *pesavis-sulcatus* conodont zones.

Description. Test free; globular (most specimens are distorted and compressed); a small number of simple apertures, flush with the surface of the test.

Dimensions. Diameter of chamber = 94-98 μm; Diameter of aperture = 1-2 μm.

Remarks. Both smooth and reticulate surfaces occur on specimens in this species. Moreman's specimens had only four apertures but Browne & Schott (1963) extended the concept of the species to include specimens with more apertures and suggested that, with enough specimens, an ontogenetic sequence would show an array of apertural projections.

All previous records of *T. arcuata* are from the Silurian (Browne & Schott, 1963; see reference list; Dunn, 1942; McClellan, 1966; Stewart & Priddy, 1941).

Thurammina sp. cf. **T. subsphaerica** Moreman, 1930 (Pl. 3, fig. 1)

Thurammina sp. Winchester-Seeto & Bell, 1994, p. 205, figs 4.1, 4.2, 4.3.

Material. 3 specimens from MUNG (sample 71.5), GCR (sample 37) and MW (sample 31).

Distribution. Garra Limestone, Wellington, NSW, *pesavis-sulcatus* conodont zones; Martins Well Limestone, Broken River, Qld, *sulcatus* Conodont Zone.

Description. Test free; globular; numerous "large", simple apertures raised on papillae; many smaller apertures between the papillae.

Dimensions. Diameter of chamber = 80-112 μm; Diameter of "large apertures" = 3-10 μm.

Remarks. Most of the specimens are broken, distorted and compressed, suggesting that the organic lining is very thin in this species. This species has been compared to *T. subsphaerica* because the papillae are rounded as in *T. subsphaerica* and there are simple apertures on each papilla, but the presence of small apertures between the papillae, ranging down to 0.5μm, has not been observed before. *T. subsphaerica* has been recorded from the Silurian of Illinois by Dunn (1942).

T**hurammina** sp. (Pl. 3, figs 10-11)

Material. 1 specimen from MW (sample 25.4).

Distribution. Martins Well Limestone, Broken River, Qld, *sulcatus* Conodont Zone.

Description. Test free; "blocky" surface, possibly due to distortion; few apertures of varying size, not raised from the surface.

Dimensions. Diameter of chamber = 69 μm; Diameter of apertures = 0.5-1.5 μm.

Remarks. As this is the only specimen showing this surface, it is unclear as to whether it is not purely a preservational feature, e.g. the impressions of pyrite framboids.

Family **Hemisphaeramminidae** Loeblich & Tappan, 1957

Hemisphaerammina Loeblich & Tappan, 1957

Type species. Hemisphaerammina batalleri Loeblich & Tappan, 1957

Hemisphaerammina coolamon n. sp. (Pl. 3, figs 6-8)

Hemisphaerammina sp. Winchester-Seeto & Bell, 1994, p. 205, fig. 4.7.

Derivation of name. From the Australian Aboriginal word coolamon, meaning water carrier, referring to a water vessel of the same shape (Aboriginal language from Queensland).

Diagnosis. Test apparently formerly attached; hemispherical chamber with a basal membrane; a thick flat attachment surface; wall surface reticulate; no apparent aperture.

Holotype. AMF102668, Pl. 3, fig. 7

Type locality and horizon. MUNG 6.3, 6.2 m above the base of the MUNG section of the Garra Limestone, central New South Wales, Australia.

Material. 5 specimens from MUNG (samples 6.3, 24.8) and MW (sample 49).

Distribution. Garra Limestone, Wellington, NSW, *pesavis-sulcatus* conodont zones; Martins Well Limestone, Broken R., Qld, *sulcatus* Conodont Zone.

Dimensions. Diameter of chamber = 83-116 μm (Av. 90.5 μm for 5 specimens).

Remarks. The basal attachment surface may show a partial lip or flange surrounding the test; this flange was a diagnostic feature used in the separation of *Metamorphina* (Browne & Schott, 1963) from *Hemisphaerammina*, but Loeblich and Tappan (1988) have synonymised these two genera. A number of our specimens only show a partial basal membrane.

Hemisphaerammina sp. (Pl. 3, fig. 5)

Hemisphaerammina sp. Winchester-Seeto & Bell, 1994, p. 205, fig. 4.6.

Material. 2 specimens from MUNG (sample 8.4) and GCR (sample 117.3).

Distribution. Garra Limestone, Wellington, NSW, *pesavis-sulcatus* conodont zones.

Description. Test apparently initially attached; hemispherical chamber with a smooth, firmly attached basal membrane; wall thick, smooth; no basal flange.

Dimensions. Diameter of chamber = 86-138 μm.

Remarks. *Hemisphaerammina* sp. differs from *Hemisphaerammina coolamon* n. sp. in the smooth wall and absence of a basal flange. It is similar to the Recent *H. bradyi* Loeblich & Tappan, but is not as domed and has a thicker wall.

This is probably a new species, but has been left in open nomenclature, pending the discovery of more individuals.

Webbinelloidea Stewart & Lampe, 1947

Type species. *Webbinelloidea similis* Stewart & Lampe, 1947

Webbinelloidea similis Stewart & Lampe, 1947, (Pl. 4 fig. 10)

Webbinelloidea similis Stewart & Lampe, 1947, p. 535, pl. 78, fig. 8.

Webbinelloidea similis Conkin & Conkin, 1970, p. 4-14, pl.1, figs 1-31; pl. 2, figs 1-27; pl. 3, figs 1-16; pl. 4, figs 1-35.

Webbinelloidea similis Malec, 1984 , p. 560-561, pl. 1, figs 1-20; pl.2 figs 1-12.

?Webbinelloidea sp. Gnoli & Serpagli, 1985, p. 214, pl. 1, fig. 21.

Webbinelloidea similis Malec & Studencki, 1988, p. 84-85, pl. 1, figs 13, 15-18; pl. 2, figs 1-4; pl. 3, figs 1-5.

Webbinelloidea similis Malec, 1992, p. 282, pl. 1, fig. 6; pl. 2, figs 6, 10; pl. 3, figs 6, 9; pl. 4, figs 1-9.

Hemisphaerammina sp. Winchester-Seeto & Bell, 1994, p. 205, fig. 4.8.

For further synonyms see Conkin & Conkin (1970).

Material. 1 specimen, from RUN (sample 199.3).

Distribution. Garra Limestone, Wellington, NSW, *pesavis* Conodont Zone ; Góry Świętokrzyskie Mountains, Poland, Upper Emsian-Lower Eifelian; Columbus Formation, USA, *patulus-costatus* conodont zones; Delaware Formation, USA, *kocklianus* Conodont Zone; Corti Baccas 3rd. section, Sardinia, Lower Lochkovian.

Description. Test probably originally attached; domed but flattened; wall surface smooth; no apparent basal membrane; aperture a small everted opening at top of dome.

Dimensions. Diameter of both chambers = 141 μm.

Remarks. The small domal aperture separates *Webbinelliodea* from *Hemisphaerammina* (Conkin & Conkin, 1970). These authors showed that contrary to the initial description of W. similis (Stewart & Lampe, 1947) there is a small aperture present which could be described as '…a single subcentrally located aperture which resembles a pin prick and looks as if a pin had been forced from the exterior into the interior of the test. An apertural protuberance is present on the interior of the shell.'. In our case the internal edge of the aperture is quite recurved; in normal sized agglutinated test foraminiferans from this locality the external appearance of the aperture is a very small arcuate opening. *W. similis* ranges from the Middle Devonian to Lower Carboniferous in the U.S.A. (Conkin & Conkin, 1981, with synonymy), and in Poland occurs in the Lower-Middle Devonian (Malec, 1992).

Hyperammina Brady, 1878

Type species. Hyperammina elongata Brady, 1878

Hyperammina devoniana Crespin, 1961 (Pl. 4, figs. 8-9)

Hyperammina devoniana Crespin 1961, p. 406, Pl. 64, figs 1-6.

Hyperammina spp. Winchester-Seeto & Bell, 1994, p. 202, figs 2.1, 2.2.

Material. 4 specimens from MUNG (sample 24.8), GCR (sample 38) and MW (sample 39.9).

Distribution. Garra Limestone, Wellington, NSW, *pesavis-sulcatus* conodont zones; Martins Well Limestone, Broken R., Qld, *sulcatus* Conodont Zone; Virgin Hills Formation, Canning Basin, ?*falsiovalis* Conodont Zone.

Dimensions. Length = 216-371 μm; (Av. 294 μm); Diameter of proloculum = 71-90 μm (Av. 81 μm); Diameter minimum = 50-79 μm (Av. 61 μm).

Remarks. Conkin & Conkin (1968) place this species in *Tolypammina* as they believed that the specimens show attachment scars which are not found in *Hyperammina*; however, we do not agree with Conkin & Conkin and prefer to leave it in *Hyperammina*. Although our specimens are much smaller than Crespin's (i.e. 250-300 μm compared with 820 μm), the relative length of the tubular section versus the diameter of the proloculum remains the same (about 5:1).

Hyperammina sp. cf. **H. sappingtonensis** Gutschick, 1962 (Pl. 4, figs 1-5)

Hyperammina spp. Winchester-Seeto & Bell, 1994, p. 202, figs 2.3, 2.4, 2.5?

Material. 2 microspheric forms from Pt. Hibbs (sample 68669) and MSh (sample 2); 18 megalospheric specimens from RUN (sample 70.6); GCR (samples 38, 53.7); MW (samples 34, 39.9); KE DDH1 (depths 448.51, 511, 805.25, 1026.54 m), MSh (samples 1, 2).

Distribution. Microspheric form: Pt Hibbs Limestone, Tasmania, *kindlei* Conodont Zone; Middle Shanda Beds, Siberia, *serotinus* Conodont Zone; megalospheric form: Garra Limestone, Wellington, NSW, *pesavis-sulcatus* conodont zones; Martins Well Limestone, Broken R., Qld, *sulcatus* Conodont Zone; Amphitheatre Group, Darling Basin, NSW, *pesavis-sulcatus* conodont zones; Middle Shanda

Beds, Siberia, *serotinus* Conodont Zone.

Dimensions. Microspheric forms: Length = 117-173 μm; Diameter of proloculum = 33-53 μm; Megalospheric forms: Length = 186-400 μm (Av. 219.5 μm); Diameter of proloculum = 35-104 μm (Av. 57 μm).

Remarks. This species is characterised by a globular proloculum with a marked constriction between the prolocular chamber and the second chamber. This linear chamber may either taper towards the apertural end (Pl. 4, fig. 5) or become flaring (Pl. 4, fig. 1) and even shows the characteristic 'hourglass' constriction of *Hyperammina* (Pl. 4, fig. 3).

Conkin & Conkin (1964) determined that H. sappingtonensis existed as both micro- and megalospheric forms. Specimens observed in this study have prolocular sizes which quite easily fit into the size ranges given for this species. In the megalospheric forms the ratio of prolocular diameter to length of specimen is one to three or four, whilst in the microspheric form this ratio is one to seven or eight. The microspheric form shows a gradual increase in test diameter from the proloculum whereas in the megalospheric form the proloculum is slightly constricted from the tubular chamber which gradually increases in diameter towards the apertural end. Our major difference to *H. sappingtonensis* is that the microspheric form is very much shorter than the megalospheric form.

H. sappingtonensis is recorded from the Upper Devonian of Louisiana (Conkin & Conkin, 1964) and the Lower Carboniferous (Kinderhookian) of Missouri and Illinois (Conkin *et al.,* 1968). Conkin & Conkin (1964) have suggested that *H. sappingtonensis* is almost certainly a junior synonym of *H. kahlleitensis* Blumenstengal 1969 from the Upper Devonian of Germany but that doubt exists as to the size range given for the German specimens.

Family **Ammodiscidae** Reuss, 1962

Tolypammina Rhumbler, 1895

Type species. Hyperammina vagans Brady, 1879

Tolypammina tantula Bell, 1996 (Pl. 4, fig. 7)

Hyperammina spp. Winchester-Seeto & Bell, 1994, p. 206, figs 3.12, 3.13.

Tolypammina tantula Bell, 1996, p. 99, figs 10C-E.

Material. 2 specimens from RUN (sample 44.5) and GCR (sample 53.7).

Distribution. Garra Limestone, Wellington, NSW, *pesavis-sulcatus* conodont zones; Bonanza Gully, Buchan Caves Limestone, Victoria, *perbonus* Conodont Zone.

Description. Test probably formerly attached; a small proloculus followed by an undivided tubular chamber; aperture at the end of a second chamber, round; wall smooth.

Dimensions. Length = 440-500 μm, Diameter of proloculum = 42-50 μm.

Remarks. Our specimens have an attached basal floor and, apart from size differences, appear to be identical to *T. tantala* from Buchan.

Family **Telamminidae** Loeblich & Tappan, 1985

Reophanus Saidova, 1970

Type species. Hormosina ovicula Brady, 1879

Reophanus proavitus n. sp. (Pl. 4, fig. 6)

Reophax sp. Winchester-Seeto and Bell, 1994, p. 206, figs 3.7, 3.8.

Derivation of name. From the Latin word proavitus, meaning ancestor.

Diagnosis. Test free; a linear arrangement of chambers; initially a pyriform proloculum followed by a second pyriform chamber of similar size; surface smooth; aperture rounded, at the end of the neck.

Holotype. AMF102677, Pl. 4, fig. 6.

Type locality and horizon. GCR 105, 105 m above the base of the GCR section of the Garra Limestone, Wellington, central New South Wales, Australia.

Material. 3 specimens from RUN (sample 85.7) and GCR (samples 105, 290.9).

Distribution. Garra Limestone, Wellington, NSW, *pesavis-sulcatus* conodont zones,

Dimensions. Length = 135-335 μm; Diameter of proloculum = 40-88 μm; Diameter of final chamber = 43-88 μm.

Remarks. The pyriform chambers and the short interconnecting neck indicate that this species is referable to the genus *Reophanus* and not *Reophax* as emended by Brönnimann & Whittaker (1980). Although only specimens with two chambers are known, in each case the neck is broken, so multithalamous specimens may be possible. Because of the time differences (*Reophanus* is only recorded from the Recent [Loeblich & Tappan, 1988]) and the much smaller size than the Recent species (*R. ovicula*) a new name is proposed.

Loeblich & Tappan (1988) state that *Reophanus* does not have an inner organic lining but Mendelson (1982) observed the presence of a lining in his Recent specimens of *R. oviculus* (Brady).

Gen. et **sp.** indet. (Pl. 4, figs 11-12)

Material. 3 specimens from Gel. Rd. (sample 16T/65).

Distribution. Taravale Formation, eastern Victoria, *serotinus* Conodont Zone.

Description. Test free; globular; no apparent large aperture but the otherwise smooth wall is perforated with many small pores, rounded to angular, placed randomly over the surface.

Dimensions. Diameter = 67-73 μm; Diameter of apertures = < 0.5 μm.

Remarks. Whilst these specimens may belong in *Psammosphaera* the many perforations have not been seen in any other member of that genus. A number of the larger perforations seem to have a slightly raised smooth ridge about them. It is of course possible that these perforations are the result of chemical reactions during processing.

ACKNOWLEDGEMENTS

We thank Prof. John Talent and Assoc. Prof. Ruth Mawson for their continuing interest and support in our studies. We greatly appreciate the meticulous work by David Mathieson (printing) and Alison Basden (plate preparation) in ensuring the quality of the plates. We also thank the New South Wales Geological Survey for access to core samples from the Darling Basin.

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Fig. 1. Maps showing general position of localities investigated in this study.

Fig. 2. Stratigraphic chart showing range of sections/bores detailed in this study, related to conodont zones.

Fig. 3. Criteria for determination of species.

Fig. 4 Ranges of identified foraminifera, based on our studies and literature search.

PLATE EXPLANATIONS

PLATE 1:

Fig.1. *Inaurus tabulata* Conkin, Conkin & Thurman, 1979, AMF102639, MSh. 1, (x300) .**Figs 2-3.** *Psammosphaera cava* Moreman, 1930: **fig. 2,** AMF102640, GCR 37, (x300); **fig. 3,** AMF102641, GCR 117.3, (x450). **Figs. 4-6, 8.** *Psammosphaera garraay* sp. nov.: **fig. 4,** Paratype, AMF102642, GCR 37, (x400); **fig. 5,** Paratype, AMF102643, RUN 76.6, (x350); **fig. 6,** Paratype, AMF102644, GCR 605, (x400); **fig. 8,** Paratype, AMF102646, MUNG 24.8, (x400). **Fig. 7.** *Psammosphaera* sp., AMF102645, MUNG 76.2, (x400). **Fig. 9.** *Sorosphaera* sp. cf. *S. confusa* Brady, 1879, AMF102647, Gel. Rd. 11T/81.7, (x300). **Figs. 10-11.** *Amphitremoida* sp. cf. *A. citroniforma* Eisenack, 1938: **fig. 10,** AMF102648, KG 1, (x150); **fig. 11,** AMF102649, MUNG 24.8, (x400).

PLATE 2:

Figs 1-2. *Lagenammina ovata* Bell, 1996: **fig. 1,** AMF102650 , KG 17, (x350); **fig.2,** AMF102651, KG 17, (x450). **Figs 3-5.** *Lagenammina* sp: **fig. 3,** AMF102652, GCR 262, (x500); **fig. 4,** AMF102653, MUNG 24.8, (350); **fig. 5,** enlargement of fig. 4, (x700). **Figs 6-9.** *Saccammina mea* sp. nov.:**fig. 6,** enlargement of fig. 7, (x1500); **fig. 7,** Paratype, AMF102654, MUNG 24.8, (x400); **fig. 8,** Paratype, AMF102655, GCR 106, (x400); **fig. 9,** Holotype, AMF102656, RUN 44.4, (x450). **Figs 10-11.** *Saccammina* sp: **fig. 10,** AMF102657, RUN 207, (x400); **fig. 11,** AMF102658, BOO 13.1, (x400). **Figs 12-14.** *Saccammina wingarri* sp. nov.: **fig.12,** Holotype, AMF102659, PD 166 388.4, (x400); **fig. 13,** Paratype, AMF102660, LSA 113, (x400); **fig. 14,**

enlargement of neck of Holotype, (x1400). **Fig. 15,** *Saccammina* sp. cf. *S. ampullacea* (Crespin, 1961), AMF102661, MUNG 8.4, (x350).

PLATE 3:

Fig. 1. *Thurammina* sp. cf. *T. subsphaerica* Moreman, 1930: AMF102662, MUNG 71.5, (x350). **Figs 2-3.** *Thurammina mirrka* sp. nov.: **fig. 2,** Paratype, AMF102663, GCR 401.8,(x300); **fig. 3,** Holotype, AMF102664, GCR 412.2, (x400). **Fig. 4.** *Thurammina* sp. cf. *T. arcuata* Moreman, 1930, AMF102665, GCR 37, (x350). **Fig. 5**. *Hemisphaerammina* sp, AMF102666, GCR 117.3, (x350). **Figs 6-8.** *Hemisphaerammina coolamon* sp. nov.: **fig. 6,** Paratype, AMF102667, MUNG 24.8, (x400); **fig. 7,** Holotype, AMF102668, MUNG 6.3, (x400); **fig. 8,** Paratype, AMF 102669, MUNG 24.8, (x350). **Fig. 9**. *Thurammina quadritubulata* Dunn, 1942, AMF102670, LSC 1.6m below 12b, (x400). **Figs 10-11.** *Thurammina* sp.: **fig. 10,** AMF102671, MW 13.7, (x400);**fig. 11,** enlargement of fig. 10, (x900).

PLATE 4:

Figs 1-5. *Hyperammina* sp. cf. *H. sappingtonensis* Gutschick, 1962: **fig.1,** AMF102672, MSh 2, (x400); **fig. 2,** AMF102673, Pt. Hibbs 68669, (x400); **fig.3,** AMF102674, MSh 2, (x400); **fig. 4,** AMF102674, KE100 Hi 448.51, (x300); **fig. 5,** AMF102676, MW 39.9, (x300). **Fig. 6,** *Reophanus proavitus* sp. nov., Holotype, AMF102677, GCR 105, (x200). **Fig. 7.** *Tolypammina tantala* Bell, 1996, AMF102678, GCR 53.7, (x120). **Figs 8-9.** *Hyperammina devoniana* Crespin, 1961: **fig.8,** AMF102679, MW 39.9, (x300); **fig. 9,** AMF102680, GCR 38, (x200). **Fig. 10**. *Webbinelloidea* sp. cf. *W. similis* Stewart & Lampe, 1947, AMF102681, RUN 199.3, (x300). **Figs 11-12.** Gen. et sp. indet., **fig. 11,** AMF102682, 16T/65.0, (x450); **fig. 12,** enlargement of fig. 11, (x2000).

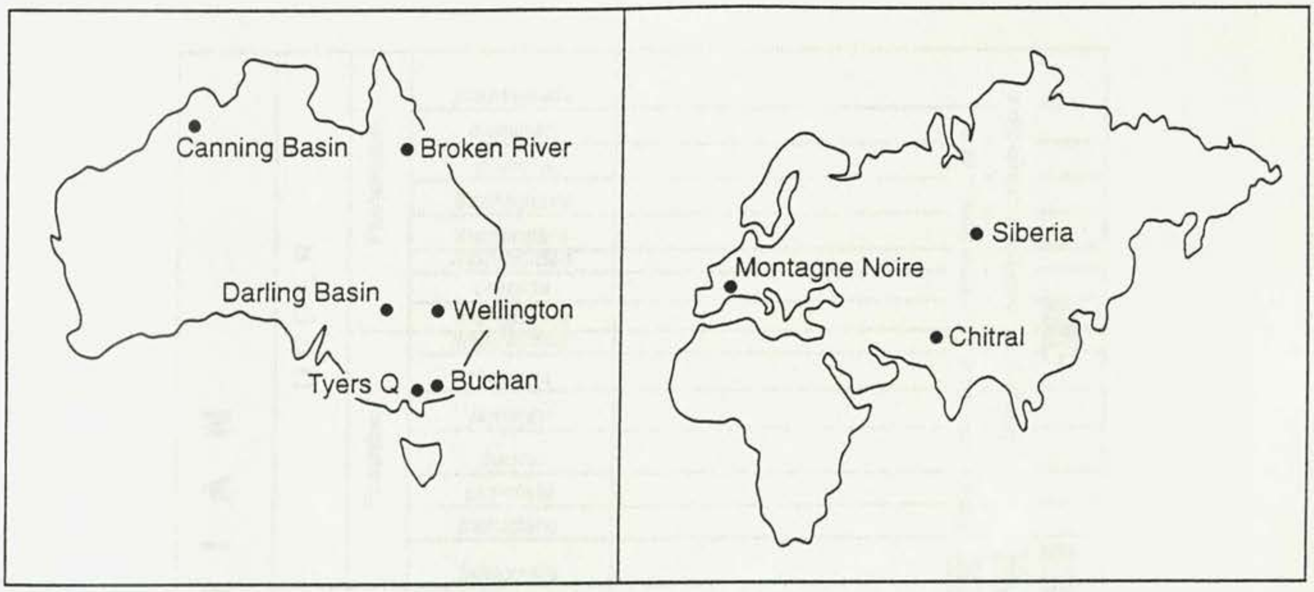

Canning Basin
Broken River
Darling Basin
Wellington
Tyers Q
Buchan
Montagne Noire
Siberia
Chitral

Fig 1

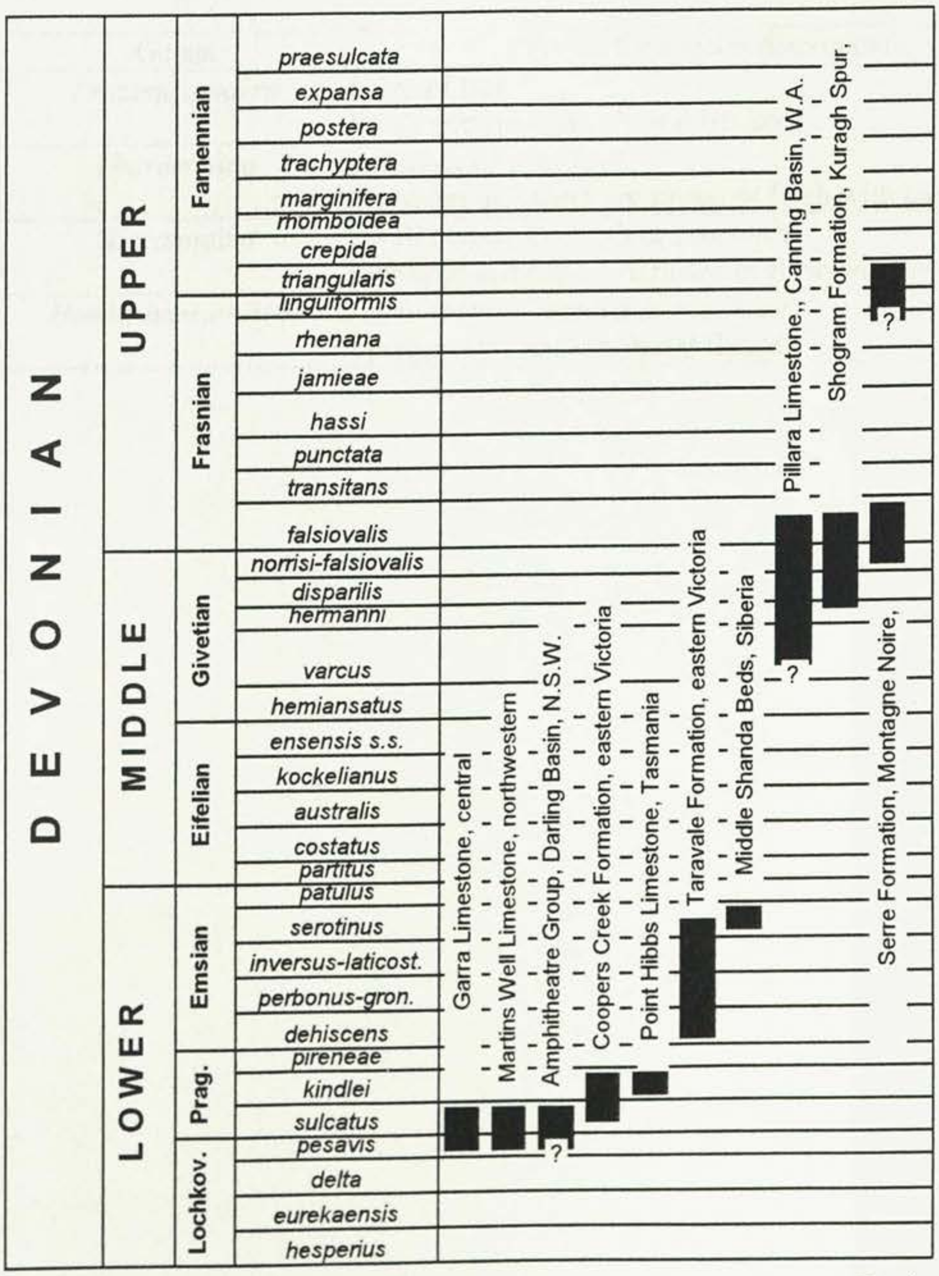
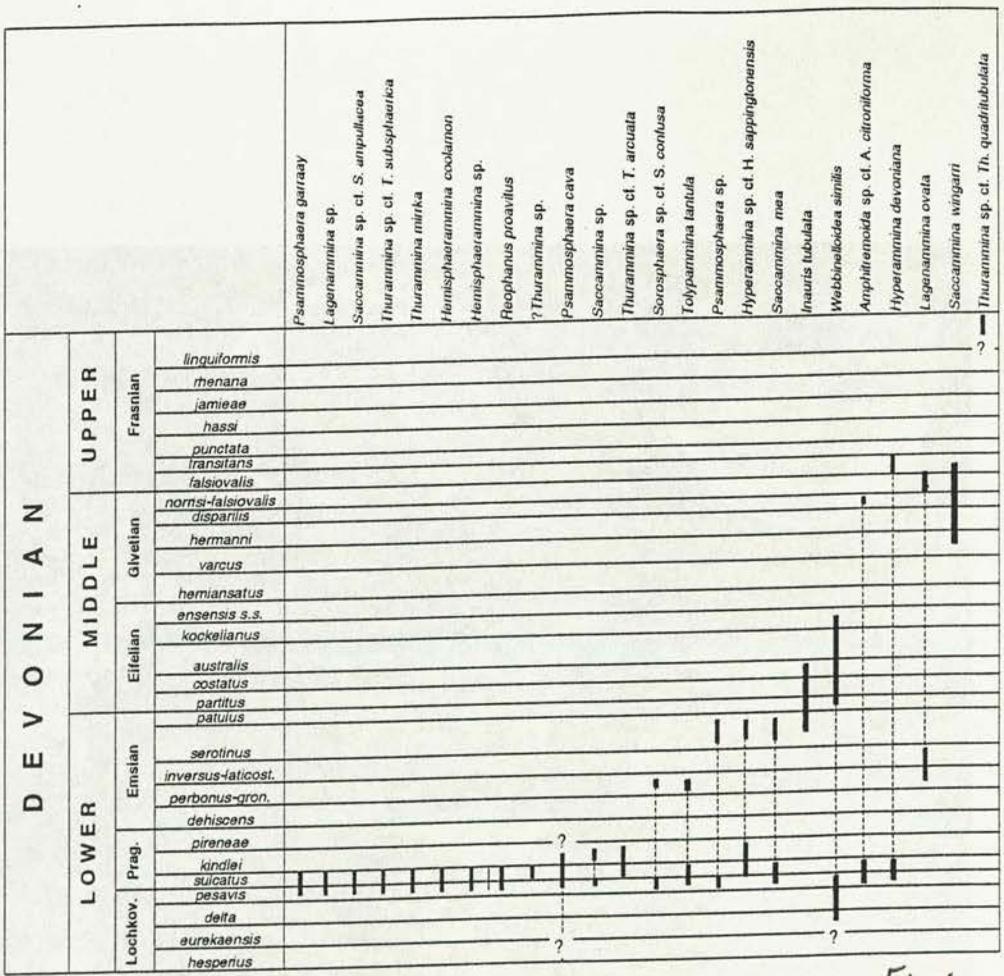

DEVONIAN
LOWER
MIDDLE
UPPER
Lochkov.
Prag.
Emsian
Eifelian
Givetian
Frasnian
Famennian
hesperius
eurekaensis
delta
pesavis
sulcatus
kindlei
pireneae
dehiscens
perbonus-gron.
inversus-laticost.
serotinus
patulus
partitus
costatus
australis
kockelianus
ensensis s.s.
hemiansatus
varcus
hermanni
disparilis
norrisi-falsiovalis
falsiovalis
transitans
punctata
hassi
jamieae
rhenana
linguiformis
triangularis
crepida
rhomboidea
marginifera
trachyptera
postera
expansa
praesulcata
Garra Limestone, central
Martins Well Limestone, northwestern
Amphitheatre Group, Darling Basin, N.S.W.
Coopers Creek Formation, eastern Victoria
Point Hibbs Limestone, Tasmania
Taravale Formation, eastern Victoria
Middle Shanda Beds, Siberia
Pillara Limestone,, Canning Basin, W.A.
Shogram Formation, Kuragh Spur,
Serre Formation, Montagne Noire,
?

Fig.2

Genus	Criteria for species determination
Psammosphaera	size of test wall texture (smooth or reticulate)
Thurammina	number of apertures whether apertures are raised or flush with the surface
Saccammina	wall texture (smooth or reticulate) whether apertures are raised or flush with the surface
Hemisphaerammina	wall texture (smooth or reticulate) presence/absence of basal flange

Fig 3


DEVONIAN
LOWER
MIDDLE
UPPER
Lochkov.
Prag.
Emsian
Eifelian
Givetian
Frasnian
hesperius
eurekaensis
delta
pesavis
sulcatus
kindlei
pireneae
dehiscens
perbonus-gron.
inversus-laticost.
serotinus
patulus
partitus
costatus
australis
kockelianus
ensensis s.s.
hemiansatus
varcus
hermanni
disparilis
norrisi-falsiovalis
falsiovalis
transitans
punctata
hassi
jamieae
rhenana
linguiformis
Psammosphaera garraay
Lagenammina sp.
Saccammina sp. cf. S. ampullacea
Thurammina sp. cf. T. subsphaerica
Thurammina mirrka
Hemisphaerammina coolamon
Hemisphaerammina sp.
Reophanus proavitus
?Thurammina sp.
Psammosphaera cava
Saccammina sp.
Thurammina sp. cf. T. arcuata
Sorosphaera sp. cf. S. confusa
Tolypammina tantula
Psammosphaera sp.
Hyperammina sp. cf. H. sappingtonensis
Saccammina mea
Inauris tubulata
Webbinelloidea similis
Amphitremoida sp. cf. A. citroniforma
Hyperammina devoniana
Lagenammina ovata
Saccammina wingarri
Thurammina sp. cf. Th. quadritubulata
?
Fig 4

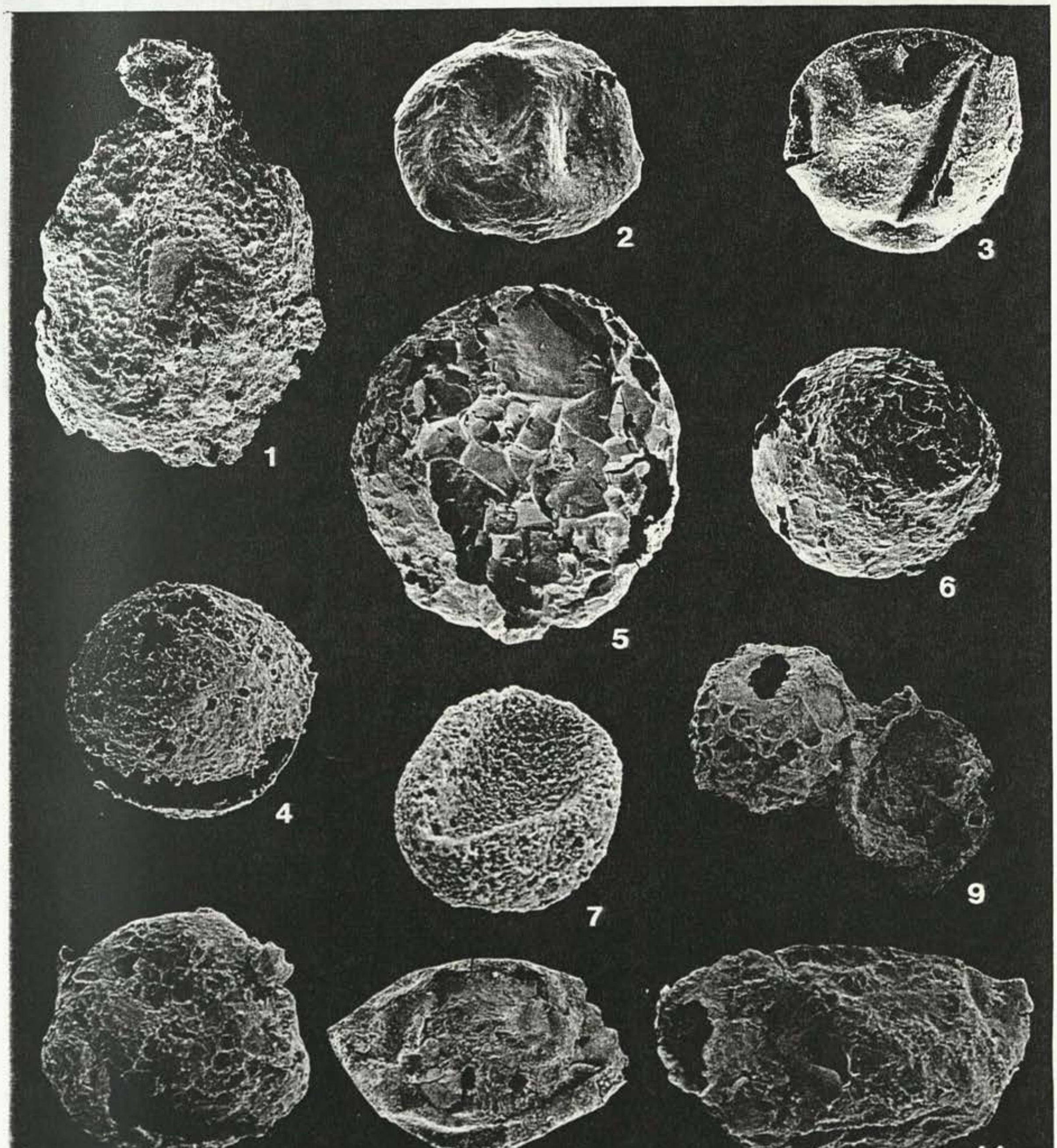


Plate 1

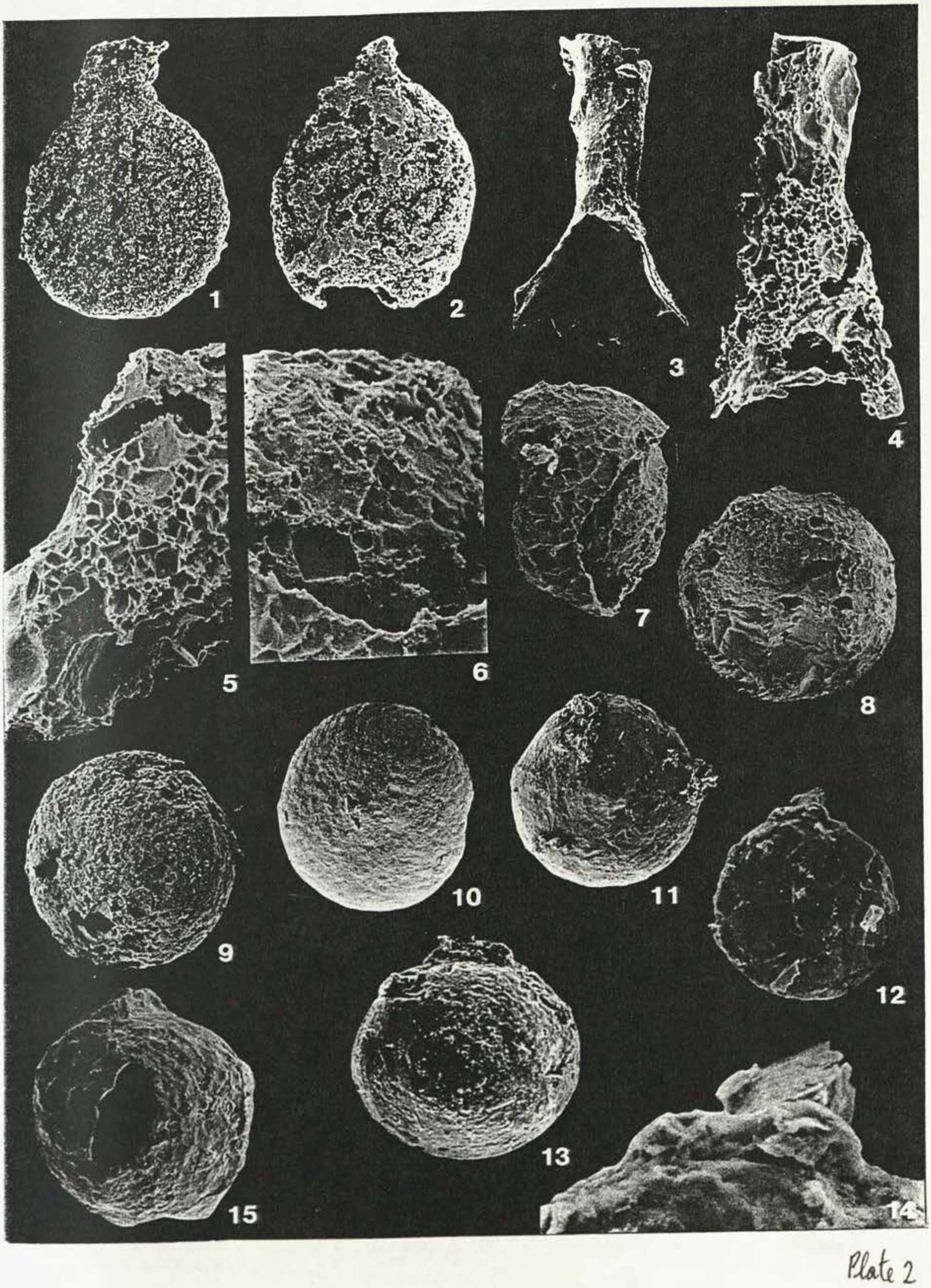


Plate 2

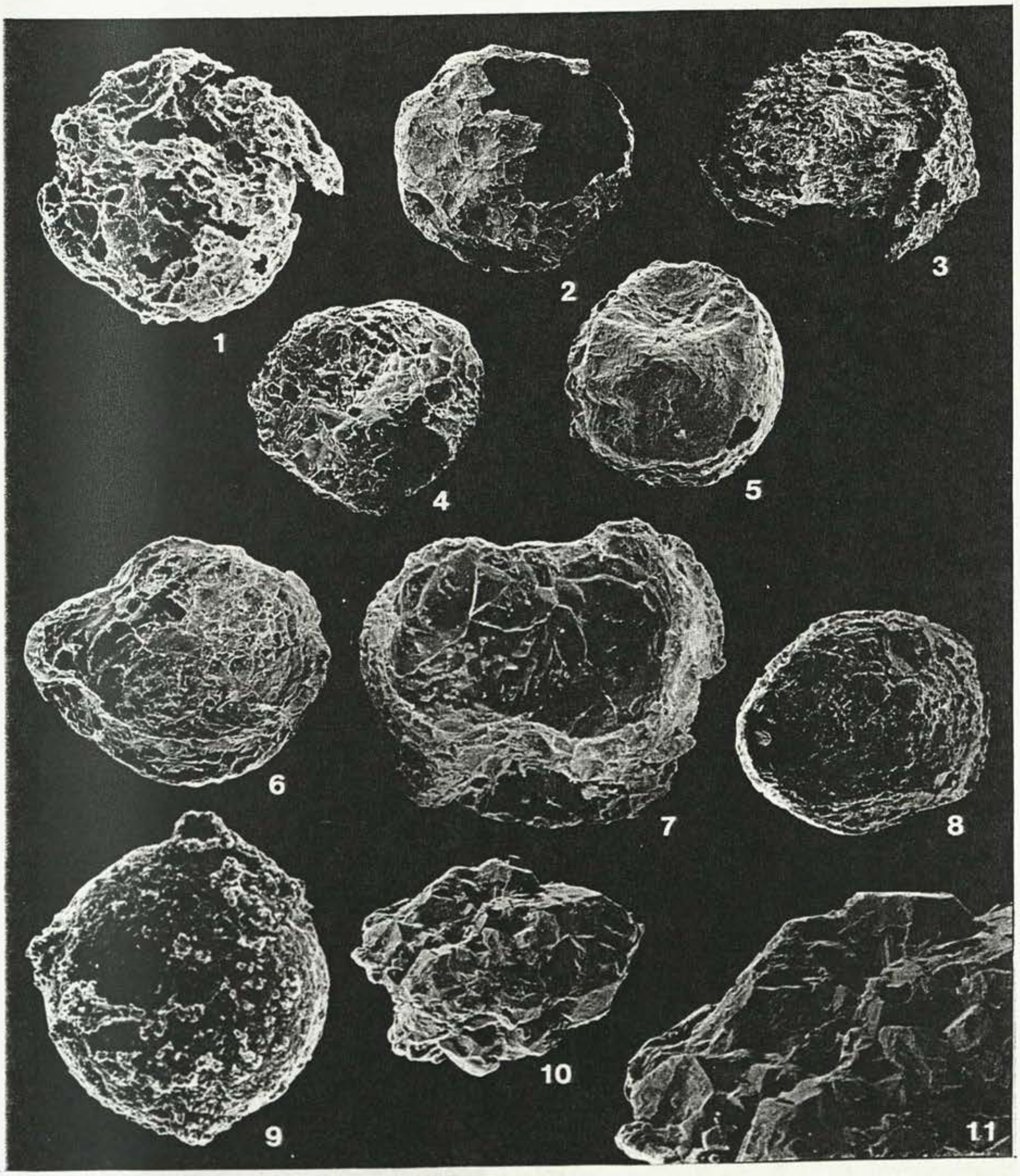


Plate 3

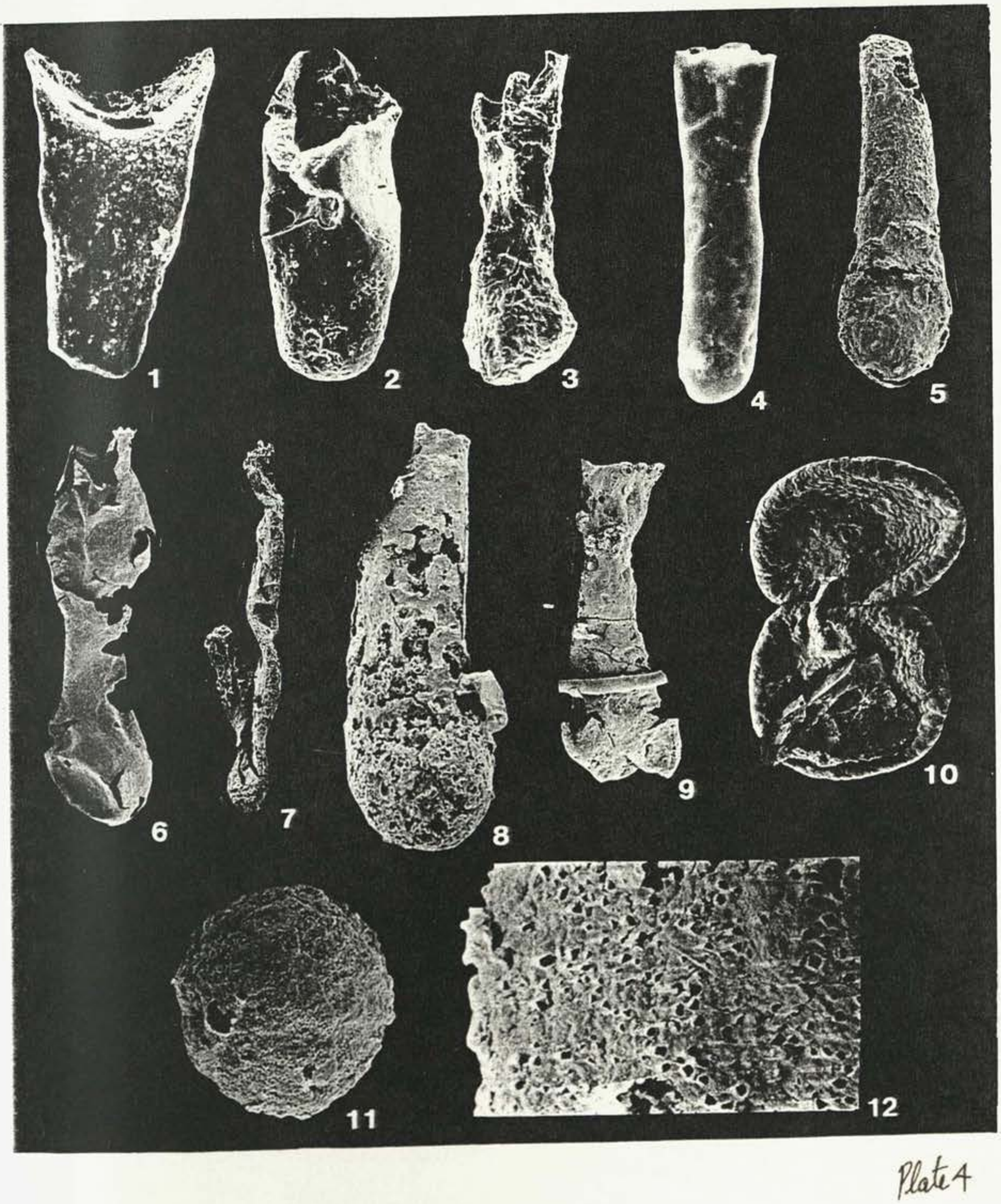


Plate 4

This paper has been submitted to and accepted by *Alcheringa,* and is due for publication in December, 1999.

I consider that I was responsible for 50% of the contents and structure of this paper.

Foraminiferal linings and other organic walled microfossils from the Devonian of the Tamworth Belt, northern New South Wales, Australia.

T.M. WINCHESTER-SEETO & K.N. BELL

Winchester-Seeto, T.M. & Bell, K.N., 1999: X. Organic walled microfossils from the Devonian of the Tamworth Belt, northern New South Wales, Australia. *Alcheringa*

Early to Late Devonian (Emsian to late Famennian) organic walled microfossils were recovered from nineteen localities throughout the Tamworth Belt, northern New South Wales. The fauna included poorly preserved chitinozoans and scolecodonts, spores and moderately well preserved foraminiferal linings. Fourteen species of foraminiferal linings from six genera are documented. Some of these linings show potential for interregional correlation.

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Keywords: Foraminiferal linings, Foraminifera, Organic walled microfossils, Devonian, Tamworth Belt, New South Wales

ORGANIC WALLED microfossils from the middle Palaeozoic include a variety of organisms such as miospores and acritarchs in the smaller size range and chitinozoans, scolecodonts, macrospores and the linings of agglutinated foraminiferans found mostly in the size range greater than 50 microns. This study is concerned with the "larger" group of acid resistant fossils, found in the sedimentary strata of the Tamworth Belt in northern New South Wales. Recent biostratigraphic work on the conodonts by Mawson & Talent (1994, 1998), Mawson *et al.* (1995, 1997) has provided a more substantial stratigraphic framework than previously known.

In samples selected from this area for study, over half contained acid resistant microfossils and most of these samples yielded linings of agglutinated foraminiferans. The existence of Palaeozoic foraminiferal linings and their relationship to normal foraminferans has been established by Winchester-Seeto & Bell (1994) and by Bell & Winchester-Seeto (1999). Prior to this study, 24 species from 12 genera and 6 agglutinate families had been found from the Devonian.

The purpose of this investigation is to describe and document the "larger" organic walled microfossils recovered from palynological processing of samples collected from the Tamworth Belt. In particular we aim to place the recovered foramininferal linings in a time context, constrained by conodonts where possible, and to explore their possible biostratigraphic utility and limitations.

Methods

The faunas described herein were recovered from marine limestones, calcareous shales, "tuffaceous cherts" and mudstones chosen for their prospectivity for acid-resistant microfossils. For many of the samples, conodont dating provides a firm stratigraphic background.

Processing methods followed those outlined by Paris (1981), including initial treatment of 20-50 g of crushed rock with 10% HCl until all the carbonate had been dissolved, followed by acid digestion by 50-70 % HF for 1-4 days. Nitric acid (concentrated) was used when necessary for surface etching, dissolving of fluorite salts and destruction of amorphous organic matter. The residue was then separated through a 53 µm sieve and picked with a micropipette. Well preserved specimens were selected for examination with a conventional Scanning Electron Microscope (SEM) or with an Environmental electroscan (ESEM); the advantages of the ESEM are outlined by Winchester-Seeto (1993).

General results

In the quest for organic walled microfossils, 196 samples from throughout the Tamworth Belt were collected and processed. Of these, 43% proved to be completely barren, 42% contained foraminiferal linings, 21% yielded scolecodonts, 10% gave spores and 12% produced chitinozoan fragments. Only one sample, from the Late Devonian Mostyn Formation, yielded complete chitinozoans (Winchester-Seeto & Paris, 1995).

Most of the specimens of the various organic walled biota are broken and compressed, indicating post-depositional trauma. All are very black and shiny, indicating a high thermal maturity, nonetheless, many of the foraminiferal linings could still be identified to species level. The lack of complete chitinozoans may be due to a hostile depositional environment, or to high thermal maturity rendering them very fragile. In general, abundances are low, ranging from one or two per 50 g of rock sample to twenty or so; this low abundance is typical of all areas studied to date.

Although spores were recovered from a number of samples, their high thermal maturity rendered them impossible to identify, even to genus level (P. Steemans, *pers. comm.* 1994). Unfortunately, despite their presence in many samples, Devonian scolecodonts are still difficult to confidently identify and are thus, at present, useless for stratigraphic purposes. Thus the results are dominantly concerned with the foraminiferal linings.

Locality information

The sequences and localities listed below describe the most productive areas investigated for this study. Figures 1-4 show the location of most of the samples yielding organic walled microfossils and figure 5 provides the stratigraphic framework of the Tamworth Belt, relevant to this paper. Grid references for the most productive sections and samples can be found in the appendix.

Glenrock area (Fig. 4)

Glenrock. Several spot samples of limestone and chert collected by Dr. James Stratford, from the Glenrock area in the southern part of the Tamworth Belt (Gamilaroi terrane) were processed for palynomophs (Fig. 4). Scolecodonts, spores and unidentifiable foraminiferal linings were recovered from four samples (viz. 0217, 0231, 0379 and 0405; see Stratford, 1995); several moderately well preserved foramininferal linings were found in sample 0217 and fragments of chitinozoans were observed in sample 0405. Foraminiferal linings were recovered from a sample yielding the radiolarian *Circulaformis admissarius* Stratford, lying stratigraphically above a limestone body dated as lower Emsian (Stratford, 1995).

Bralga Tops. A small number of samples from an interbedded limestone-shale sequence from the top of the Frog Hollow Formation at Bralga Tops on "Glenrock" Station (Fig. 4; Metcalfe *et al.*, 1997) yielded scolecodonts, foraminiferal linings and chitinozoan fragments. Conodonts recovered from this section suggest a Late Emsian age (*serotinus* Conodont Zone; Metcalfe *et al.*, 1997).

Timor area (Fig. 3)

Timor limestone. Two sections, measured through the Timor Limestone yielded relatively rich assemblages of organic walled microfossils. The TIM section, commencing opposite the junction of the Lilberne Road and continuing west on the right flank of the gully, is the equivalent of section 7 of Pedder *et al.* (1970). Fragments of a species of the chitinozoan genus *Hoegisphaera* were found in one sample (TIM 17.5), and spores, scolecodonts and foramininferal linings were recovered from several samples, particularly from low in the section (e.g. TIM 18.9, 25.7, 33.3, 36.6). Conodonts from sample numbers 17.5, 18.9, 22.3, 33.3, 39.4 and 48.7 indicate that this part of the section can be dated as *costatus* Conodont Zone (R. Mawson, *pers. comm.*, 1998).

The ISIS section, situated stratigraphically below the TIM section and approximately 2 km to the north along the Nundle-Blandford road, was similarly rich in acid-resistant fossils. Fragments of a chitinozoan, probably a species of *Bulbochitina*, were found in 6 samples (ISIS 1.7, 4.8, 9.4, 9.8, 10, 18.5), and the section also yielded moderately well preserved foraminiferal linings and scolecodonts. Sample ISIS 11.2 produced the conodont *Eognathodus bipennatus bipennatus,* which ranges from the beginning of the *costatus* Conodont Zone (R. Mawson, *pers. comm.*, 1998). This section is stratigraphically below the TIM section, and it is probably no younger than *costatus*.

Isis river below Timor. Samples were collected from both bedded strata and clasts directly below the ISIS section, on the eastern side of the Nundle-Blandford road, down to the rivers edge. The samples yielded specimens of what may have been a chitinozoan, *Bulbochitina* sp., spores, scolecodonts, and foraminiferal linings. The precise nature of the contact is unclear and no conodonts were recovered; the contact is assumed herein to be conformable, and this is not contradicted by the assemblages of organic walled microfossils, thus the age is assumed to be approximately Early Eifelian.

Gilwhite Limestone. A rich assemblage of organic walled microfossils were recovered from the "calcareous conglomerate" (Manser, 1968) Gilwhite Limestone Member of the Lilberne beds. The clasts, collected from Perrys Creek, yielded chitinozoan fragments, spores, scolecodonts and foraminiferal linings. Age is unknown, but does not appear to be much older than the Timor Limestone.

Kiah Limestone. A small number of spot samples were collected from the Kiah Limestone Member (= Borah Limestone; Mory, 1981) of the Lincount Mudstone (= ?Goonoo Goonoo Mudstone; Mory, 1981), on the western limb of the Timor Anticline. The precise age is unknown, but outcrops to the north are generally accepted to be very Late Devonian (Lischmund *et al.*, 1986). An interesting array of foraminiferal linings were recovered.

Nundle area

Copes Creek. A small number of spot samples of cherts within the Pipe Clay Creek Formation at Copes Creek were processed for acid-resistant microfossils. These samples repeated those collected by Stewart (1995), who found paraconodonts, suggesting an age of Middle to early Late Cambrian. Abundant, very small ?scolecodonts were recovered from two samples.

Upper Barnard River. Several spot samples were collected, and a small section was measured the Upper Barnard River, above the base of the Silver Gully Formation, near Chittick, 55 km SE of Tamworth (Mawson *et al.*, 1995). Mawson

& Talent (1998) assign this interval to early *patulus* Conodont Zone. Chitinozoan fragments, possibly of a species of *Hoegisphaera,* were recovered from one sample (Barnard 3/2.9) as well as scolecodonts and foraminiferal linings (see Mawson *et al.*, 1995 for detailed map of location).

Chaffey Island. Several allochthonous blocks within the Bog Hole Formation on an island in the Chaffey Dam, 34 km SE of Tamworth (Mawson & Talent, 1998), yielded unidentifiable foraminiferal linings. Conodonts recovered from these block indicate an Emsian age, *serotinus* Conodont Zone.

Loomberah Heights. Spot samples from basal Silver Gully Formation, in Norman Close at Loomberah Heights (Mawson *et al.*, 1995) yielded unidentifiable foraminiferal linings. Mawson & Talent (1998) dated this horizon as possibly early *patulus* or *serotinus* conodont zones. (See Mawson *et al.*, 1995 for a detailed map of sample location.)

Tamworth Area

Willow Tree Creek. A section through the Glencairn Limestone, yielded very little organic material, except for scolecodonts in one sample and unidentifiable foraminiferal linings in another. Conodonts collected from the same section indicate an age of Late Lochkovian, *pesavis* Conodont Zone, (Mawson & Talent, 1998).

Hospital Quarry. Samples were collected from a sequence exposed on north face of Tamworth Hospital Quarry (Mawson *et al.*, 1997) Conodonts were recovered from several samples, but only HQ0 was in situ and the rest proved to be allochthonous (Mawson *et al.*, 1997). Formamininferal linings were recovered from many samples, but were unidentifiable; one large, obviously allochthonous block between samples 2A and 3 (Mawson *et al.*, 1997) yielded a single, broken chitinozoan specimen, possibly of the genus *Hoegisphaera.*

David & Pitman's Locality 8. Conglomeratic limestones within the Yarrimie Formation identifed by Mawson *et al.* (1997) as "Locality 8" of T.W.E David & E.F. Pitman (1899) produced spores and unidentifiable foraminiferal linings, but no age-constraining conodonts.

Mostyn Vale Formation. A single sample of the Mostyn Vale Formation from L7 just below the "Bulga Ignimbrite Member" (Wright *et al.*, 1990) yielded a conodont assemblage indicative of late Frasnian *linguiformis* Conodont Zone. Chitinozoans detailed in Winchester-Seeto & Paris (1995) were also extracted as well as many scolecodonts and foraminiferal linings.

Attunga area (Fig. 2)

OKE section. A section was measured through the Lower Yarrimie and into Moore Creek Limestone, in the old kiln excavation west of DMM Quarry, Attunga (Mawson & Talent, 1994). Organic walled microfossils including spores, scolecodonts and foraminiferal linings were recovered from 4 out of 32 samples (OKE 0.9, 83.5, 100, 120m), spaning the *costatus* to *australis-varcus* zones (Mawson & Talent, 1994).

Cores. A series of borecores through the "Wyaralong limestone" (=Moore Creek Limestone Member, Mawson & Talent, 1994), in vicinity of Arkland Quarry on "Wyaralong Station" southeast of Attunga were described Pohler & Herbert (1993) and investigated for organic walled microfossils. Samples yielding organic walled microfossils equate to the "nodular limestone" of Pohler & Herbert (1993), especially from cores 2 and 7 (19 samples from core 2 in the range of depths 50-95m), but there were also some productive spot samples from cores 4 and 59. Core 2 parallels the WY section sampled by Mawson & Talent (1994), and replicates the interval of WY labelled as "nodular limestone interbedded with cherty siltstone" (p. 40), which starts within the *costatus* Conodont Zone and finishes in the *kocklianus*-?post-*kocklianus* zones (Mawson & Talent, 1998; Mawson *et al.*, 1997). The cores were, in general, quite productive, yielding chitinozoan fragments (DDH2 62.1m, 73m; DDH4 28m, 49.7m), numerous spores (from 12 samples), scolecodonts and foraminiferal linings.

Carey's Quarry. Samples from a small section through strata overlying the "Wyaralong Limestone" (=Moore Creek Limestone Member; Mawson & Talent, 1994) yielded a few unidentifable foraminiferal linings. The strata from the NCCQ section were interpreted to be *kocklianus-ensensis* conodont zones by Mawson & Talent (1994).

Jacksons Deposit. A number of spot samples from the DMM Quarry, Attunga, in the Moore Creek Limestone yielded scolecodonts and unidentifable foraminiferal linings. Studies by Mawson & Talent (1994) determined the *australis* Conodont Zone at one spot locality within the limestone.

Yarrimie below Jacksons Deposit. A single spot sample from the lower Yarrimie Formation, stratigraphically below Jacksons Deposit, yielded foraminiferal linings. Conodonts from this vicinity suggest an age of *costatus-australis* conodont zones (Mawson & Talent, 1994).

*Warrawilla***.** Klyza (1995) identified an occurrence of Moore Creek Limestone, 4.5km east of Attunga. Conodonts suggest an age spanning the *australis-hemiansatus* conodont zones (Klyza, 1995; Mawson & Talent, 1998; Mawson *et al.*, 1997). Unidentifiable foraminiferal linings were found in one sample and what may be algal or fungal material occurred inseveral beds near the top of the section

*Sulcor Limestone***.** Several samples of the Sulcor Limestone from a variety of localites (e.g. SULC section) yielded no organic walled microfossils.

Discussion

We wish to stress that this work is incidental to the chitinozoan studies of TW-S, and that we believe a concerted study directed just towards foraminiferal linings would greatly increase the number of specimens, and more than likely, the number of species to be found. Thus this study cannot be construed as defining the full ranges of the species found, nor does it give a comprehensive investigation of the localities or environments in which foraminiferal linings are to be found.

In the following discussion the term "normal" foraminiferan means a normal sized foraminiferan with intact agglutinated wall.

At the many localities studied, the diverse organic walled biota, including chitinozoans, foraminiferal linings and scolecodonts show differing preservation. Few localities had intact chitinozoans, but many had fair to excellently preserved foraminiferal linings and scolecodonts. This implies that foraminiferal linings and scolecodonts are more robust and can withstand the rigours of diagenesis or, perhaps, able to better withstand the extraction procedures.

Of the total number of 19 sites (but not necessarily in the same samples at those sites), significant differences were found in the occurrences of foraminiferal linings and "normal" foraminiferans (Table 1). The predominance of sites with only foraminiferal linings is marked. This may be due to (a) possible procedural artefacts i.e. it may be easier to extract the linings than intact foraminiferans; (b) foraminiferal linings were more common than "normal" foraminiferans in the Palaeozoic or in this area; (c) foraminiferal linings are more easily preserved than the intact forms. At the moment we are unable to distinguish between these possibilities. It must be considered that in Recent agglutinated foraminiferal species the grains forming the outer test wall are held together by some type of cement (organic, calcareous, siliceous) (Bender,1995). There is no reason to suppose that similar cements were not used in the Palaeozoic. We know nothing about the lifetimes of these cements or the effects of diagenesis on them, so it is possible that "normal" foraminiferans disintegrate over time and this would bias any results.

From the Tamworth area, 14 species of foraminiferal linings are reported. This, together with material reported elsewhere (Winchester-Seeto & Bell, 1994; Bell & Winchester-Seeto, 1999) brings to 31 the number of foraminiferal linings described from the Early – Late Devonian in Australia. The total number of 'normal' agglutinated foraminiferan species from the Tamworth area is about 24 (Bell, MS) (calcareous species are also present but not considered here, as taxonomically they have not been documented fully and no linings attributable to calcareous foraminiferans have yet been found in this area). The total number of foraminiferal species in the Tamworth area (i.e. "normal" and linings) is 32; of these 8 are only known as linings, and 2 in both lining and "normal" form. Thus by studying the linings, the number of known forms in the area is increased by one-third. Again, as we have pointed out elsewhere (Bell & Winchester-Seeto, 1999) several interpretations are possible: (a) some species only occur as organic linings, (b) some species have only weakly attached wall matrix, and (c) the biota live in differing environments which may have differing effects on life style (e.g. wall formation or not), on preservation and on diagenesis.

Many of the species described herein, have a wide geographic spread, both as "normal" foraminiferans and as linings. Those found on two or more continents include *Inauris tubulata* (Kentucky, Siberia and northern NSW), *Saccammina mea* (central and northern NSW, northern Queensland, Siberia and Kentucky), *Thurammina pustulosa* (northern NSW and Texas), *T.* sp. cf. *T. subsphaerica* (northern NSW and USA), *Thuramminoides sphaeroidalis* (northern NSW, USA, Europe) and *Saccammina wingarri* (Canning Basin, northern NSW and France). The following species, though found so far only in eastern Australia, occur in localities separated by hundreds of kilometers: *Saccammina* sp. cf. *S. ampullacea* (central and northern NSW), *T. mirrka* (central and northern NSW) and Gen. et sp. indet. (northern NSW and northern Victoria).

While some foraminiferal species have very long ranges, others may have a limited utility for solving stratigraphic problems in the absence of other fossils with higher resolution. Three species of foraminiferans have relatively restricted ranges,

Inauris tubulata ranges from *serotinus* to *costatus* conodont zones (late Emsian – middle Eifelian), *Thurammina pustulosa* ranges from the *linguiformis* Conodont Zone into the Kinderhookian of Texas, (late Frasnian – early Carboniferous), and *Pelosina* sp. which ranges from *costatus* to middle *varcus* conodont zones (middle Eifelian – middle Givetian). Useful, but somewhat longer ranges are associated with *Thurammina mirrka* which spans the *pesavis – australis* conodont zones (Lochkovian – middle Eifelian), *Sacammina mea* which ranges from *pesavis – australis* (Lochkovian – middle Eifelian), and *Sacammina* sp. cf. *S.*

ampullacea which extends from *pesavis* to *costatus* (Lochkovian – middle Eifelian).

Systematic Palaeontology

Specimens with the prefix AMF are lodged with the Australian Museum, Sydney, Australia.

Order **Foraminiferida** Eichwald, 1830

Suborder **Textulariina** Delage & Héouard, 1896

Family **Astrohizidae** Brady, 1881

Inauris Conkin, Conkin & Thurman, 1979

Type species. Inauris tubulata Conkin, Conkin & Thurman, 1979.

Inauris tubulata Conkin, Conkin & Thurman, 1979 (Fig. 7A)

1979 *Inauris tubulata* Conkin, Conkin & Thurman; Conkin, Conkin & Thurman, p.4, pl. 1, figs 1-10.

1999 (in press) *Inauris tubulata* Conkin, Conkin & Thurman; Bell & Winchester-Seeto, p.??, pl. 1, fig. 1.

Material. 2 specimens; one fairly complete, the other fragmentary.

Locality and age. Glenrock, sample 0217, ?late Emsian – early Eifelian; Yarrimie below Jacksons Quarry, *costatus* Conodont Zone

Known occurrence. late Emsian - early Eifelian (*costatus* Conodont Zone), Jeffersonville Limestone, Kentucky, (Conkin et al 1981); *serotinus* Conodont Zone, Middle Shanda Beds, Siberia (Bell & Winchester-Seeto, 1999)

Size. Diameter (max.) = 95-147 μm; diameter of hole = 10.5 μm

Remarks. Two forms are present - one with a small central hole, the other with a much larger (though damaged) hole; both fit within the variation shown in the original description (Conkin *et al.*,1979). Neither specimen shows any evidence of a central membrane as found in a specimen from the Middle Shanda Beds, Siberia (Bell & Winchester-Seeto, 1999). The neck is broken close to the main body of the test in both specimens.

Family PSAMMOSPHAERIDAE Haeckel, 1894

Psammosphaera Schulze, 1875

Type species. Psammosphaera fusca Schulze, 1875.

Psammosphaera cava Moreman, 1930. (Fig. 7B-C)

1930 *Psammosphaera cava* Moreman ; Moreman, p. 48, pl.6, fig 12.

? 1934 *Bion perforatum* Eisenack ; Eisenack, p. 71, pl. 5, fig. 30, text-fig. 35.

For full synonymies of *P. cava* see Browne & Schott (1963), Kristan -Tollmann (1971) and Bell & Winchester-Seeto (1999).

Material. 7 specimens

Locality and age. DDH2 depth 66.2m, DDH7 depth 95m *costatus-australis* conodont zones; TW-T, Isis river below Timor Limestone Early Eifelian, ?*costatus* conodont zone; TIM 18.9, Timor Limestone, *costatus* Conodont Zone

Known occurrence. This species is known from a number of localities globally, and has a claimed stratigraphic range from the Ordovician (Gutschick, 1986) into the upper Carboniferous (Toomey, 1974). See synonmy for full list of occurrences.

Size. Diameter (max.) = 78-85 μm

Remarks. A widespread species in the Tamworth area, both as organic linings and as normal foraminiferans. As noted with *P. cava* from other localities (Bell &

Winchester-Seeto, 1999) some specimens show an equatorial splitting of the test. Eisenack (1934) described, from the Silurian of the Baltic area, *Bion perforatum*, which he considered to be a cyst and that also displays this equatorial splitting; Eisenack's description appears to be that of an organic lining with a roughened (? reticulated) surface and is very similar to our specimens placed in *P. cava.*

Psammosphaera sp. A (Fig. 7D-E)

Description. Test free; ellipsoidal, with the longest axis about one and a half times as long as the other two subequal axes; cross-section circular; surface reticulated with sharp raised edges; rare small pores(~ 5 μm diam.) scattered over the surface; no apparent aperture.

Material. 2 specimens.

Locality and age. DDH2 depth 63.5m, *costatus-australis* conodont zones; Mostyn Vale Formation, *linguiformis* Conodont Zone;

Size. Length = 90-133 μm; Width = 60-107 μm; l/w= 1.3-1.5

Remarks. The ellipsiodal shape and the reticulate surface distinguishes this species from other *Psammosphaera* species which are normally subspherical to spherical. Conkin & Conkin (1964) recorded a possible ellipsoidal *Psammosphaera* (from the Upper Devonian Louiseville Limestone, Missouri) which had a thin wall formed of fine grains. This is probably a new species, but has been left in open nomenclature due to a lack of specimens.

Psammosphaera sp B. (Fig. 7F-G)

Description. Test free; ellipsiodal with longest axis about one and one-third times as long as the other two subequal axes; more or less circular cross-section; surface smooth; very small (~1 μm) rare pores scattered over surface.

Material. 3 specimens.

This material extends the range of *S. mea* from the *pesavis – serotinus* conodont zones (Bell & Winchester-Seeto, 1999) into the middle Eifelian (*costatus* - ?*ensensis* conodont zones).

Saccammina wingarri Bell & Winchester-Seeto 1999 (Fig. 8I-K)

1999 (in press) *Saccammina wingarri* Bell & Winchester-Seeto. Bell & Winchester-Seeto, p., pl. 2, figs 10-12

*Materia*l 2 specimens.

Locality. ?TIM 36.6, Timor Limestone, *costatus* Conodont Zone; Mostyn Vale Formation, *linguiformis* Condont Zone

Known occurrence. varcus Conodont Zone, Pillara Limestone, Canning Basin; early *asymmetricus* Conodont Zone, Serre Formation, France

Size: specimen from TIM 36.6, diameter (max.) = 138 μm

specimen from Mostyn Vale, diameter (max.) = 73 μm

R*emarks*. Size and appearance of the specimen from Mostyn Vale closely matches previously described specimens from the Pillara Limestone and Serre Formation (Bell & Winchester-Seeto, 1999); however the specimen from the Timor Limestone shows a more "bumpy" (mogular) surface, and a less defined apertural neck, and may not belong to this species.

The stratigraphic range of this species is confidently extended up to *linguiformis* Condont Zone, and questionably down to *costatus* Conodont Zone.

Saccammina sp. cf. **S. ampullacea** (Crespin, 1961) (Fig. 8H)

Material. 1 broken specimen.

Locality and age. TIM 18.9, Timor Limestone, *costatus* Condont Zone

Known occurrence. pesavis-sulcatus conodont zones, Garra Limestone

Size. Diameter (max.) = approx. 170 μm; diameter of neck = 36 μm

Locality and age. OKE 0.9m, 112m, *costatus-varcus* conodont zones

Size. Length = 80-101 μm; width = 70-80 μm; l/w = 1.1-1.3

Remarks. *Psammosphaera* sp. B differs from *Psammosphaera* sp A in its smooth wall surface and the fewer, and smaller surface pores. That the test wall was flexible is shown in specimen OKE 0.9 (Fig. 7 G) which has partially collapsed and which may even show an attachment scar.

?Psammosphaera sp. C (Fig. 7H-J)

Description. Test free; globular; surface with many strongly rimmed, subcircular craters; no obvious aperture; possible small pores (1-2 μm) in the rims of the craters.

Material. 5 specimens

Locality and age. TW-T Isis River, below Timor Limestone, Early Eifelian ?*costatus* Conodont Zone; Isis section, base Timor Limestone, *costatus* Conodont Zone; TIM 17.5m, Timor Limestone, *costatus* Conodont Zone; DDH2 depth 62.1m, *costatus-australis* conodont zones; Gilwhite Limestone, age unknown – probably Early Eifelian

Size. Diameter = 97-160 μm (Av. 130)

Remarks. The presence of large, sharp-edged craters serves to distinguish this *Psammosphaera* species. It is possible that this surface structure may be a diagenetic feature.

Family SACCAMMINIDAE Brady, 1884

Saccammina Carpenter, 1869

Type species. *Saccammina sphaerica* Brady, 1871

Saccammina mea Bell & Winchester-Seeto, 1999 (Fig. 8A-F)

1999 (in press) *Saccammina mea* Bell & Winchester-Seeto; Bell & Winchester-Seeto, p. ??, pl. 2, figs 6-9.

Material. 9 specimens.

Locality and age. OKE sample 0.9, *costatus* Conodont Zone; DDH2 depths 55.9m, 59.2m, 62.1m, 68.2m, *costatus-australis* conodont zones; Yarrimie below Jacksons Quarry, *costatus* Conodont Zone

Known occurrence. pesavis-sulcatus conodont zones, Garra Limestone, N.S.W.; *sulcatus* Condont Zone, Martins Well Limestone, Queensland; *serotinus* Conodont Zone, Middle Shanda Beds, Siberia.

Size. Diameter (max.) = 90-107 μm; diameter of aperture = 3-5 μm (for 3 specimens)

Remarks. The linings show a finely reticulated surface, although the size of the reticulated ridges varies from specimen to specimen (compare OKE 0.9 and DDH2/89 55.9; Fig. 8A, B-C); this variation may be due to the presence of small grains in the original test, or degradation of the surface subsequently. Some specimens have an oily residue partially covering the surface (figs 8D-E); this surface feature has previously been observed on chitinozoans and other organic-walled microfossils.

The surface texture does not vary significantly from that encountered in specimens from the Garra Limestone, Martins Well Limestone and Middle Shanda Beds, Siberia (Bell & Winchester-Seeto 1999); the diameter of the test falls within a similar size range, but the diameter of the aperture is slightly smaller. Figure 8F (DDH2/55.9m) shows a specimen with what appears to be an encrusting, hollow, growth; this may be either foraminiferan or algal in nature.

Remarks. Although the only specimen from the Tamworth area (TIM 18.9) is broken it appears to be the same as *ampullacea* previously described (Bell & Winchester-Seeto, 1999). This specimen is, however, significantly larger than the previously described specimens.

Genus **Thuramminoides** Plummer, 1945

Type species. Thuramminoides sphaeroidalis Plummer, 1945

Thuramminoides sphaeroidalis Plummer, 1945 (Fig. 9A-C)

1945 *Thuramminoides sphaeroidalis* Plummer, 218, pl. 15, figs. 4-10.

1964 *Thuramminoides sphaeroidalis* Plummer; Conkin & Conkin, p. 71, pl. 12, figs 36-38 (with synonymy).

1981 *Thurammina sphaeroidalis* Plummer; Conkin *et al.*, p. 344, pl. 1, figs 4-7 (with extensive synonmy).

1996 *Thuramminoides sphaeroidalis* Plummer; Bell, p. 103, fig. 10 L.

1996 *Thurammina sphaeroidalis* (Plummer); Riegraf & Niemeyer, p. 26, figs 4-6, 8-11, 14-15, 17, 20-23, 25-31, 45, 58-60, 63.

Material. 15 specimens

Locality and age. DDH2 depths 55.9m, 63.5m, 73m, *costatus-australis* conodont zones; 0217, Glenrock, ?late Emsian-early Eifelian; OKE sample 0.9, *costatus* Conodont Zone; Yarrimie below Jacksons Quarry, *costatus-australis* conodont zones; TIM 18.9, *costatus* Conodont Zone

Known occurrence. Upper Ordovician, U.S.A (Conkin *et al.,*1981); Devonian, Australia (Bell, 1996); Carboniferous, U.S.A. (Conkin & Conkin, 1964); Permian, Australia (Crespin, 1958).

Size. Diameter (max.) = 72-120 μm (Av. 95)

Remarks. This is the first report of an organic lining for this species and lends weight to the placement of *Thuramminoides* within the Foraminifera. Loeblich & Tappan (1988) have suggested that there were several species included in the original description of this species and they have restricted the concept of *T. sphaeroidalis* Plummer to forms with a smooth exterior and interior.

The actual taxonomic position of this species is not known; it has been referred to as a foraminiferan (Plummer 1945; Loeblich & Tappan 1988), as having spore-like affinities (Conkin *et al.*,1965) and having radiolarian affinities (Conkin *et al.*, 1968; Conkin *et al.*, 1981), but these differing placements may be due to confusion over what actually constitutes *T. sphaeroidalis*.

This is a very common species in the present material. The specimens show a variety of surface styles which may represent, in part, some pyritization of the wall matrix.

Pelosina Brady, 1879

Pelosina sp. (Fig. 9 D-E)

Description. Test free; spindle shaped, about four times as long as broad; widest in the middle third of test and then rapidly attenuated to narrow arms each about one third of test length; surface smooth, with scattered, round, relatively large punctae; aperture oblique at end of each arm.

Material. 2 specimens.

Locality and age. Isis river, below Timor Limestone, Early Eifelian possibly *costatus* conodont zone

Size. Length = 233-250 μm; width (max.) = 50-61 μm; diameter of aperture = 11-12μm; diameter of wall punctae = 11-12 μm

Remarks. The genus *Pelosina* has been recorded from the Emsian (*perbonus-inversus* zones) of Victoria (Bell, 1996). The present specimens differ from *P. grandaeva* Bell 1996 in having more attenuated extremities and a more inflated central section. Specimens of this species have also been found as "normal" foraminiferans from the Moore Creek member of the Yarrimie Formation at Yarramanbully (Eifelian, conodont age uncertain); they range in length from 630 μm to 850 μm.

Thurammina Brady, 1879

Type species. Thurammina papillata Brady, 1879

Thurammina mirrka Bell & Winchester-Seeto 1999 (Fig. 9F)

1999 (in press) *Thurammina mirrka* Bell & Winchester-Seeto . Bell & Winchester-Seeto, p., pl. 3, figs 1, 2

Material. 2 specimens

Locality and age. 0217, Glenrock, ?late Emsian–early Eifelian; Yarrimie, below Jacksons Quarry, *costatus-australis* conodont zones

Known occurrence. pesavis-sulcatus conodont zones, Garra Limestone, Australia.

Size. Diameter (max.) = 80-150 μm; diameter of pores = 2-3 μm

Remarks. These specimens increase the previous known range of this species from the Lochkovian-Pragian (*pesavis-sulcatus* conodont zones; Bell & Winchester-Seeto, 1999) into the Eifelian.

Thurammina pustulosa Gutschick, Weiner & Young, 1961 (Fig. 9 G-H)

1961 *Thurammina pustulosa* Gutschick, Weiner & Young. Gutschick, Weiner & Young, p. 1211, text-fig. 4, 22.

Description. Test free; subglobular to globular; surface with many short, pointed, randomly placed protruberances; small rounded apertures at ends of most of these protuberances; larger pores occur between the projections.

Material. 5 specimens.

Locality and age. Mostyn Vale, *linguiformis* Conodont Zone

Known occurrence. Tournasian, Chappel Limestone, Texas,

Size. Diameter (max.) = 92 -144μm; diameter (min) = 80-140;

diameter of apertures = 1-2 μm; diameter of pores = 3-6 μm;

Diameter max./diameter min. = 1-1.2

Remarks. These specimens closely match *T. pustulosa* from the Tournasian Chappel Limestone of Texas (Gutschick *et al* ,1961), and differs from *T. adamsi* Conkin & Conkin 1964 in having a greater number of, and shorter, more pointed papillae.

Thurammina sp. cf. **T. subsphaerica Moreman, 1930** (Fig. 9I-K)

1996 ? *Thurammina subsphaerica* Moreman. Bell, p. 96, fig. 8G.

1999 (in press) *Thurammina* sp. cf. *subsphaerica* Moreman. Bell & Winchester-Seeto, p. , pl. 3, fig. 5.

Material. 8 specimens

Locality and age. Isis river below Timor Limestone, Early Eifelian, possibly *costatus* conodont zone; TIM 36.6, *costatus* Conodont Zone; DDH7 95 *costatus-australis* conodont zones; Kiah Limestone, late Famennian; Gilwhite Limestone, age unknown- probably Early Eifelian.

Known occurrence. T. subsphaerica is known from the Ordovician and Silurian of Oklahoma (Moreman 1930), Silurian of Mississippi Basin (Dunn, 1942), Early Devonian at Buchan and Bindi, Victoria (Emsian, *dehiscens-perbonus* zones;

Bell, 1996). *T.* sp. cf. *T. subsphaerica* is known from the Garra Limestone, Wellington N.S.W. (*pesavis-sulcatus* zones, Martins Well Limestone, Broken River, Qld., *sulcatus* Zone; Bell & Winchester-Seeto, 1999).

Size. Diameter (max.) = 50-146 μm (Av.102); diameter of apertures = 6-12 μm; diameter of pores = 1-3 μm

Remarks. A widespread and common species in the Tamworth area, both as foraminiferal linings and as normal foraminiferans. Typical specimens show variously deformed tests each having numerous larger raised apertures and smaller pores over the surface. These specimens are not definitely assigned to *T. subsphaerica* because of the presence of small pores between the papillae (see also Bell & Winchester-Seeto, 1999). One specimen from Isis River, below the Timor Limestone (Fig. 9 J-K) shows what appear to be sieve plates in some of the smaller pores.

Gen. et sp. indet. (Fig. 8G)

1999 (in press) ?Gen. et sp. indet. Bell & Winchester. Bell & Winchester-Seeto, p. , pl. 4, figs 11-12.

Material. 1 specimen.

Locality and age. TIM 18.9, Timor Limestone, *costatus* Conodont Zone

Known occurrence. serotinus Conodont Zone, Taravale Formation, Buchan

Size. Diameter = 123 μm; diameter of pores = 3 μm

Remarks. This specimen is about twice the size of that found at Buchan (Bell & Winchester-Seeto, 1999) and has correspondingly larger pores which show the same slightly raised, smooth rim.

Acknowledgements

We thank Ruth Mawson for supplying her unpublished conodont ages for certain localities. We also thank R. Mawson, J.A. Talent, E. Leitch and the many members of the MUCEP team for helping to collect samples from all over the Tamworth Belt; Mark Hocking, Alison Basden, David Mathieson, Caroline Lehmen and the Macquarie University SEM Unit for assistance with processing the samples and with preparation of figures and plates. Dean Oliver drafted with maps with panache. Financial assistance was afforded to TW-S from the ARC Large Grant number XXXX.

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Captions for Figures.

Fig. 1. Generalized geological map of the Tamworth Belt, showing localities and studied areas.

Fig. 2. Detailed map of the Attunga area, showing location of spot samples and sections studied. (adapted from Lishmund *et al.*, 1986).

Fig. 3. Detailed map of the Timor area, showing location of spot samples and sections studied. (adapted from Manser, 1968).

Fig. 4. Detailed map of the Glenrock area, showing localities sampled. (adapted from Stratford & Aitchison, 1996).

Fig. 5. Stratigraphic columns, showing the ages and relationships between the studied sections (adapted from Mawson & Talent, 1998).

Fig. 6. Range chart of the species of foraminiferal lining species found in the Tamworth area, showing both the ranges found in this paper (black bars) and previously known ranges (diagonal shading).

Fig. 7. A, *Inauris tubulata* Conkin, Conkin & Thurman, AMF 105180; 0217 Gelnrock, x300; B-C, *Psammosphaera cava* Moreman: B, AMF 105181; DDH2 55.9m, x 475; C, AMF 105182; DDH2 66.2m, x450; D-E, *Psammosphaera* sp. A, AMF 105183; Mostyn Vale: D, x 350; E, x900; F-G, *Psammosphaera* sp. B: F, AMF 105184; OKE 112, x500; G, AMF 105185; OKE 0.9, x 475; H-J, ?*Psammosphaera* sp. C: H, AMF 105186; TIM 17.5, x 300; I-J, AMF 105187; Isis below Timor, I x400, J x1200.

Fig. 8. A-F, *Saccammina mea* Bell & Winchester-Seeto: A, AMF 105188; OKE 0.9, x475; B-C, AMF 105189; DDH2 55.9m, B x400, C x1100; D-E, AMF 105190; TIM 18.9, D x600, E x350; F, AMF 105191; DDH2 55.9m, x 300; G, gen.et sp. indet., AMF 105192; TIM 18.9, x360; H, *Saccammina* sp. cf. *S. ampullacea* (Crespin), AMF 105193; TIM 18.9, x300; I-K, *Saccammina wingarri* Bell & Winchester-Seeto: I, AMF 105194; Mostyn Vale, x 450; J-K, AMF 105195, J x300, K x650.

Fig. 9. A-C, *Thuramminoides sphaeroidalis* Plummer: A, AMF 105196; DDH2 73m, x450; B-C, AMF 105197; DDH2 55.9m, B x375, C x1100; D-E, *Pelosina* sp.: D, AMF 105198; Isis below Timor, x250; E, AMF 105199; Isis below Timor, x250; F, *Thurammina mirrka* Bell & Winchester-Seeto, AMF 105200; 0217 Glenrock, x400; G-H, *Thurammina pustulosa* Gutschick, Weiner & Young: G, AMF 105201; Mostyn Vale, x350; H, AMF 105202; Mostyn Vale, x400; I-K, *Thurammina* sp. cf. *T. subsphaerica* Moreman: I, AMF 105203; Kiah Limestone, x350; J-K, AMF 105204; Isis below Timor, J x425, K x900.

*Table 1.*Comparison of sites with foraminiferal linings and "normal" foraminiferans.

Sites with "normal" forams., no foram. linings	3	16%
Sites with "normal" forams. and foram. linings	5	26%
Sites without "normal" forams. but with foram. linings	11	58%

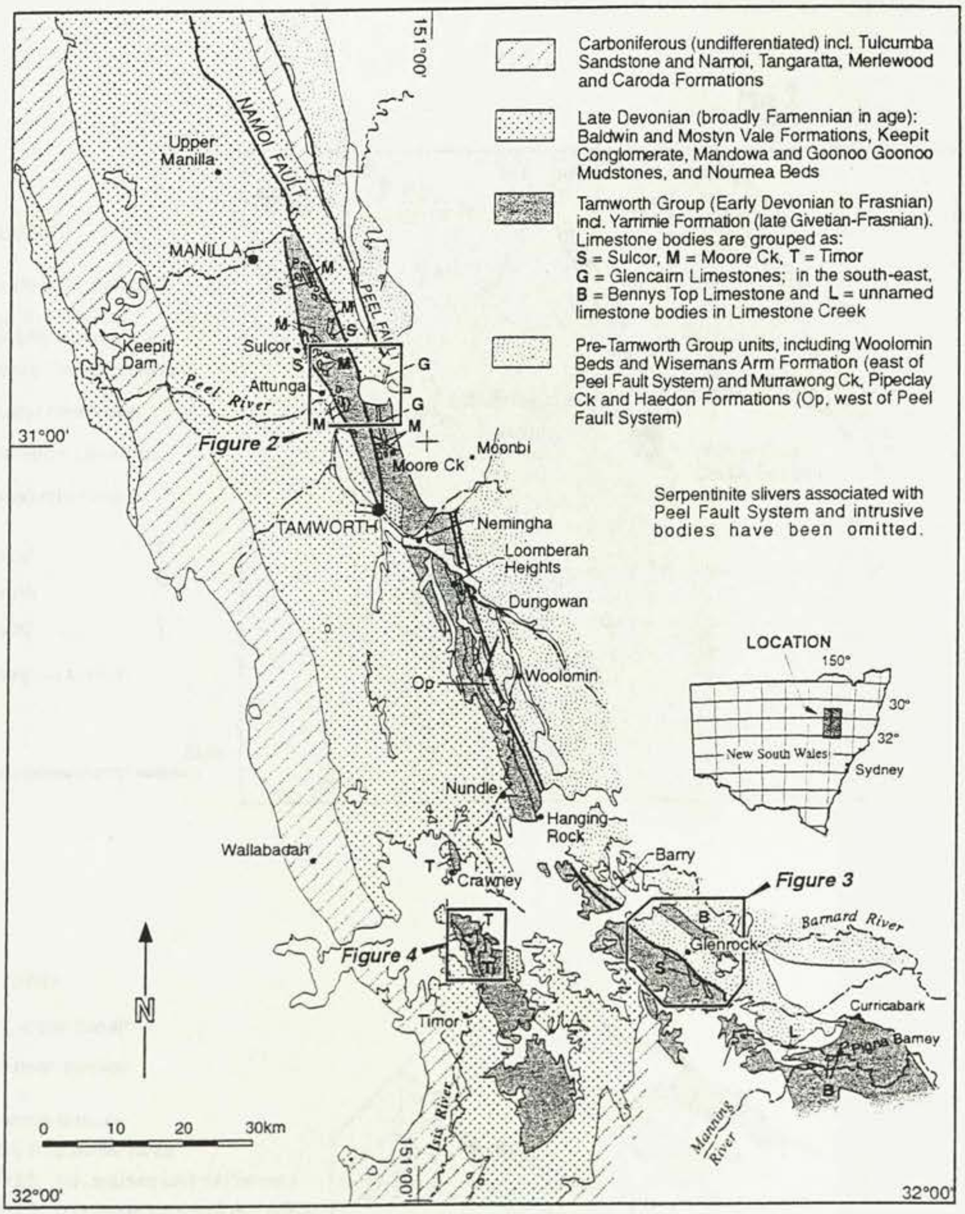
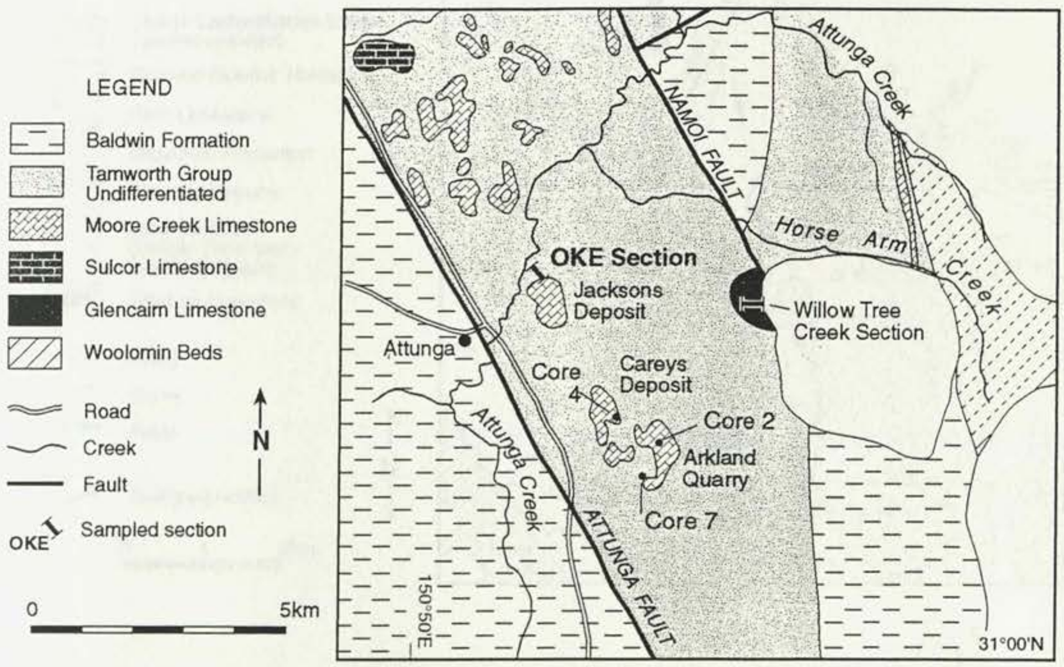

Carboniferous (undifferentiated) incl. Tulcumba Sandstone and Namoi, Tangaratta, Merlewood and Caroda Formations
Late Devonian (broadly Famennian in age): Baldwin and Mostyn Vale Formations, Keepit Conglomerate, Mandowa and Goonoo Goonoo Mudstones, and Noumea Beds
Tamworth Group (Early Devonian to Frasnian) incl. Yarrimie Formation (late Givetian-Frasnian). Limestone bodies are grouped as: S = Sulcor, M = Moore Ck, T = Timor G = Glencairn Limestones; in the south-east, B = Bennys Top Limestone and L = unnamed limestone bodies in Limestone Creek
Pre-Tamworth Group units, including Woolomin Beds and Wisemans Arm Formation (east of Peel Fault System) and Murrawong Ck, Pipeclay Ck and Haedon Formations (Op, west of Peel Fault System)
Serpentinite slivers associated with Peel Fault System and intrusive bodies have been omitted.
151°00'
NAMOI FAULT
PEEL FA
Upper Manilla
MANILLA
Keepit Dam
Sulcor
Attunga
Peel River
31°00'
Figure 2
Moonbi
Moore Ck
TAMWORTH
Nemingha
Loomberah Heights
Dungowan
Woolomin
Op
Nundle
Hanging Rock
Wallabadah
Crawney
Barry
Figure 3
Barnard River
Glenrock
Figure 4
Timor
Curricabark
Barney
Isis River
Manning River
LOCATION
150°
30°
32°
New South Wales
Sydney
N
0 10 20 30km
32°00'
151°00'
32°00'

Fig 1

Fig 2


LEGEND
Baldwin Formation
Tamworth Group Undifferentiated
Moore Creek Limestone
Sulcor Limestone
Glencairn Limestone
Woolomin Beds
Road
Creek
Fault
OKE
Sampled section
0
5km
N
Attunga Creek
NAMOI FAULT
Horse Arm Creek
OKE Section
Jacksons Deposit
Willow Tree Creek Section
Attunga
Core 4
Careys Deposit
Core 2
Arkland Quarry
Core 7
Attunga Creek
ATTUNGA FAULT
150°50'E
31°00'N

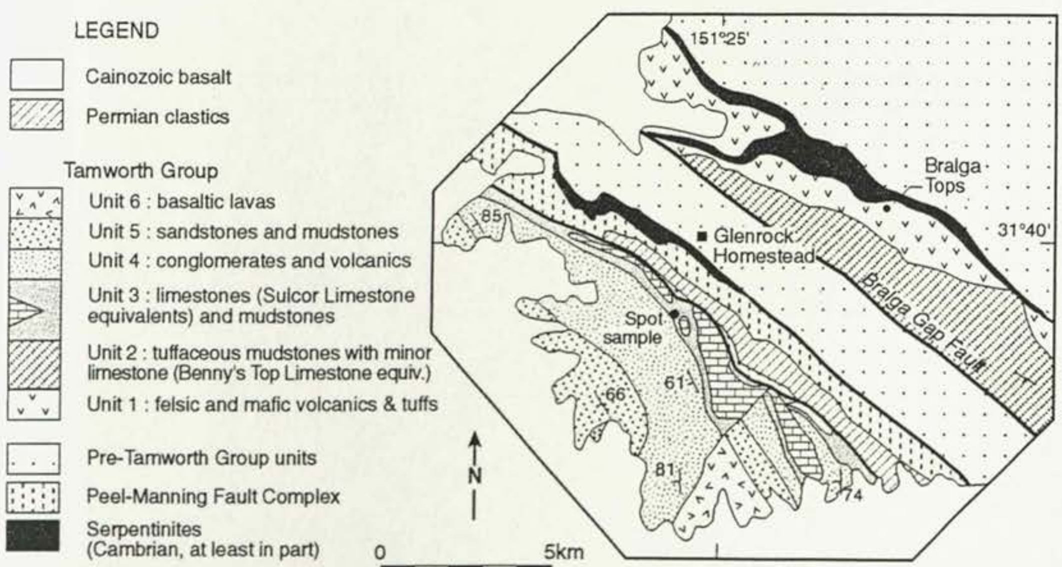
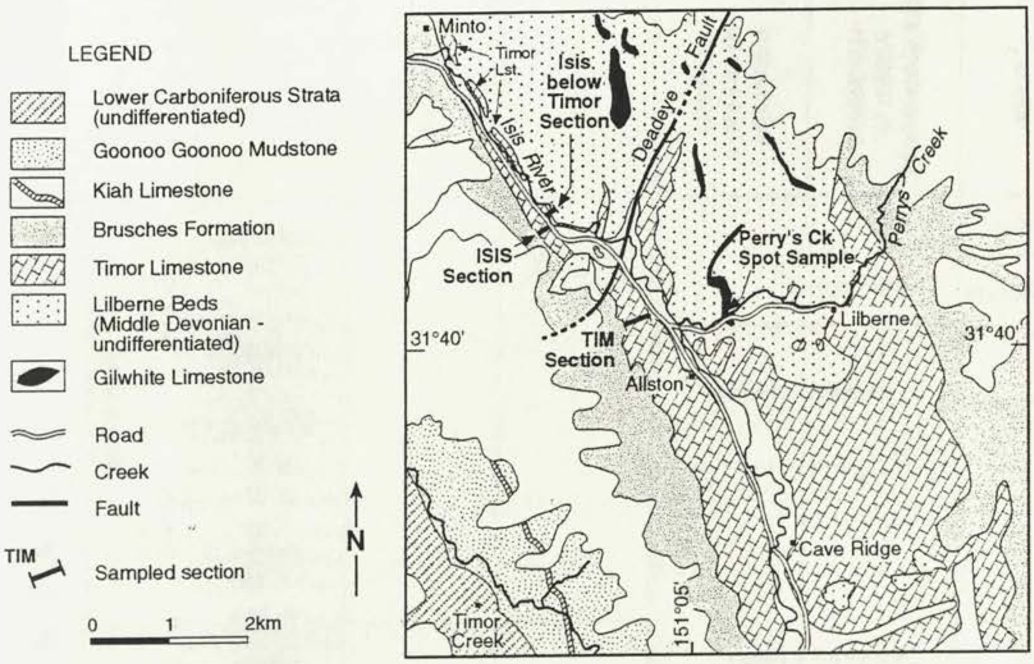

LEGEND
Cainozoic basalt
Permian clastics
Tamworth Group
Unit 6 : basaltic lavas
Unit 5 : sandstones and mudstones
Unit 4 : conglomerates and volcanics
Unit 3 : limestones (Sulcor Limestone equivalents) and mudstones
Unit 2 : tuffaceous mudstones with minor limestone (Benny's Top Limestone equiv.)
Unit 1 : felsic and mafic volcanics & tuffs
Pre-Tamworth Group units
Peel-Manning Fault Complex
Serpentinites (Cambrian, at least in part)
N
0
5km
151°25'
Bralga Tops
31°40'
85
Glenrock Homestead
Bralga Gap Fault
Spot sample
61
66
81
74

Fig 4



LEGEND
Lower Carboniferous Strata (undifferentiated)
Goonoo Goonoo Mudstone
Kiah Limestone
Brusches Formation
Timor Limestone
Lilberne Beds (Middle Devonian - undifferentiated)
Gilwhite Limestone
Road
Creek
Fault
TIM
Sampled section
0
1
2km
N
Minto
Timor Lst.
Isis below Timor Section
Deadeye Fault
Isis River
ISIS Section
TIM Section
Perry's Ck Spot Sample
Perrys Creek
Lilberne
31°40'
31°40'
Allston
Cave Ridge
151°05'
Timor Creek

Fig 3

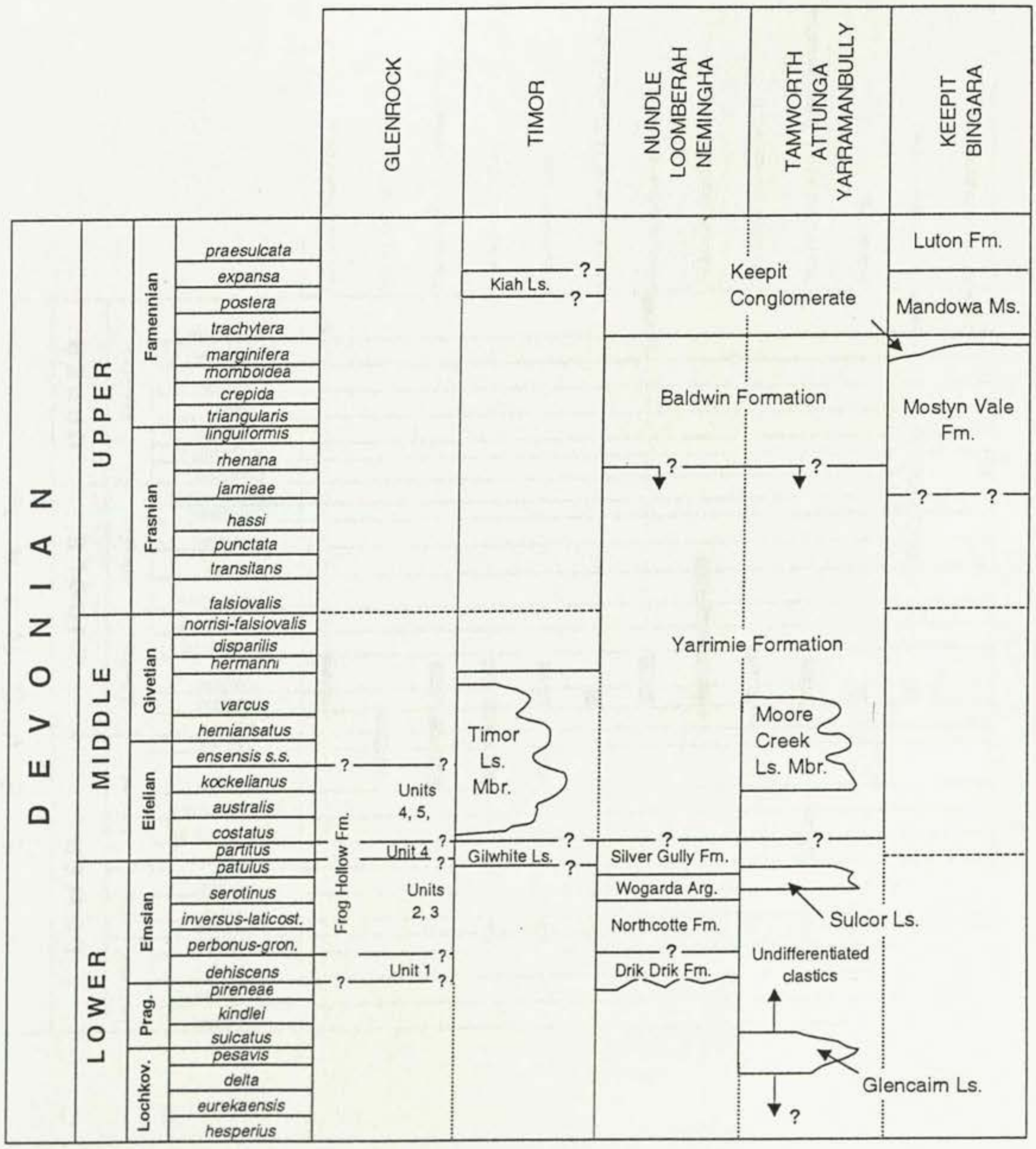

DEVONIAN
LOWER
MIDDLE
UPPER
Lochkov.
Prag.
Emsian
Eifelian
Givetian
Frasnian
Famennian
praesulcata
expansa
postera
trachytera
marginifera
rhomboidea
crepida
triangularis
linguiformis
rhenana
jamieae
hassi
punctata
transitans
falsiovalis
norrisi-falsiovalis
disparilis
hermanni
varcus
hemiansatus
ensensis s.s.
kockelianus
australis
costatus
partitus
patulus
serotinus
inversus-laticost.
perbonus-gron.
dehiscens
pireneae
kindlei
sulcatus
pesavis
delta
eurekaensis
hesperius
GLENROCK
TIMOR
NUNDLE
LOOMBERAH
NEMINGHA
TAMWORTH
ATTUNGA
YARRAMANBULLY
KEEPIT
BINGARA
Frog Hollow Fm.
Units
4, 5,
Unit 4
Units
2, 3
Unit 1
Kiah Ls.
Timor
Ls.
Mbr.
Gilwhite Ls.
Keepit
Conglomerate
Baldwin Formation
Yarrimie Formation
Silver Gully Fm.
Wogarda Arg.
Northcotte Fm.
Drik Drik Fm.
Moore
Creek
Ls. Mbr.
Sulcor Ls.
Undifferentiated
clastics
Glencairn Ls.
Luton Fm.
Mandowa Ms.
Mostyn Vale
Fm.

Fig 5

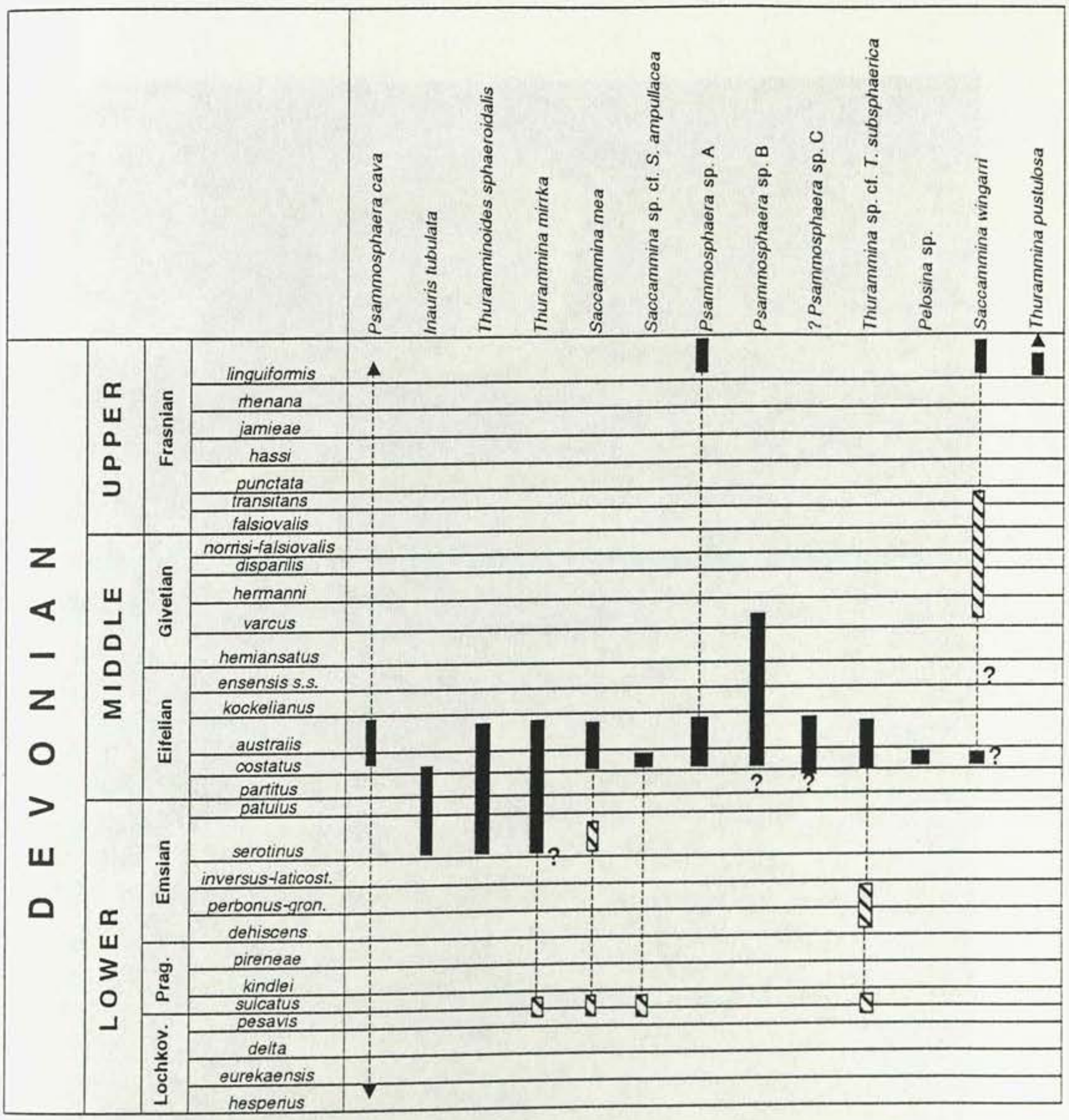

DEVONIAN
LOWER
MIDDLE
UPPER
Lochkov.
Prag.
Emsian
Eifelian
Givetian
Frasnian
hesperius
eurekaensis
delta
pesavis
sulcatus
kindlei
pireneae
dehiscens
perbonus-gron.
inversus-laticost.
serotinus
patulus
partitus
costatus
australis
kockelianus
ensensis s.s.
hemiansatus
varcus
hermanni
disparilis
norrisi-falsiovalis
falsiovalis
transitans
punctata
hassi
jamieae
rhenana
linguiformis
Psammosphaera cava
Inauris tubulata
Thuramminoides sphaeroidalis
Thurammina mirka
Saccammina mea
Saccammina sp. cf. S. ampullacea
Psammosphaera sp. A
Psammosphaera sp. B
? Psammosphaera sp. C
Thurammina sp. cf. T. subsphaerica
Pelosina sp.
Saccammina wingarri
Thurammina pustulosa

Fig 6

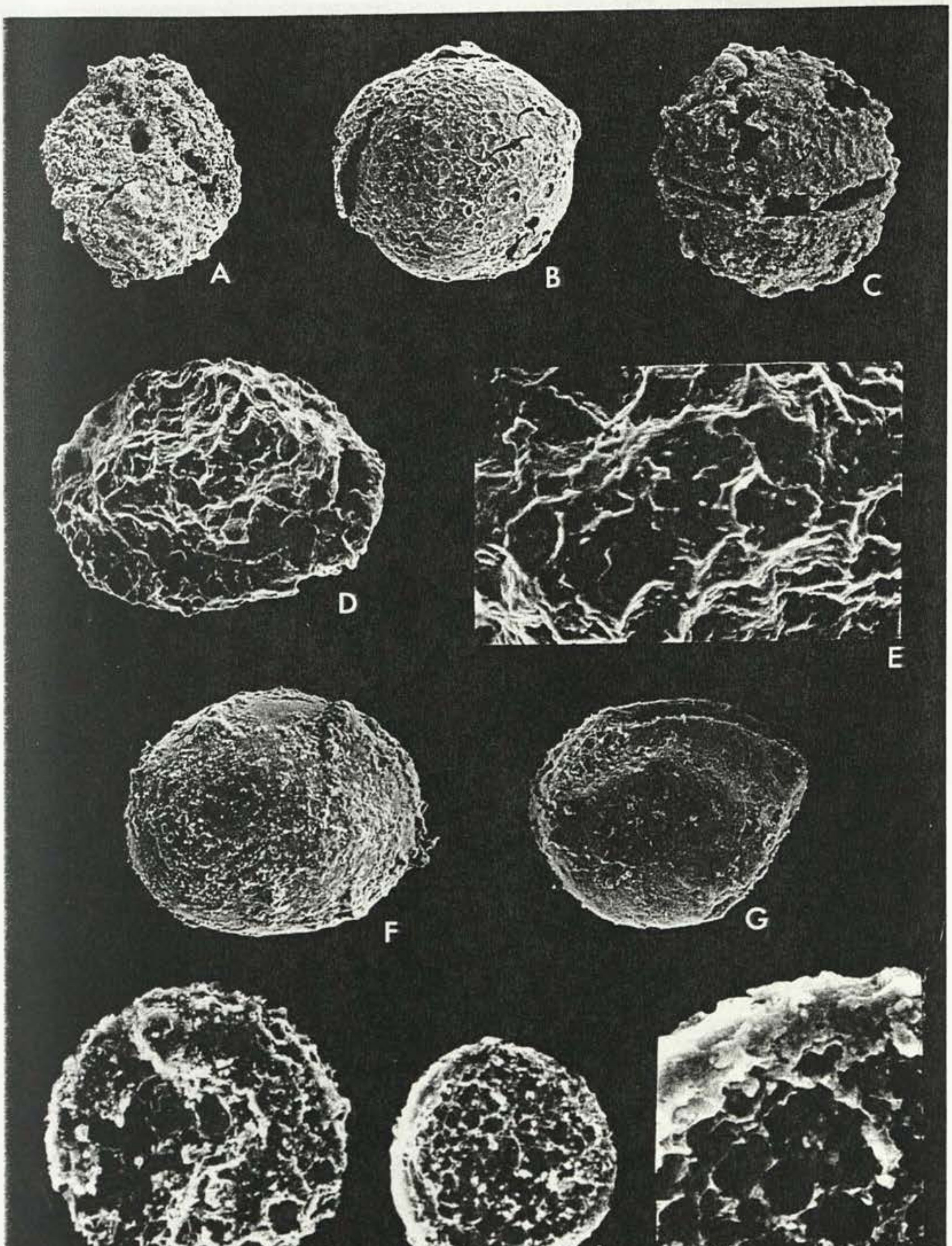


Fig 7

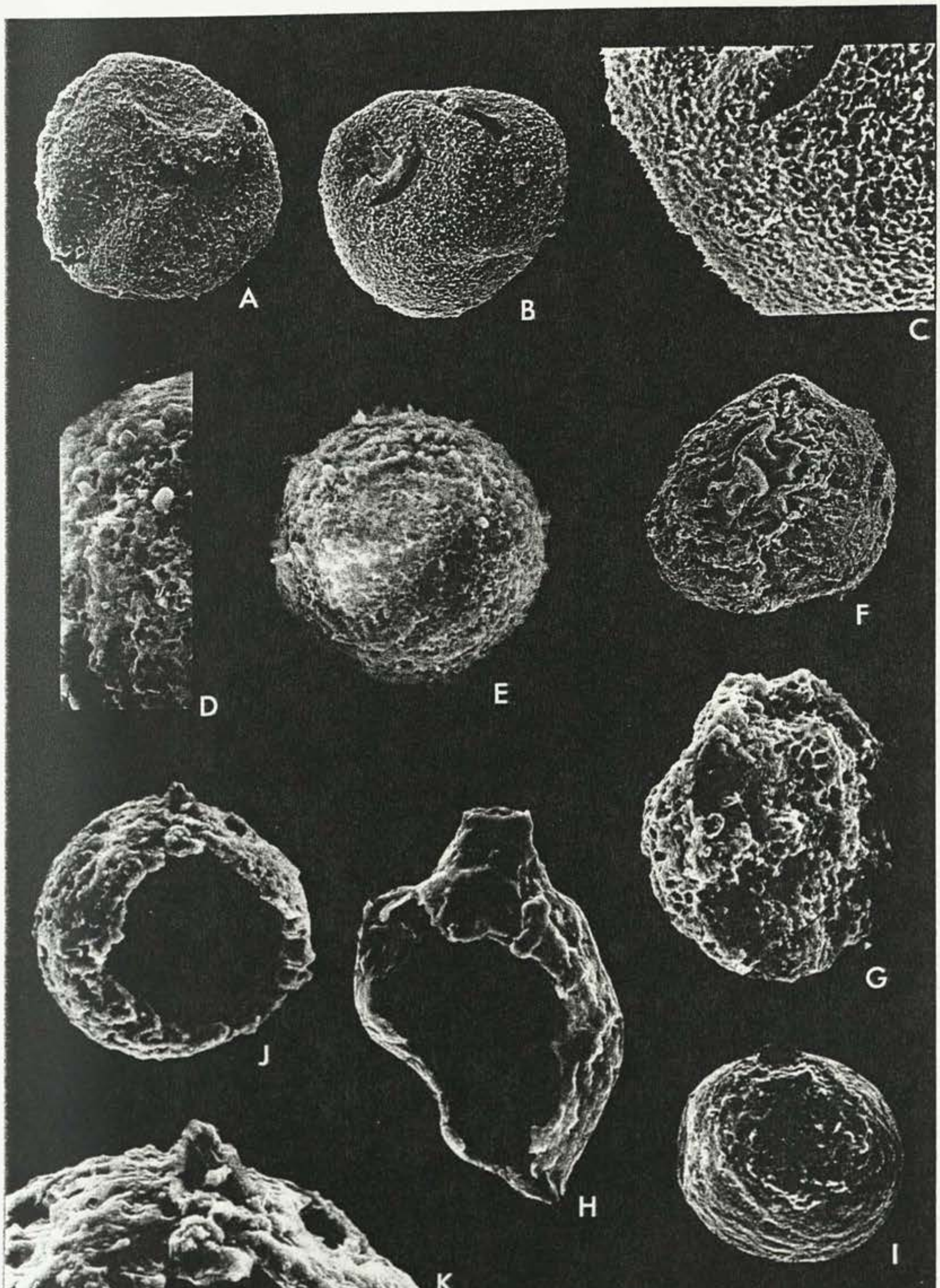


Fig8

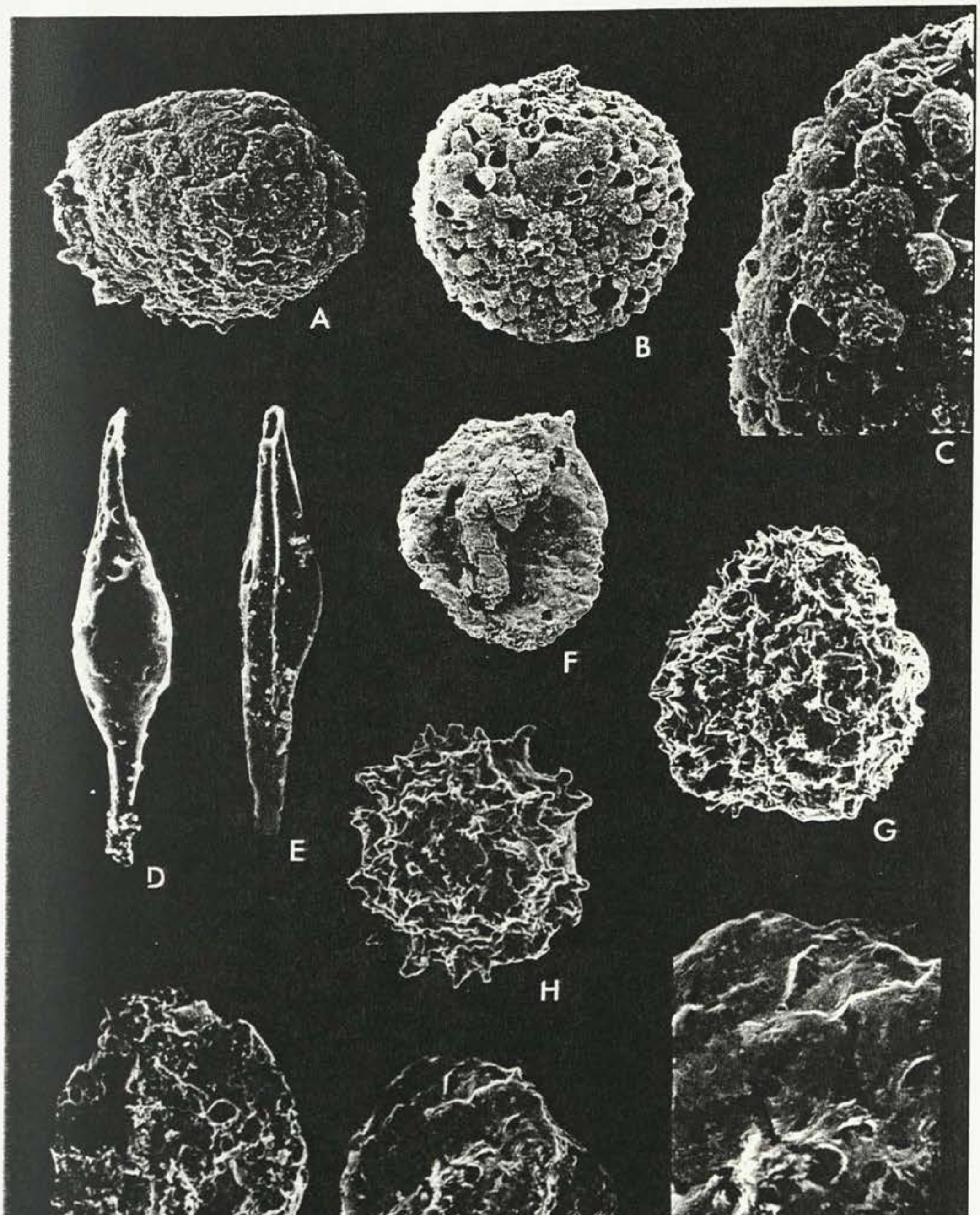


Fig9

Locality	Grid Ref.	Map sheet	Reference
Glenrock 0217	482_5937_5	Glenrock 9134-I-S CMA mapsheet	Stratford, 1995
Glenrock 0231	482_5937_5	Glenrock 9134-I-S CMA mapsheet	Stratford, 1995
Glenrock 0379	432_5961_5	Glenrock 9134-I-S CMA mapsheet	Stratford, 1995
Glenrock 0405	522 891	Glenrock 9134-I-S CMA mapsheet	Stratford, 1995
Bralga Tops	543 957	Glenrock 9134-I-S CMA mapsheet	Metcalfe et al., 1997
TIM section	183_3951_0	Isis River 9134-IV-S 1:25,000 topographic	Mawson & Talent, unpub.
ISIS section	168_5967_0	Isis River 9134-IV-S 1:25,000 topographic	Mawson & Talent, unpub
Isis below Timor	169_0966_4	Isis River 9134-IV-S 1:25,000 topographic	Mawson & Talent, unpub
Gilwhite Ls.; Perrys Creek	189_7949_5	Isis River 9134-IV-S 1:25,000 topographic	Mawson & Talent, unpub
Copes Creek	192 335	Woolomin 9135-III-N 1:25,000 topographic	Stewart, 1995
Upper Barnard River	321_5062_8	Crawney Pass 9134-IV-N 1:25,000 topog.	Mawson et al., 1995; Furey-Grieg, 1995
Chaffey Island	217298	Woolomin 9135-III-N 1:25,000 topographic	Mawson & Talent, 1998
Loomberah Hgts.	132_6481_1	Dungowan 9135-4-S 1:25,000 topographic	Mawson et al., 1995
Willow Tree Creek section	025_1805_2	Attunga 9036-2-S, 1:25,000 topographic	Mawson & Talent, 1998; Leitch, Cawood & Mawson, 199?
Hospital Quarry	023_5607_0	Tamworth 9035-I-N 1:25,000 topographic	Mawson et al., 1997
David & Pitamn's Locality 8	014_6611_8	Tamworth 9035-I-N 1:25,000 topographic	Mawson et al., 1997
Mostyn Vale spot sample	579 817	Kelvin 8936-II-N 1:25,000 topographic	Wright et al., 1990
OKE section	949_5769_0	Attunga 9036-2-S, 1:25,000 topographic	Mawson & Talent 1994
Arkland Wyaralong Core 2	977 742	Attunga 9036-2-S, 1:25,000 topographic	Pohler & Herbert, 1993
Arkland Wyaralong Core 4	965 744	Attunga 9036-2-S, 1:25,000 topographic	Pohler & Herbert, 1993
Arkland Wyaralong Core 7	975 736	Attunga 9036-2-S, 1:25,000 topographic	Pohler & Herbert, 1993
Carey's Quarry section	962_8748_0	Attunga 9036-2-S, 1:25,000 topographic	Mawson & Talent 1994
Jackson's Deposit	954766	Attunga 9036-2-S, 1:25,000 topographic	Mawson & Talent 1994
Yarramie below Jacksons' Dep.	951_8768_7	Attunga 9036-2-S, 1:25,000 topographic	Mawson & Talent 1994
Warrawilla section	981_5774_1	Attunga 9036-2-S, 1:25,000 topographic	Klyza, 1995; 1997

Append 1

CONCLUDING REMARKS

Prior to this study the middle Silurian –Middle Devonian foraminiferan faunas in eastern Australia were almost totally unknown with two species described and five other species reported as occurring.

1. As a result of my research it is shown that the Middle Silurian-Middle Devonian carbonate sequences in eastern Australia contain a large and diverse foraminiferal fauna (100 species), with both agglutinated and calcareous species present.

2. Four new genera and 37 new species of foraminiferans and 6 new species of organic foraminiferal linings have been proposed.

3. For the first time the organic linings of Devonian agglutinated foraminiferans have been recognized and their stratigraphic importance both regionally and globally has been indicated. A number of the organic linings could be identified with known normal-sized agglutinated species.

4. A species of the calcareous genus *Tikhinella* has been recognized in horizons dated by conodonts as *serotinus* Zone (Early Devonian, upper Emsian) in the Sulcor Limestone, near Attunga, NSW. This is possibly the oldest known calcareous walled foraminiferan.

5. A number of genera have had time ranges significantly increased:

Reophanus – Early Devonian, Lochkovian/Pragian, *pesavis* and *sulcatus* zones, previously only known from Recent horizons.

Pelosina – Early Devonian, Emsian, *dehiscens* Zone, previously the oldest report of the genus was the Cretaceous.

Sagenina – Late Silurian Ludlow, *crispa* Zone, previously known only from Recent horizons.

Trochammina – Middle Devonian, Eifelian, previously recognized in horizons no older than Early Carboniferous.

Hormosina – Early Devonian, Emsian, I*perbonus* Zone, previously known to range from Jurassic to Recent.

6. Devonian species of *Rhabdammina, Bathysiphon* and *Reophax* have been identified.

7. The genus *Nanicella* has been recognized in horizons of Middle Devonian age (Eifelian, *costatus-ensensis* zones). This genus had previously been recorded with certainty from horizons no older than Givetian. Records of the genus from Tunisia as possibly Pragian/Emsian age was based on stratigraphic inferences rather than palaeontological dating.

8. Comparisons with previously described faunas from elsewhere in the world has shown moderate degrees of endemism in the Silurian and Early Devonian (Lochkovian, Pragian) in Australia but a much greater endemic fauna in the Emsian.

9. A biozonation scheme based on foraminiferans and organic linings for the Middle Silurian-Middle Devonian of eastern Australia is proposed.

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PLATE CAPTIONS

Note: The size and different numbering on the plates relates to the requirements of the different journals to which papers have been or will be submitted.

Plate 1. A – H, *Hyperammina teres* Bell. A. Holotype, NMV P137616, x75. B, Paratype NMV P137617, x30. C, Paratype NMV P137618, x60. D, Paratype NMV P137619, x45. E, Paratype NMV P137620, x45. F, proloculum and platey wall of holotype, x450. G. rough pitted wall of NMV P137620. H, smooth platey wall of NMV P137619, x500. I, *Stomasphaera globosa* Bell, Holotype, NMV P137621, x45, arrows indicate apertures. J, *Trepeilopsis recurvidens* Gutschick & Treckman, NMV P137622, x65. K, *Rhizammina* sp., NMV P137623, x75. L, M. *Tolypammina* sp. L, attached surface of NMV P137625, x75. M, dorsal view of NMV P137626, x60; arrows indicate proloculum. N, *Sagenina filiformis* Bell, Holotype NMV P137627, x60. O, P. *Saccammina cyclops* Bell. O, Holotype NMV P137624, x75. P, aperture of holotype showing neck only one grain high, x250.

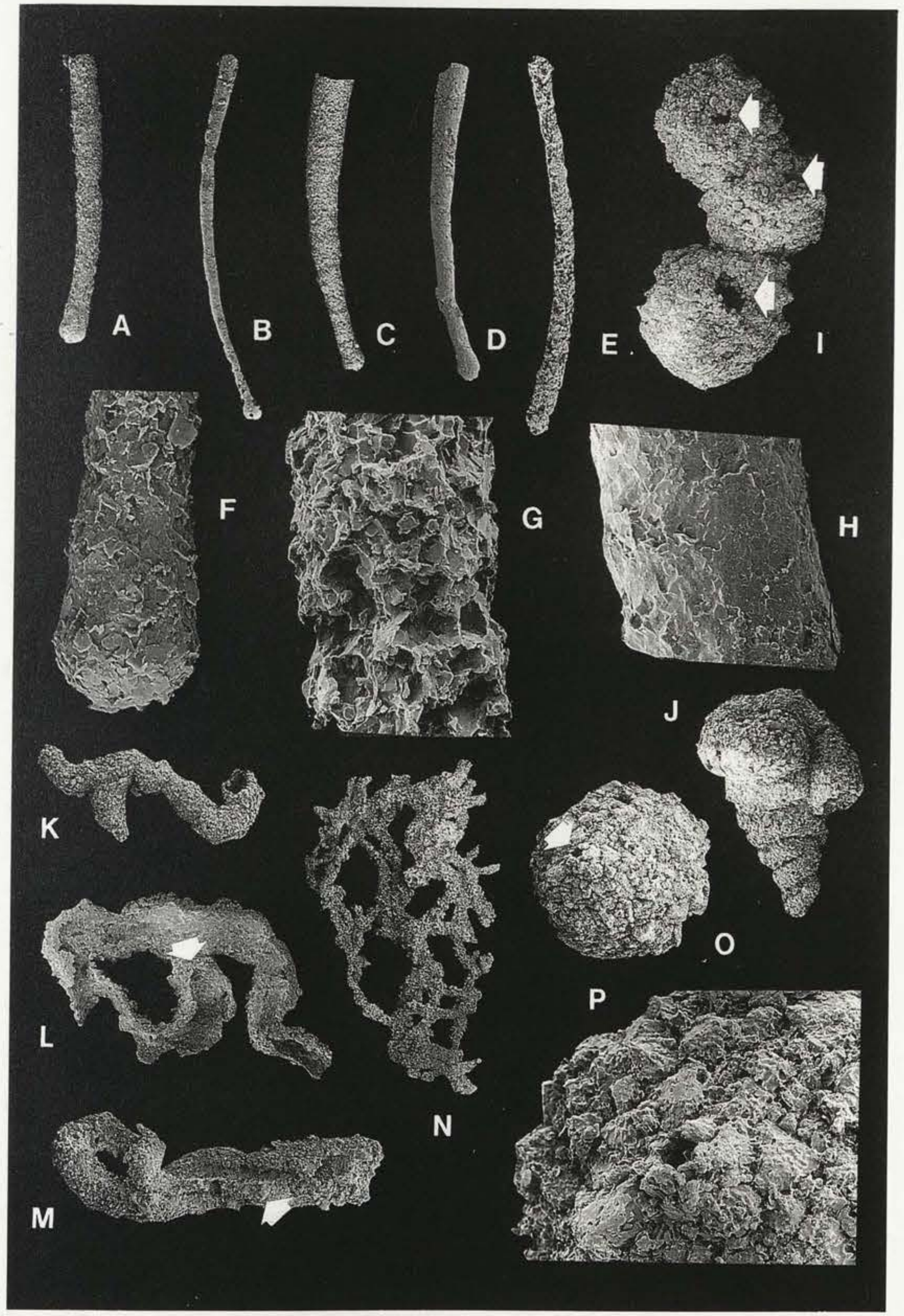


Plate 2. A - B, *Astrorhiza triquetra* Bell. A, Holotype NMV P 126952, x72, Ma 13. B, Paratype NMV P199387, x72, OTRC 7. C – D, *Astrorhiza constans* Bell. C, Holotype NMV P126953, x54, SALC 7. D, Paratype NMV P199388, x60, BON 13.5-15. E – G, *Astrorhiza sinus* Bell. E, Holotype NMV P126954, x45, SALC 7. F, Paratype NMV P199391, x63, ORCQ 10-15. G, Paratype NMV P126955, x36, BON 13.5-15. H, *Cystingarhiza tribrachia* Bell, Holotype NMV P126958, x72, ORCQ 10-15. I – J, *Cystingarhiza mawsonae* Bell. I, Holotype NMV P126956, x90, SALC 9. J, Paratype NMV P199392, x72, SALC 9. K – L, *Cystingarhiza corona* Bell. K, Paratype NMV P199394, x36, ORCQ 10-15. L, Holotype NMV P126957, x90, SALC 9. M – O, *Cystingarhiza furca* Bell. M, Paratype NMV P199398, x90, SALC 7. N, Holotype NMV P126959, x63, SALC 7. O, Paratype NMV P199399, x72, SALC 7.

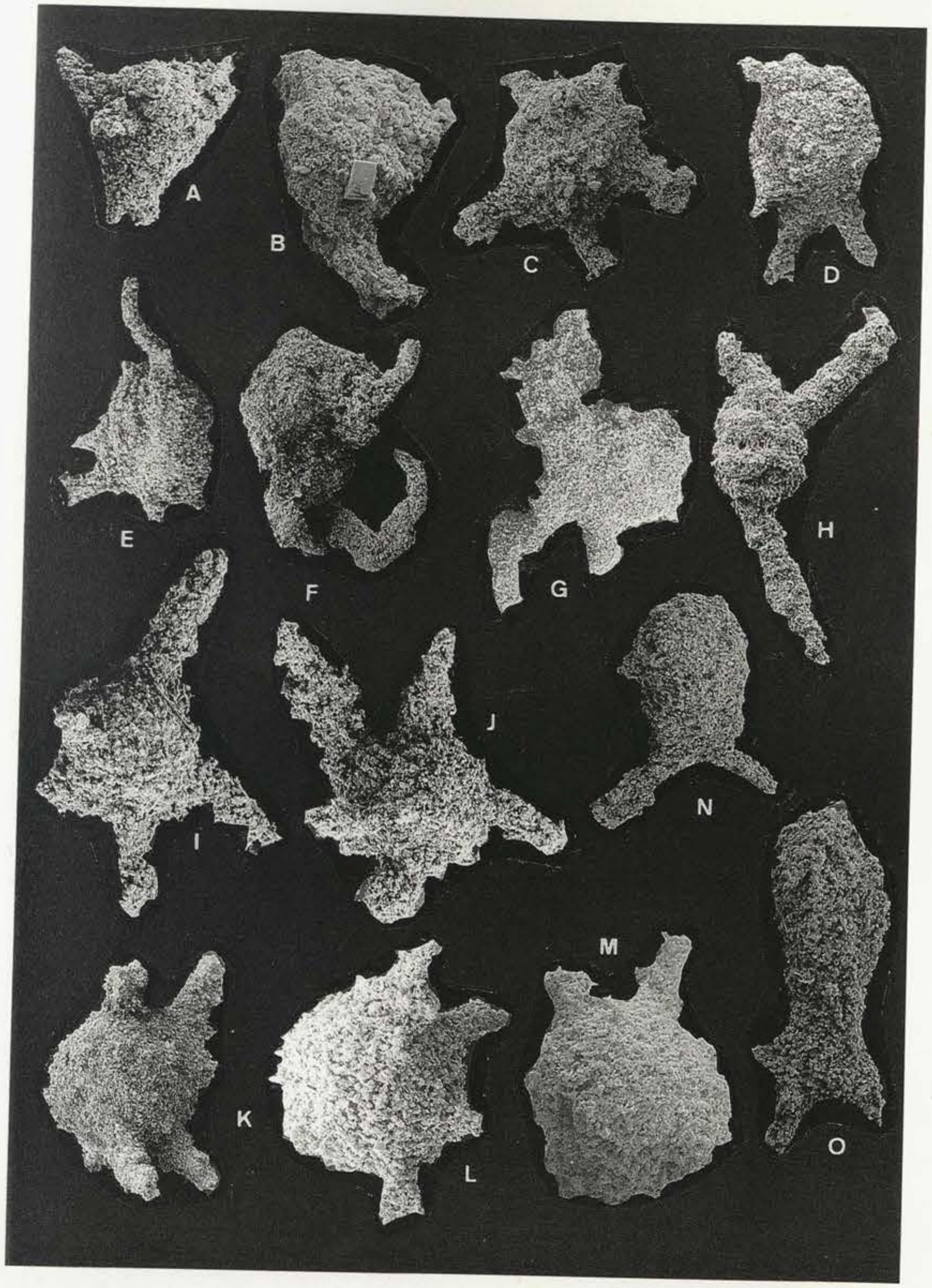


Plate 3 A – C, *Cylindrammina stolonifera* Bell. A, Paratype NMV P199402, x34, SALC 7. B, Holotype NMV P126994, x36, SALC 7. C, Paratype NMV P199404, x36, SALC 9. D – E, *Saccorhiza surculus* Bell. D, Holotype NMV P126962, x180, ORCQ 10-15. E, Paratype NMV P199411, x180, ORCQ 10-15. F, *Rhabdammina proavita* Bell, Holotype NMV P126961, x54, OTRC 7. G – I, *Rhabdammina linearis* Brady. G, NMV P199405, x59, Ma 13. H, NMV P199407, x90, BON 13.5-15. I, NMV P126960, x54, SALC 7. J, *Psammosphaera cava* Moreman, NMV P126965, x200, OTRC 7. K, *Stegnammina cylindrica* Morman, NMV P126967, x135, OTRC 2. L –M, *Sorosphaera* sp. cf. *S. confusa* Brady. L, NMV P126966, x108, OTRC 2. M, NMV P199418, x180, OTRC 2. N, *Saccammina cumberlandiae* (Conkin), NMV P126982, x144, BON 36-39. O, *Saccammina biosculata* Moreman, NMV P126968, x180, ORCQ 10-15.

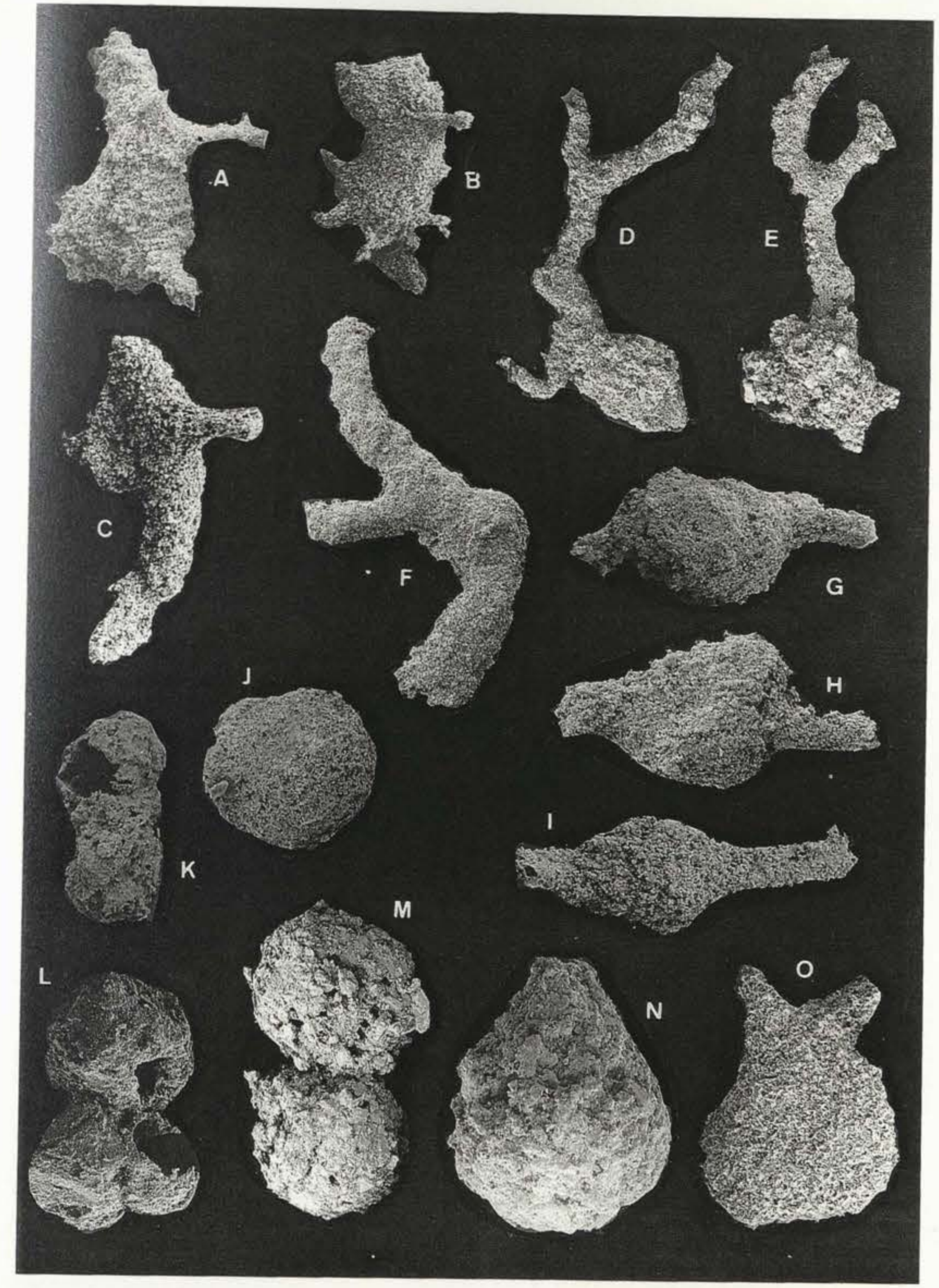


Plate 4 A – B, *Hyperammina proboscis* Bell.A, Paratype NMV P199414, x90, ORCQ 10-15. B, Holotype NMV P126964, x45, Ma 13. C – D, *Hyperammina reflua* Bell. C, Holotype NMV P126963, x54, ORCQ 10-15. D, Paratype NMV P199412, x54, ORCQ 10-15. E, *Hyperammina* sp., NMV P126955, x144, OTRC 7. F, *Lagenammina stilla* Moreman, NMV P126970, x90, Ma 13. G – I, *Lagenammina talenti* Bell. G, Holotype NMV P126971, x90, SALC 7. H, Paratype NMV P199419, x54, SALC 7. I, Paratype NMV P199420, x63, ORCQ 10-15. J, L, *Lagenammina sphaerica*. J, NMV P126975, x72, ORCQ 10-15. L, NMV P126969, x59, Ma 13. K, M – N, *Lagenammina laxacolla* Bell. K, Holotype NMV P126972, x45, Ma 13. M, Paratype NMV P199423, x72, SALC 7. N, Paratype NMV P199422, x117, SALC 9. O – P, *Lagenammina ovata* Bell. O, Holotype NMV P126973, x54, SALC 9. P, Paratype NMV P199426,x90, ORCQ 10-15.

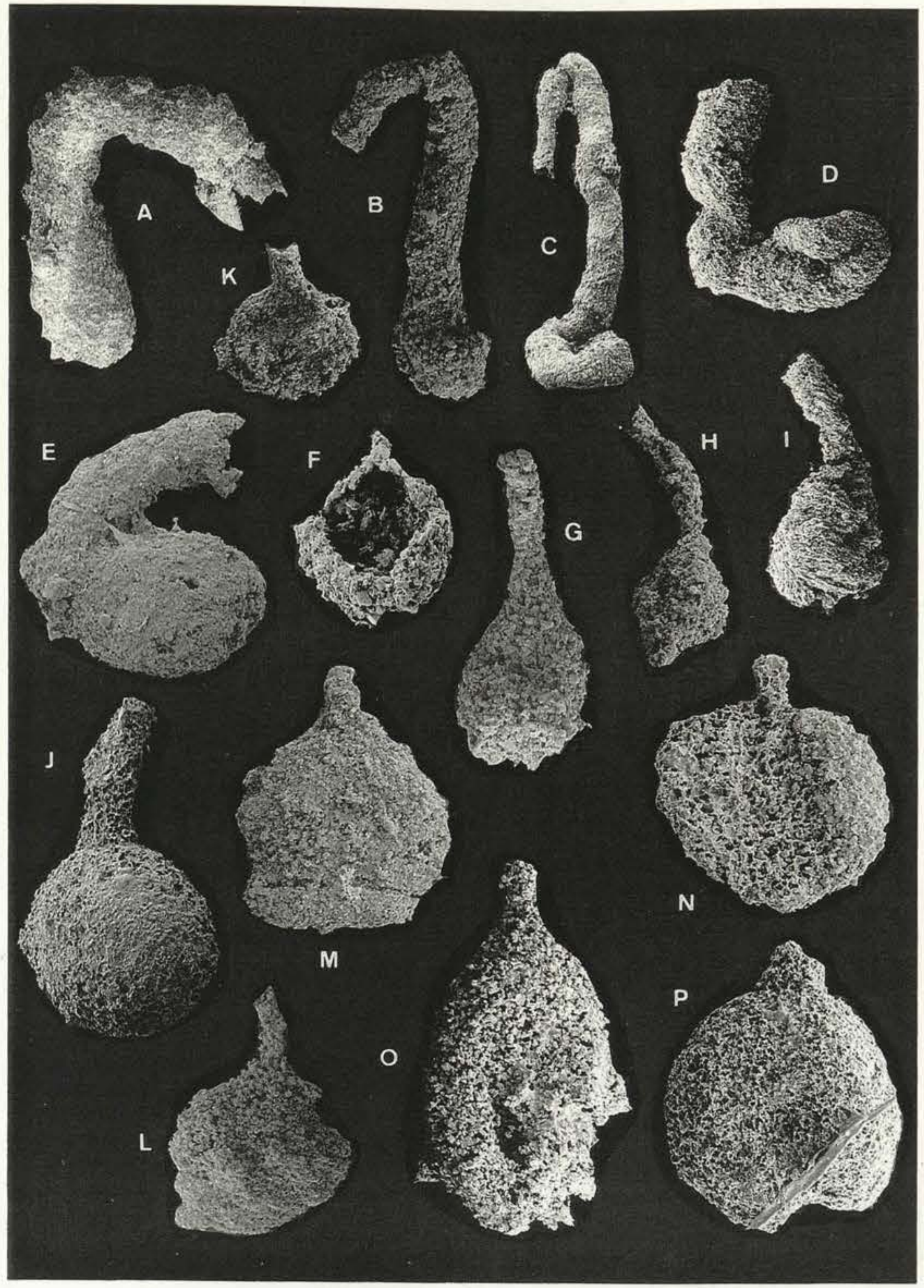


Plate 5 A, *Lagenammina laxacolla* Bell, Paratype NMV P199424, x90, Ma 13; note abapertural spine. B – C, *Pelosina grandaeva* Bell. B, Holotype NMV P126976, x135, ORCQ 10-15. C, Paratype NMV P126999, x59, Ma 13. D – E, *Thurammina echinata* Dunn. D, NMV P126977, x90, OTRC 7.E, NMV P126978, x72, BON 36-39. F, *Thurammina foesteri* Dunn, NMV P 126981, x72, ORCQ 10-15. G, *Thurammina subsphaerica* Moreman, NMV P126979, x72, BON 13.5-15. H, *Thurammina tributa* Dunn, NMV P126980, x108, BON 39-44. I – K, *Amphitremoida eisenacki* Conkin & Conkin. I, NMV P127000, x72, BON 36-39. J, NMV P127001, x126, BON 13.5-15. K, NMV P199434, x135, ORCQ 10-15. L – M, *Patellammina prona* Bell. L, Holotype NMV P126985, x54, BON 220-240. M, Paratype NMV P126998, x63, BON 220-240. N, *Hemisphaerammina crassa* Bell, Holotype NMV P199599, x126, OTRC 7.

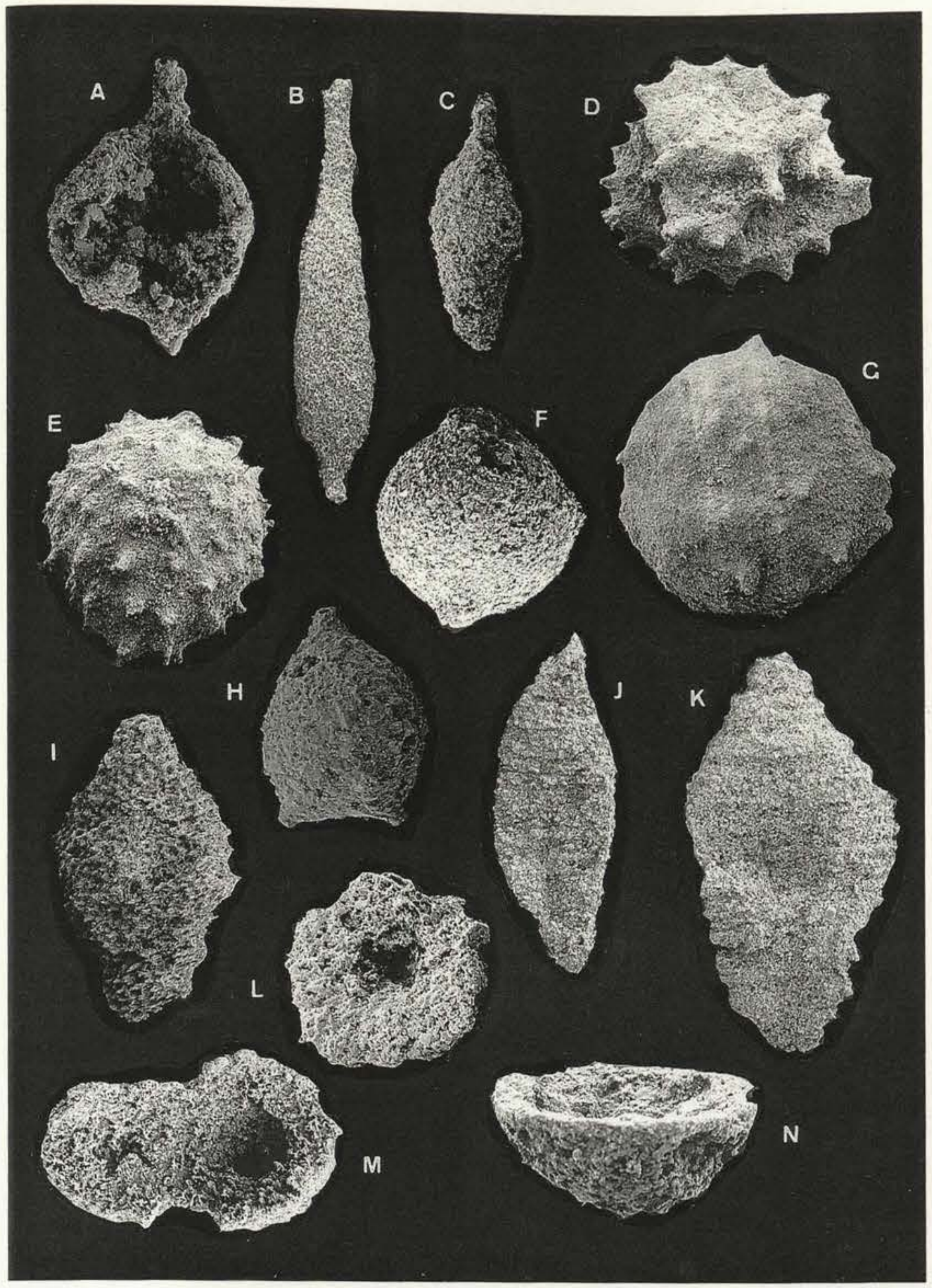


Plate 6 A – D, *Stomasphaera cyclops* Bell. A, Holotype NMV P126977, x72, BON 220-240. B, close-up of aperture of Holotype, x180. C. Paratype NMV P199432, x54, BON 220-240. D, close-up of aperture pf paratype, x180. E, *Metamorphina tholus* (Moreman), NMV P126984, x72, BON 13.5-15. F, *Thurammina zaramama* Bell, Holotype NMV P126974, x72, Ma 13. G, *Reophax troca* Bell, Holotype NMV P126993, x126, OTRC 7. H. *Lituotuba torquata* Bell, Holotype NMV P126990, x126, OTRC 7.I, *Lituotuba helix* Bell, Holotype NMV P126991, x72, OTRC 5. J, *Hormosina divitiae* Bell, Holotype NMV P126992, x72, BON 220-240. K – M, *Kerionammina prolata* Bell. K, Holotype NMV P126986, x117, ORCQ 10-15. L, Paratype NMV P199597, x180, ORCQ 10-15, showing internal longitudinal walls. M, close-up of paratype, arrows indicating transverse partitions between longitudinal walls, x540.

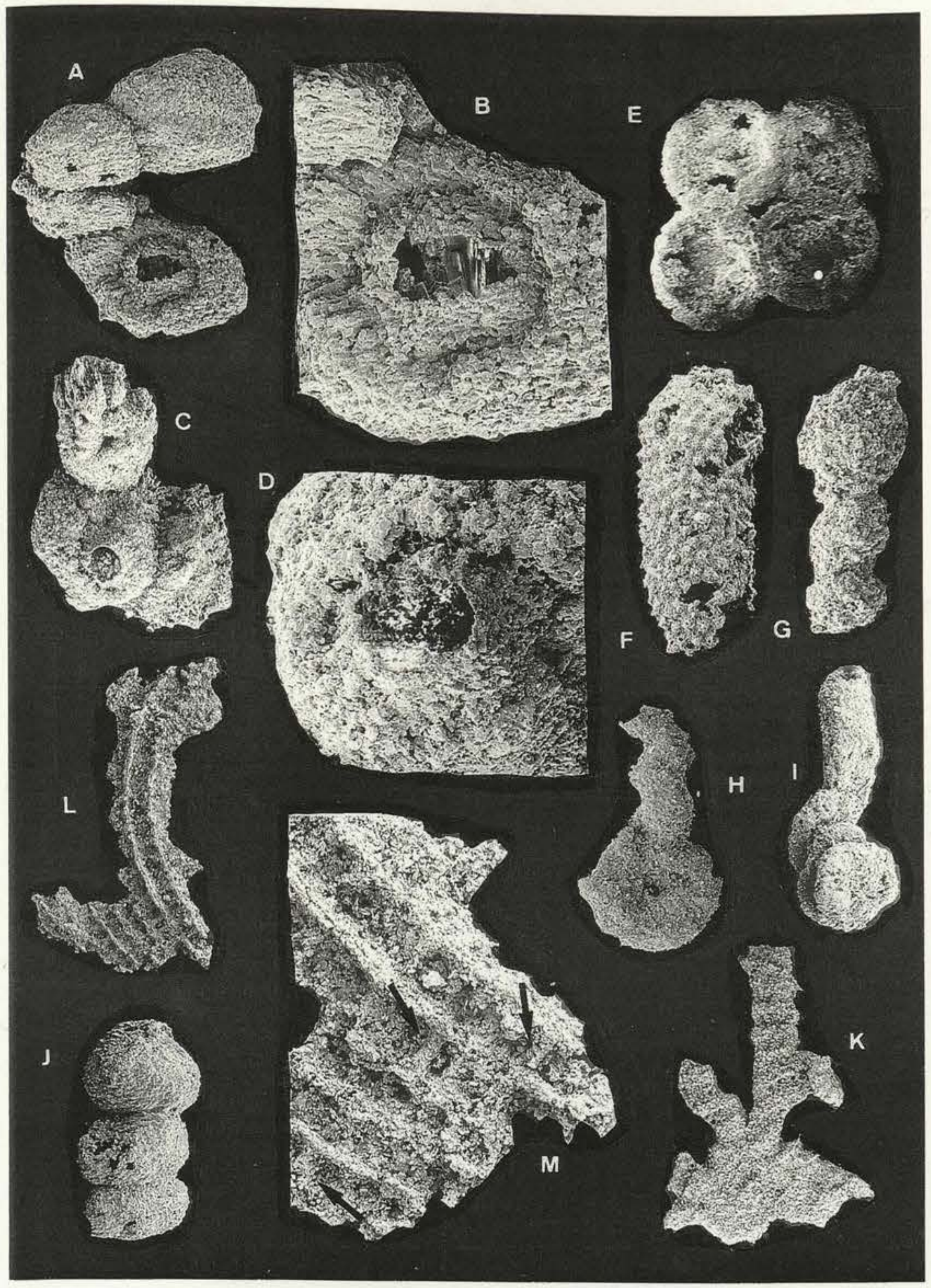


Plate 7 A – B, *Tolypammina anguinea* Bell. A, Holotype NMV P126988, x180, ORCQ 10-15, attached side view. B, Paratype NMV P199427, x72, ORCQ 10-15, dorsal view. C – E, *Tolypammina tantula* Bell. C, Paratype NMV P199903, x63, BON 29-35, attached surface view. D, Holotype NMV P126995, x 54, BON 13.5-15, dorsal view. E, Paratype NMV P199902, x72, BON 13.5-15, dorsal view. F – I, *Ammovertella calyx* Bell. F, Holotype NMV P126989, x180, BON 13.5-15, attached surface view. G, Paratype NMV P199429, x90, BON 13.5-15, dorsal view. H, Paratype NMV P199430, x135, BON 13.5-15, attached surface view. I, Paratype NMV P199901, x270, BON 13.5-15, attached surface view, arrow indicates double wall. J – K, *Webbinelloidea crassus* Bell. J, Holotype NMV P126983, x110, BON 206, oblique view of attached surface. K, Paratype NMV P199900, x90, oblique view of attached surface, arrow indicates small attachment aperture. L, *Thuramminoides sphaeroidalis* Plummer, NMV P126987, x54, OTRC 7.

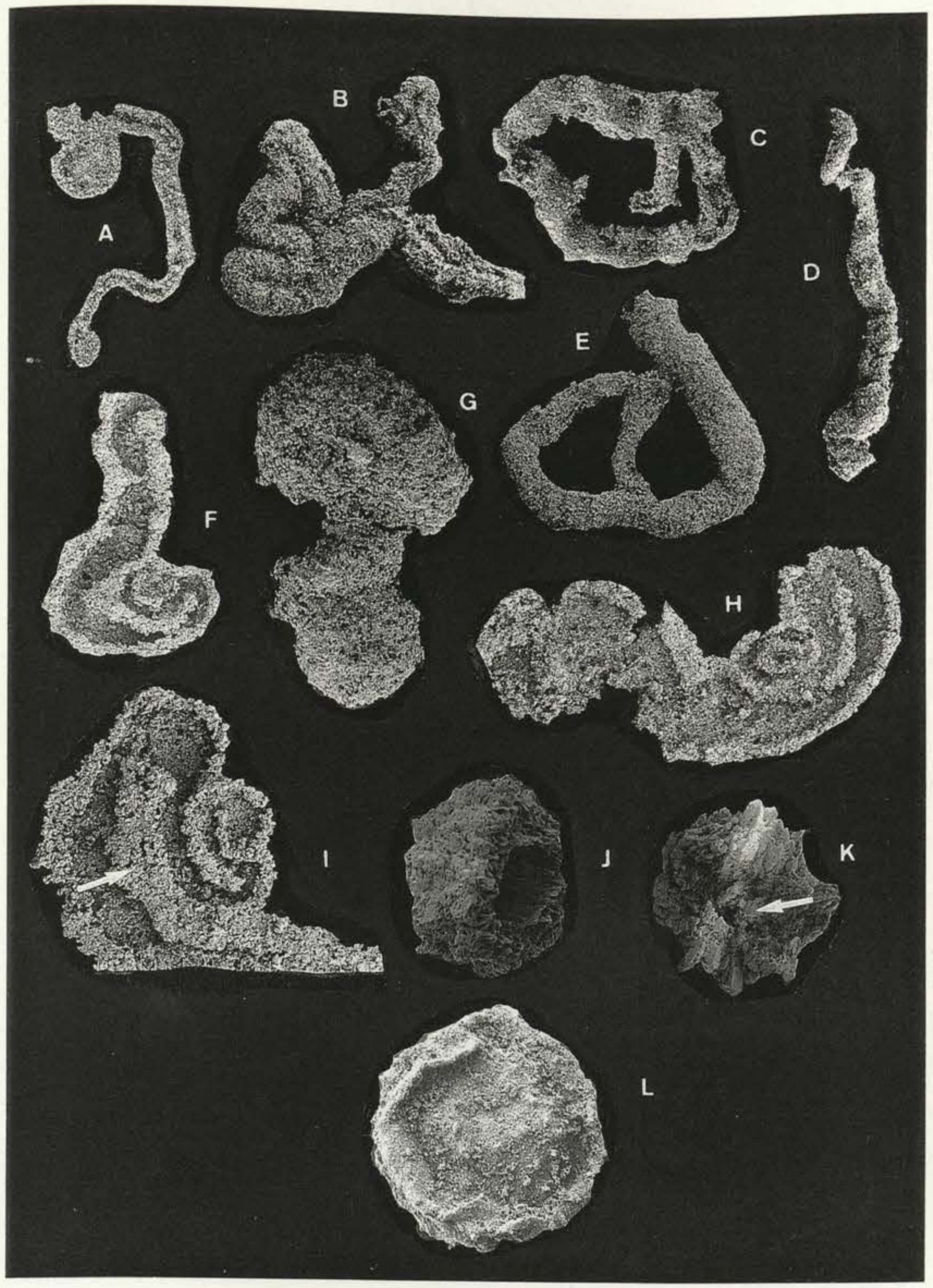


Plate 8 1–5, *Hyperammina* spp. 1, sample GCR 38, x150, AMF87205. 2, sample MUNG 24.8, x150, AMF87206. 3, sample GCR 53.7, x200, AMF87207. 4, sample GCR 38, x200, AMF87208. 5, sample GCR 38, x200, AMF87209. 6, *Sorosphaera* sp. cf. *S. confusa*. Sample MUNG 76.2, x300, AMF87210. 7, 9, 14, *Psammosphaera cava*. 7, sample MN 13.7, x400, AMF8721; 9, sample GCR 50.2, x300, AMF87213; 14, sample GCR 479.6, x350, AMF87216. 8, 10-13, *Psammosphaera garraay*. 8, sample RUN 44.4, x400, AMF87212. 10, sample MUNG 24,8, x400, AMF87214. 11, enlargement of surface and attachment scar of 10, x1150. 12. sample MUNG 24.8, x400, AMF87215; 13, enlargement of surface and attachment scar of 12, x800.

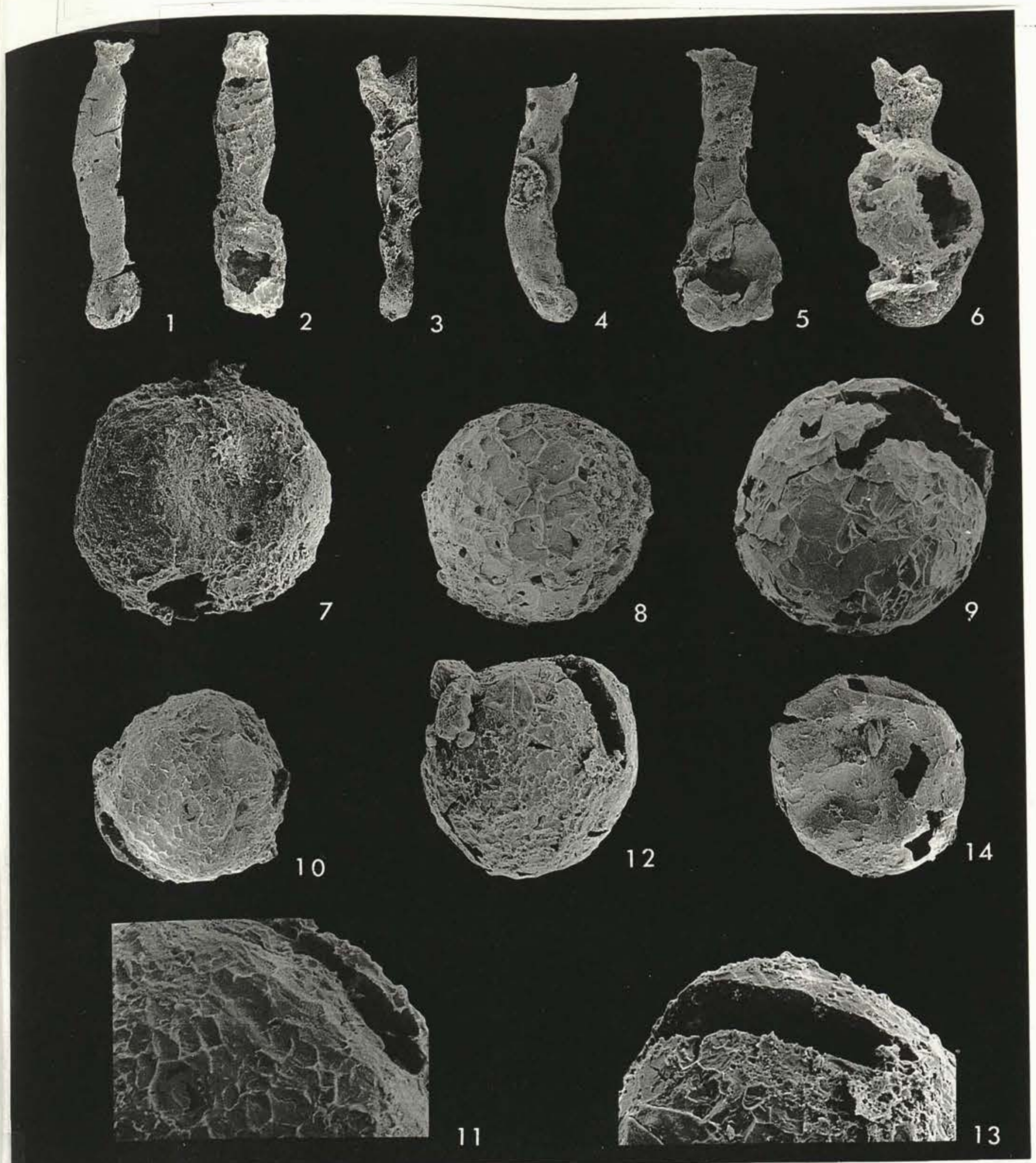


Plate 9 1–6, *Saccammina* spp. 1, sample RUN 70.6, x400, AMF87217. 2, sample GCR 412.2, x400, AMF87218. 3, sample GCR 412.2, x300, AMF87219. 4, sample RUN 85.7, x400, AMF 87220, arrow points to apertural pores. 5, sample GCR 50.2, x300, AMF87221. 6, enlargementof aperture of Fig. 3, x1100. 7–8, *Reophanus proavitus* n. sp. 7, sample GCR 105, x180, AMF87222. 8, sample GCR 290.9, x200, AMF87223. 9–11, Miscellaneous tubes. 9, sample RUN 85.7, x200, AMF87224. 10, sample MUNG 24.8, x150, AMF87225. 11, enlargement of wall of Fig. 10 showing ribbing, x500. 12–13, *Tolypammina* sp. 12, sample RUN 44.4, x150, AMF87226. 13, sample GCR 53.7, x120, AMF87227. 14–16, *Amphitremoida* sp. cf. *A. citroniforma*. 14, sample GCR 74.3, x200, AMF87228. 15, sample RUN 70.6, x250, AMF87229. 16, enlargement of wall of Fig. 15, x1200.

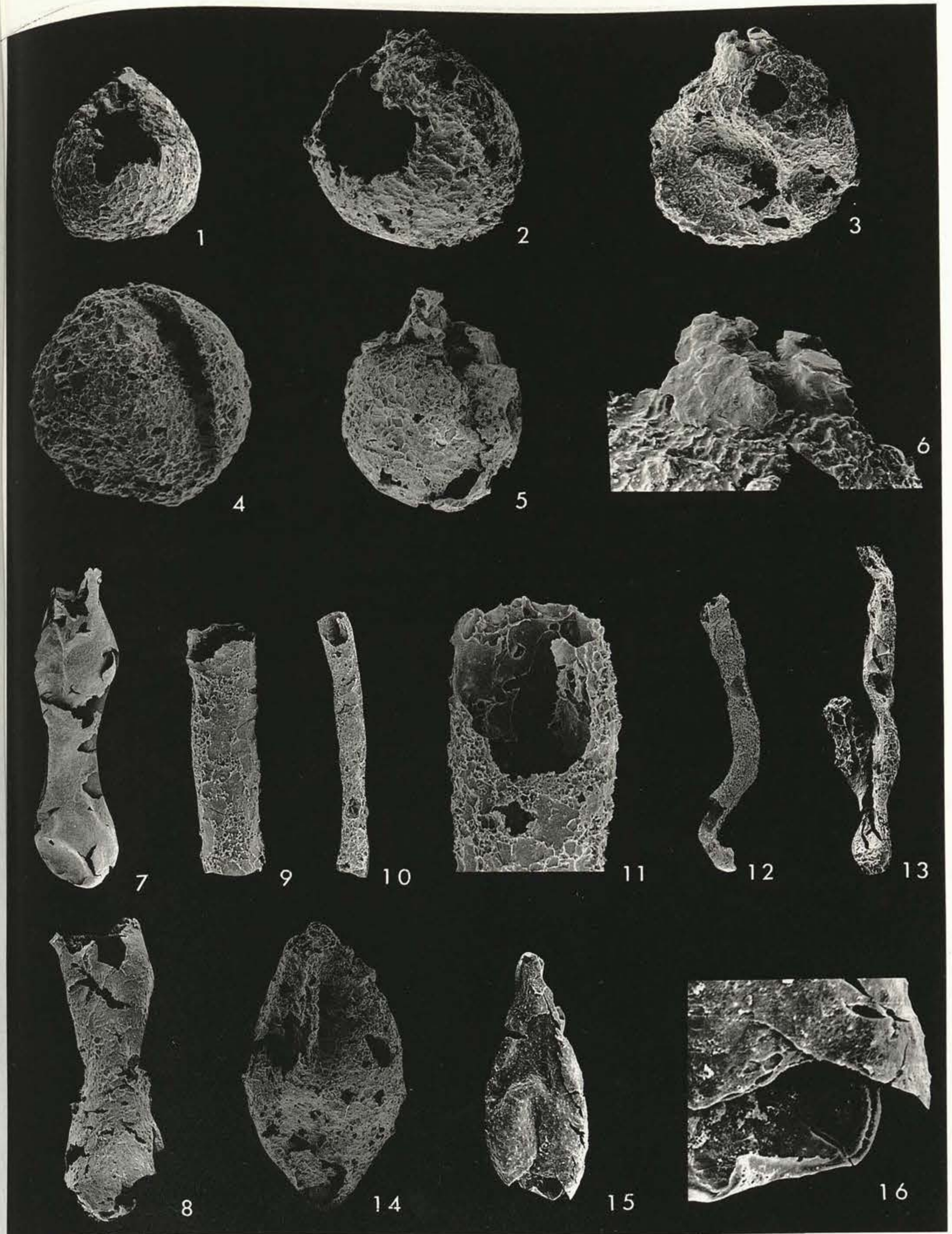


Plate 10 1–3, *Thurammina* sp. cf. *T. subspherica.* 1, sample MW 34.4, x400, AMF87230. 2, enlargement of fig. 1, x900. 3, sample GCR 37, x300, AMF87231, arrows point to apertural pores. 4, 5, *Lagenammina* sp. 4, sample GCR 117.3, x300, AMF87232. 5, sample MUNG 8.4, x300, AMF87233. 6, 8, *Hemisphaerammina* sp. 6, sample MUNG 8.4, x400, AMF87234; 8, sample RUN 199.3, x200, AMF87236. 7, *Hemisphaerammina coolamon* n.sp. Sample MUNG 24.8, x400, AMF87235.

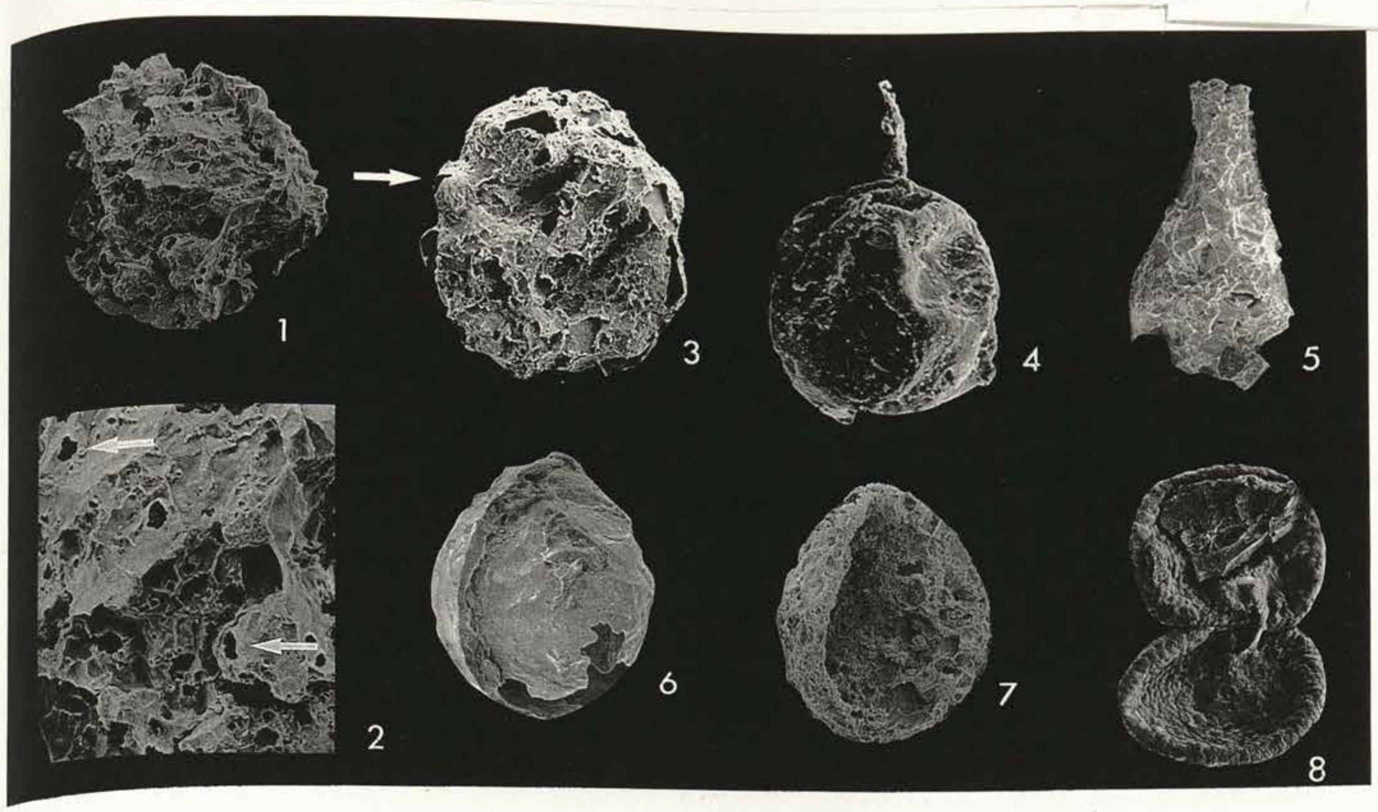


Plate 11 **Fig.1.** *Inaurus tubulata* Conkin, Conkin & Thurman, 1979, AMF102639, MSh. 1, (x300) .**Figs 2-3.** *Psammosphaera cava* Moreman, 1930: **fig. 2,** AMF102640, GCR 37, (x300); **fig. 3,** AMF102641, GCR 117.3, (x450). **Figs. 4-6, 8.** *Psammosphaera garraay* sp. nov.: **fig. 4,** Paratype, AMF102642, GCR 37, (x400); **fig. 5,** Paratype, AMF102643, RUN 76.6, (x350); **fig. 6,** Paratype, AMF102644, GCR 605, (x400); **fig. 8,** Paratype, AMF102646, MUNG 24.8, (x400). **Fig. 7.** *Psammosphaera* sp. D, AMF102645, MUNG 76.2, (x400). **Fig. 9.** *Sorosphaera* sp. cf. *S. confusa* Brady, 1879, AMF102647, Gel. Rd. 11T/81.7, (x300). **Figs. 10-11.** *Amphitremoida* sp. cf. *A. citroniforma* Eisenack, 1938: **fig. 10,** AMF102648, KG 1, (x150); **fig. 11,** AMF102649, MUNG 24.8, (x400).

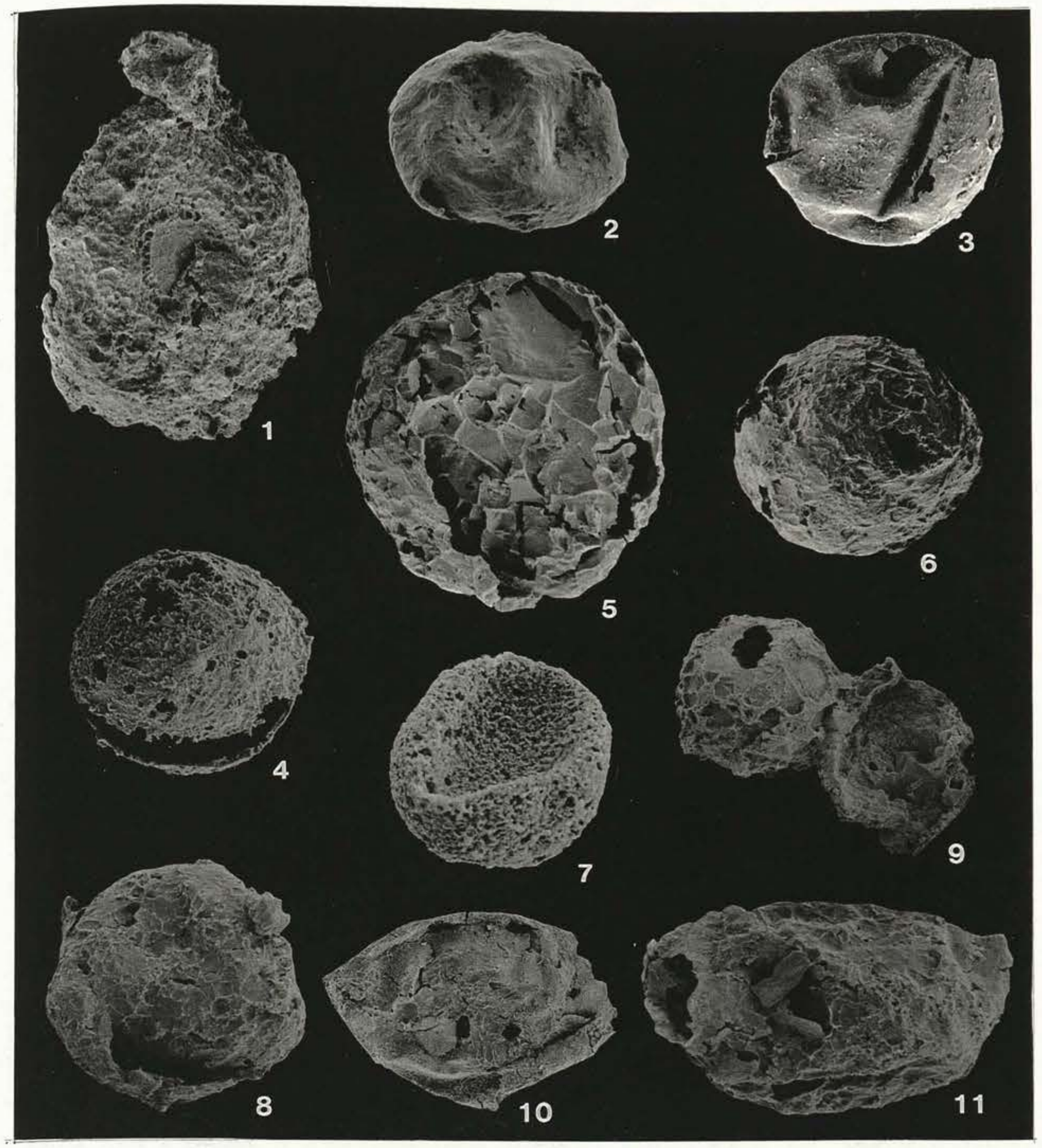


Plate 12 **Figs 1-2.** *Lagenammina ovata* Bell, 1996: **fig. 1,** AMF102650 , KG 17, (x350); **fig.2,** AMF102651, KG 17, (x450). **Figs 3-5.** *Lagenammina* sp: **fig. 3,** AMF102652, GCR 262, (x500); **fig. 4,** AMF102653, MUNG 24.8, (350); **fig. 5,** enlargement of fig. 4, (x700). **Figs 6-9.** *Saccammina mea* sp. nov.:**fig. 6,** enlargement of fig. 7, (x1500); **fig. 7,** Paratype, AMF102654, MUNG 24.8, (x400); **fig. 8,** Paratype, AMF102655, GCR 106, (x400); **fig. 9,** Holotype, AMF102656, RUN 44.4, (x450). **Figs 10-11.** *Saccammina* sp: **fig. 10,** AMF102657, RUN 207, (x400); **fig. 11,** AMF102658, BOO 13.1, (x400). **Figs 12-14.** *Saccammina wingarri* sp. nov.: **fig.12,** Holotype, AMF102659, PD 166 388.4, (x400); **fig. 13,** Paratype, AMF102660, LSA 113, (x400); **fig. 14,** enlargement of neck of Holotype, (x1400). **Fig. 15,** *Saccammina* sp. cf. *S. ampullacea* (Crespin, 1961), AMF102661, MUNG 8.4, (x350).

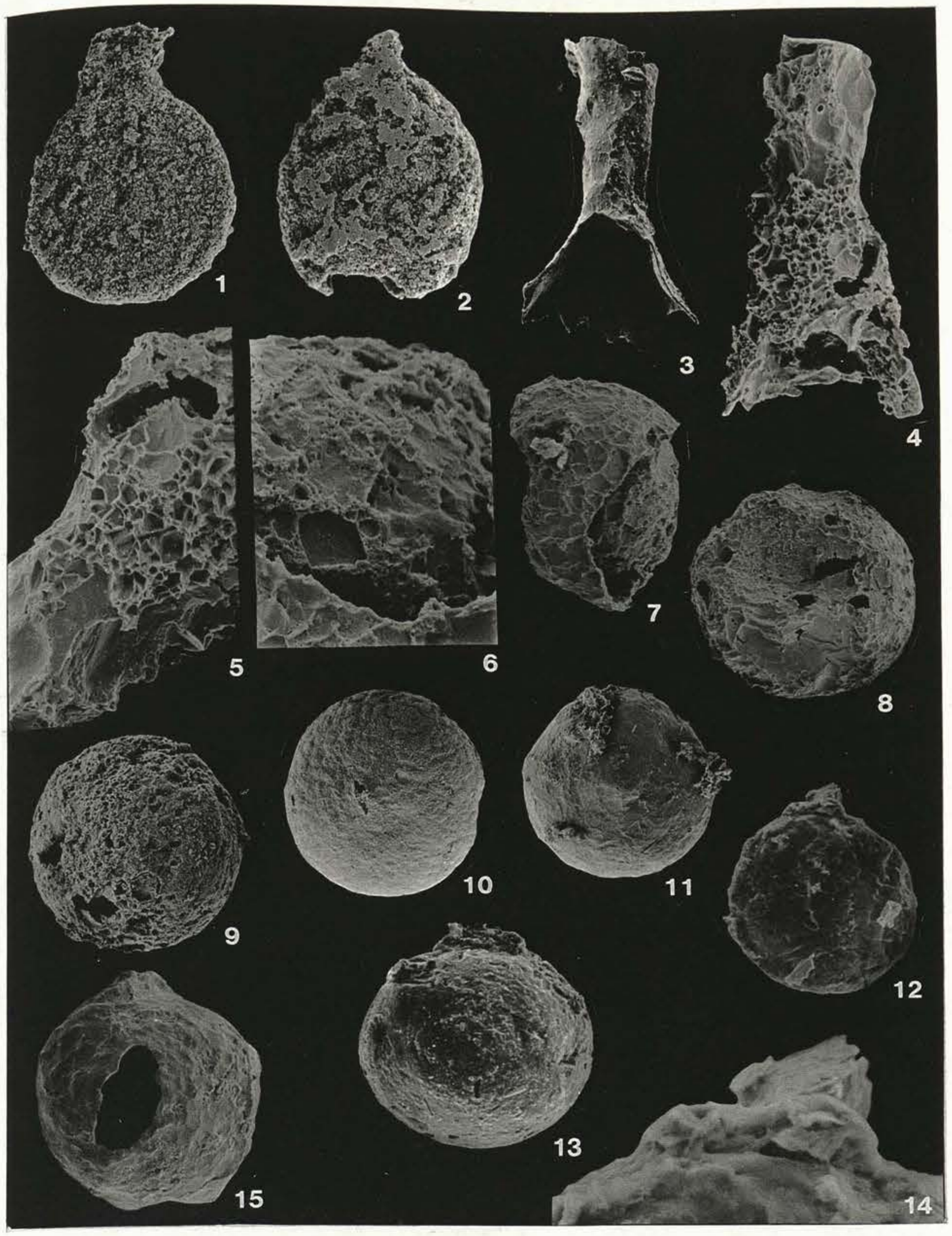
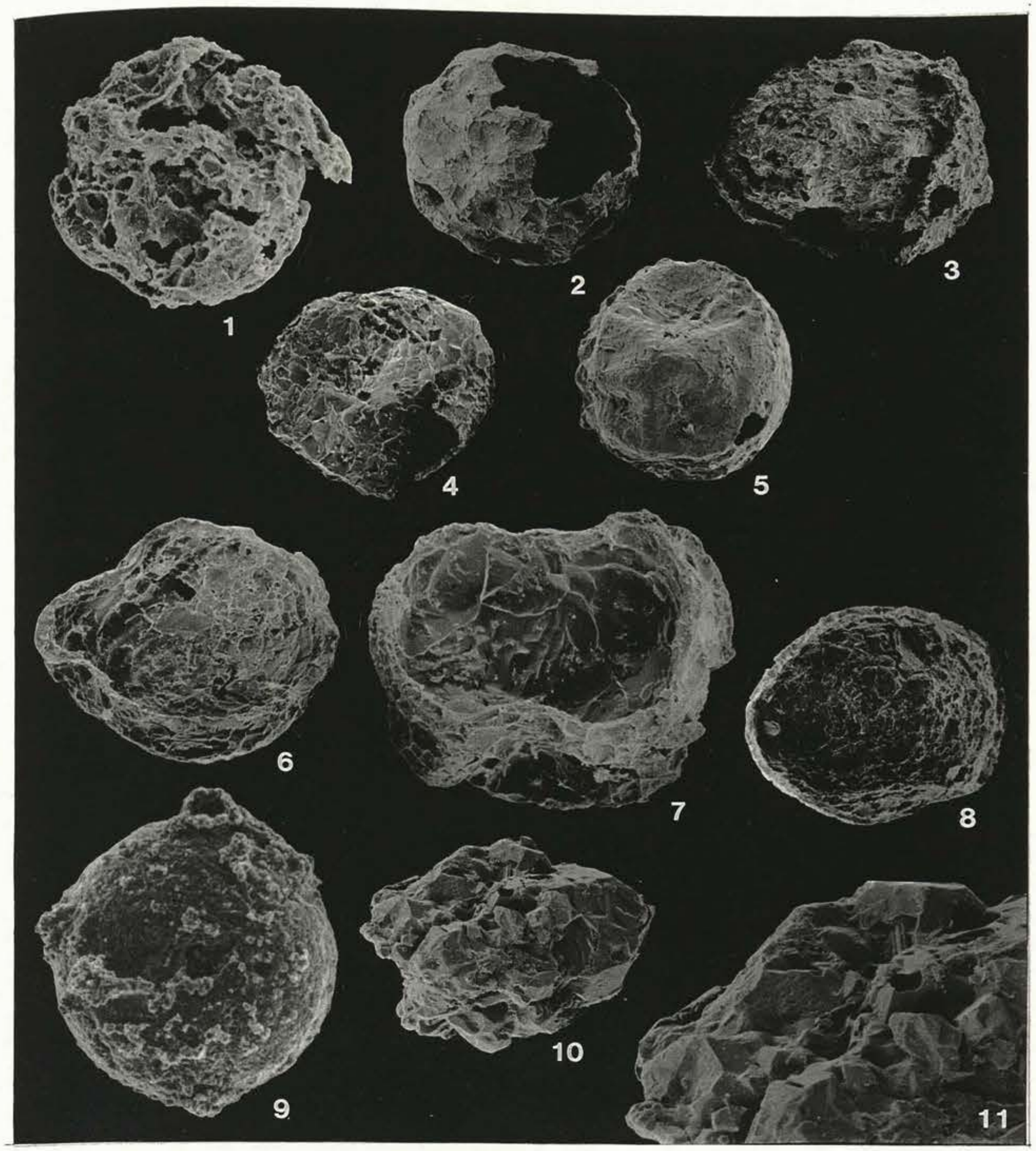


Plate 13 **Fig. 1.** *Thurammina* sp. cf. *T. subsphaerica* Moreman, 1930: AMF102662, MUNG 71.5, (x350). **Figs 2-3.** *Thurammina mirrka* sp. nov.: **fig. 2,** Paratype, AMF102663, GCR 401.8,(x300); **fig. 3,** Holotype, AMF102664, GCR 412.2, (x400). **Fig. 4.** *Thurammina* sp. cf. *T. arcuata* Moreman, 1930, AMF102665, GCR 37, (x350). **Fig. 5**. *Hemisphaerammina* sp, AMF102666, GCR 117.3, (x350). **Figs 6-8.** *Hemisphaerammina coolamon* sp. nov.: **fig. 6,** Paratype, AMF102667, MUNG 24.8, (x400); **fig. 7,** Holotype, AMF102668, MUNG 6.3, (x400); **fig. 8,** Paratype, AMF 102669, MUNG 24.8, (x350). **Fig. 9**. *Thurammina quadritubulata* Dunn, 1942, AMF102670, LSC 1.6m below 12b, (x400). **Figs 10-11.** *Thurammina* sp.: **fig. 10,** AMF102671, MW 13.7, (x400);**fig. 11,** enlargement of fig. 10, (x900).



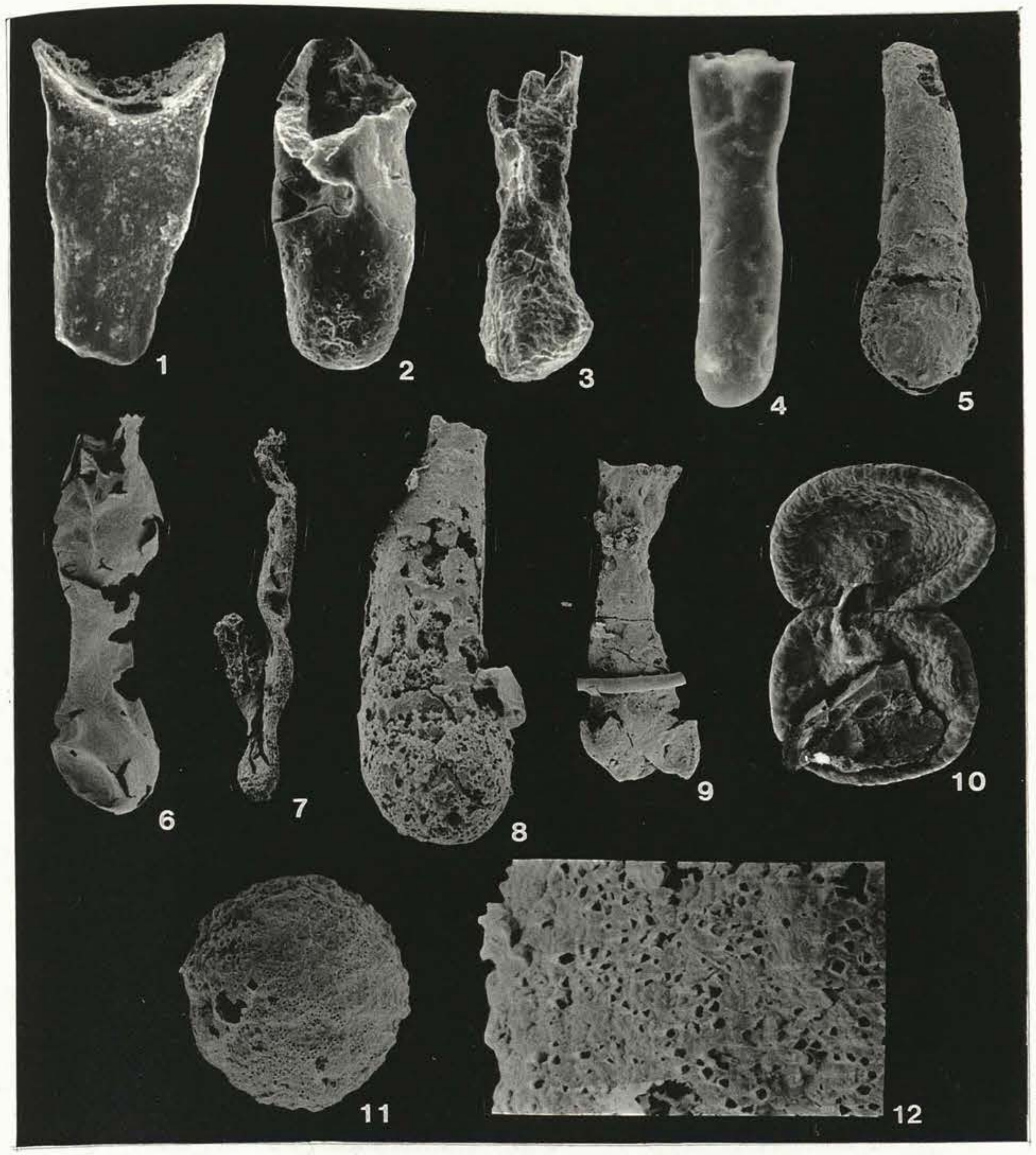


Plate 14 **Figs 1-5.** *Hyperammina* sp. cf. *H. sappingtonensis* Gutschick, 1962: **fig.1,** AMF102672, MSh 2, (x400); **fig. 2,** AMF102673, Pt. Hibbs 68669, (x400); **fig.3,** AMF102674, MSh 2, (x400); **fig. 4,** AMF102674, KE100 Hi 448.51, (x300); **fig. 5,** AMF102676, MW 39.9, (x300). **Fig. 6,** *Reophanus proavitus* sp. nov., Holotype, AMF102677, GCR 105, (x200). **Fig. 7.** *Tolypammina tantula* Bell, 1996, AMF102678, GCR 53.7, (x120). **Figs 8-9.** *Hyperammina devoniana* Crespin, 1961: **fig.8,** AMF102679, MW 39.9, (x300); **fig. 9,** AMF102680, GCR 38, (x200). **Fig. 10.** *Webbinelloidea similis* Stewart & Lampe, 1947, AMF102681, RUN 199.3, (x300). **Figs 11-12.** Gen. et sp. indet., **fig. 11,** AMF102682, 16T/65.0, (x450); **fig. 12,** enlargement of fig. 11, (x2000).

Plate 15 A, *Inauris tubulata* Conkin, Conkin & Thurman, AMF 105180; 0217 Glenrock, x300; B-C, *Psammosphaera cava* Moreman: B, AMF 105181; DDH2 55.9m, x 475; C, AMF 105182; DDH2 66.2m, x450; D-E, *Psammosphaera* sp. A, AMF 105183; Mostyn Vale: D, x 350; E, x900; F-G, *Psammosphaera* sp. B: F, AMF 105184; OKE 112, x500; G, AMF 105185; OKE 0.9, x 475; H-J, ?*Psammosphaera* sp. C: H, AMF 105186; TIM 17.5, x 300; I-J, AMF 105187; Isis below Timor, I x400, J x1200.

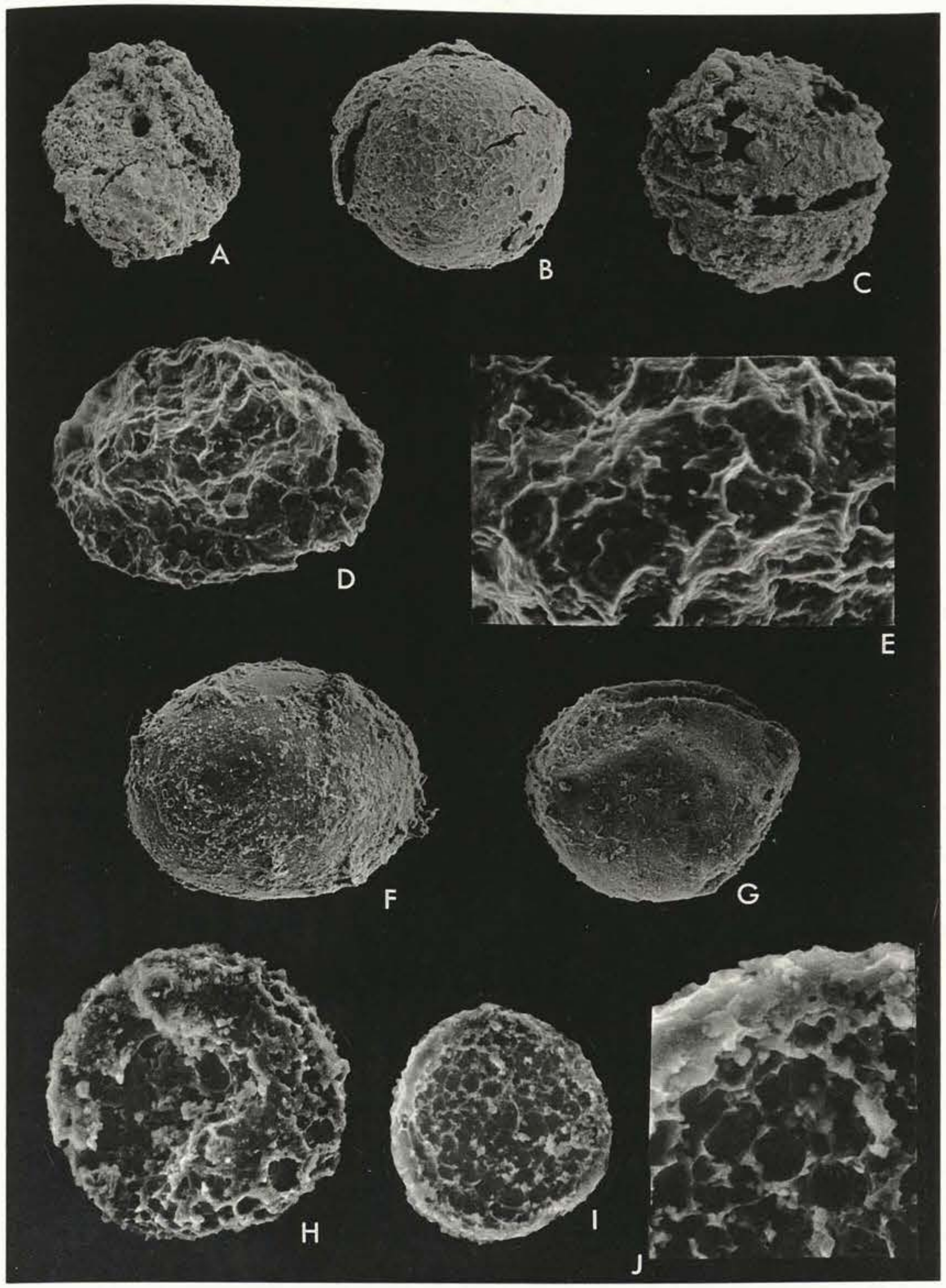


Plate 16 A-F, *Saccammina mea* Bell & Winchester-Seeto: A, AMF 105188; OKE 0.9, x475; B-C, AMF 105189; DDH2 55.9m, B x400, C x1100; D-E, AMF 105190; TIM 18.9, D x600, E x350; F, AMF 105191; DDH2 55.9m, x 300; G, gen.et sp. indet., AMF 105192; TIM 18.9, x360; H, *Saccammina* sp. cf. *S. ampullacea* (Crespin), AMF 105193; TIM 18.9, x300; I-K, *Saccammina wingarri* Bell & Winchester-Seeto: I, AMF 105194; Mostyn Vale, x 450; J-K, AMF 105195, J x300, K x650.

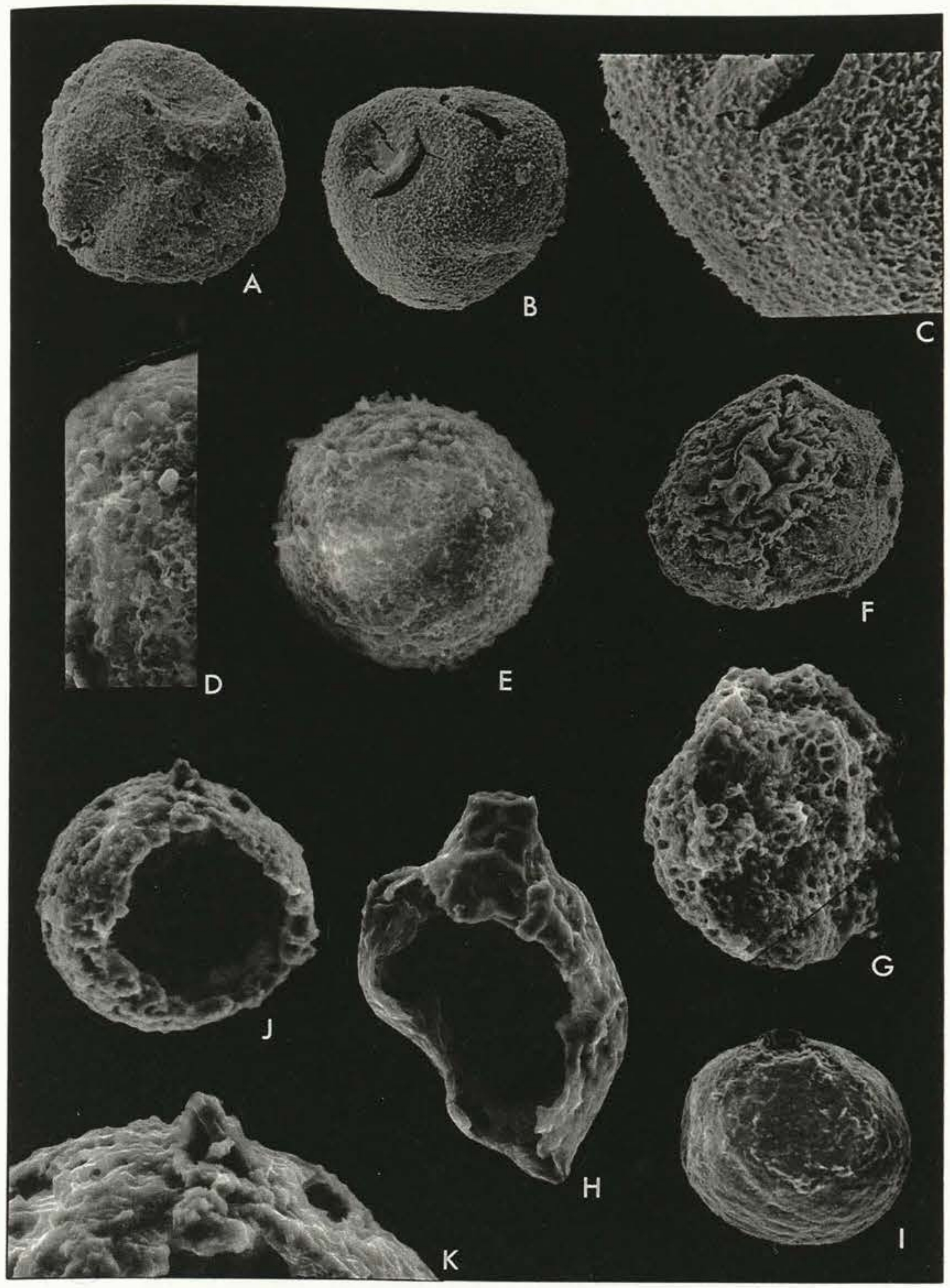


Plate 17 A-C, *Thuramminoides sphaeroidalis* Plummer: A, AMF 105196; DDH2 73m, x450; B-C, AMF 105197; DDH2 55.9m, B x375, C x1100; D-E, *Pelosina* sp.: D, AMF 105198; Isis below Timor, x250; E, AMF 105199; Isis below Timor, x250; F, *Thurammina mirrka* Bell & Winchester-Seeto, AMF 105200; 0217 Glenrock, x400; G-H, *Thurammina pustulosa* Gutschick, Weiner & Young: G, AMF 105201; Mostyn Vale, x350; H, AMF 105202; Mostyn Vale, x400; I-K, *Thurammina* sp. cf. *T. subsphaerica* Moreman: I, AMF 105203; Kiah Limestone, x350; J-K, AMF 105204; Isis below Timor, J x425, K x900.

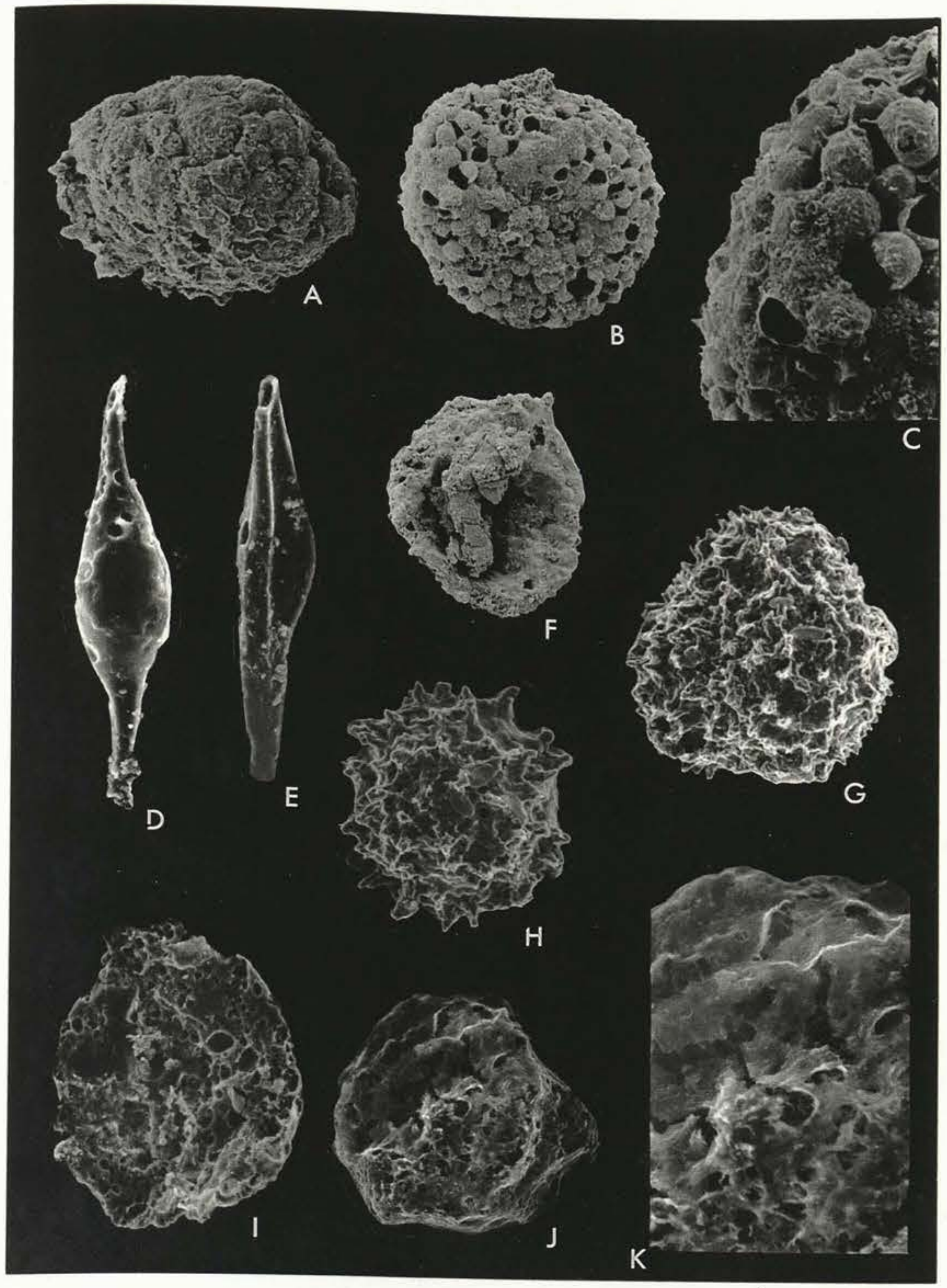


Plate 18. A – D, *Serpenulina uralica* Tschernick. A, Figd. spec. NMV P208019, x 30, Q7. B, Figd. spec. NMV P208020, x 30, Q7. C, Figd. spec. NMV P208021, x 30, Q7. D, Figd. spec. NMV P208022, x 20, Q7, showing multichambered aperture, arrows indicate intercameral apertures. E – F, *Serpenulina aulax* n. sp. E, Holotype NMV P208023, x 25, Q 7. F, Paratype NMV P208024, x 15, Q7. G – H, *Ammovolummina bostryx* n. sp. G, Holotype NMV P208025, x 30, Q7. H, Paratype NMV P208026, x 25, Q7. I – K, *Trochammina* sp. I, Figured specimen NMV P208027, x 130, YAR6/126. J, Figured specimen NMV P208028, x 130, YAR6/126. K, , Figured specimen NMV P208029, x 130, YAR6/126.

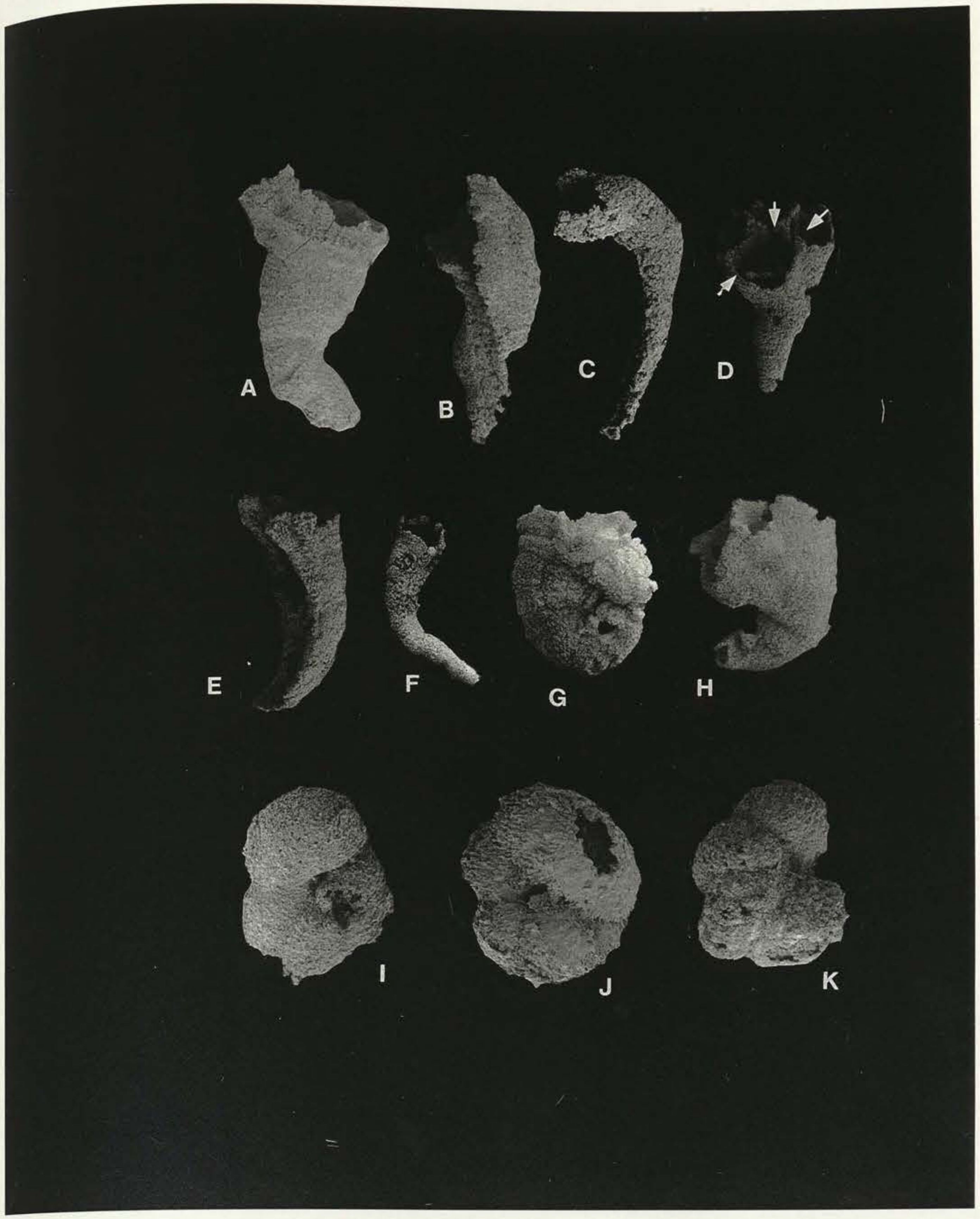


Plate 19. A – B, *Pelosina* sp. A, Figured specimen NMV P208030, x 55, YAR6/126. B, Figured specimen NMV P208031, x 52, YAR6/126. C – D, *Bathysiphon* sp., C, closeup of epizoan on Figured specimen NMV P208032, x 110. D, Figured specimen NMV P208032, x 15, QU 166; arrow points at epizoan. E – G, *Semitextularia thomasi* Miller & Carmer. E, Figured specimen NMV P208033, x 90, D&P B. F, Figured specimen NMV P208034, x 130, D&P B. G, Figured specimen NMV P208035, x 80, D&P B. H – M, *Nanicella* sp. H, Figured specimen NMV P208036, x 60, TIM 36.6. I, Figured specimen NMV P208037, x 80, TIM 36.6. J, Figured specimen NMV P208038, x 80, ISIS 2.2. K, Figured specimen NMV P208039, x 115, ISIS 2.2. L, Figured specimen NMV P208040, x 115, ISIS 2.2. M, Figured specimen NMV P208041, x 42, TIM 36.6.

Plate 20. A – C *Moravammina segmentata* Pokorný. A, Figured specimen NMV P208043, x 85, Tim 36.6 B, Figured specimen NMV P208044, x 85, TIM 36.6. C, Figured specimen NMV P208045, x 60, TIM 36.6. D, K – L, *Saccorhina trivirgulina* Bykova. D, Figured specimen NMV P208046, x 90, D&P B. K, Figured specimen NMV P208047, x 70, TIM 18.9. L, Figured specimen NMV P208048, x 80, TIM 18.9.

E –H, *Vermiculammina isis* n, gen, n. sp. E, Holotype NMV P208049, x 60, ISIS 2.2. F, Paratype NMV P208050, x 60, ISIS 2.2. G, Paratype NMV P208051, x 60, ISIS 2.2. H, Paratype NMV P208052, x 60, ISIS 2.2. I , *Rhabdammina* sp. A., Figured specimen NMV P208054, x 25, WERR 13. J, *Rhabdammina* sp. B., Figured specimen NMV P208055, x 25, WERR 13.

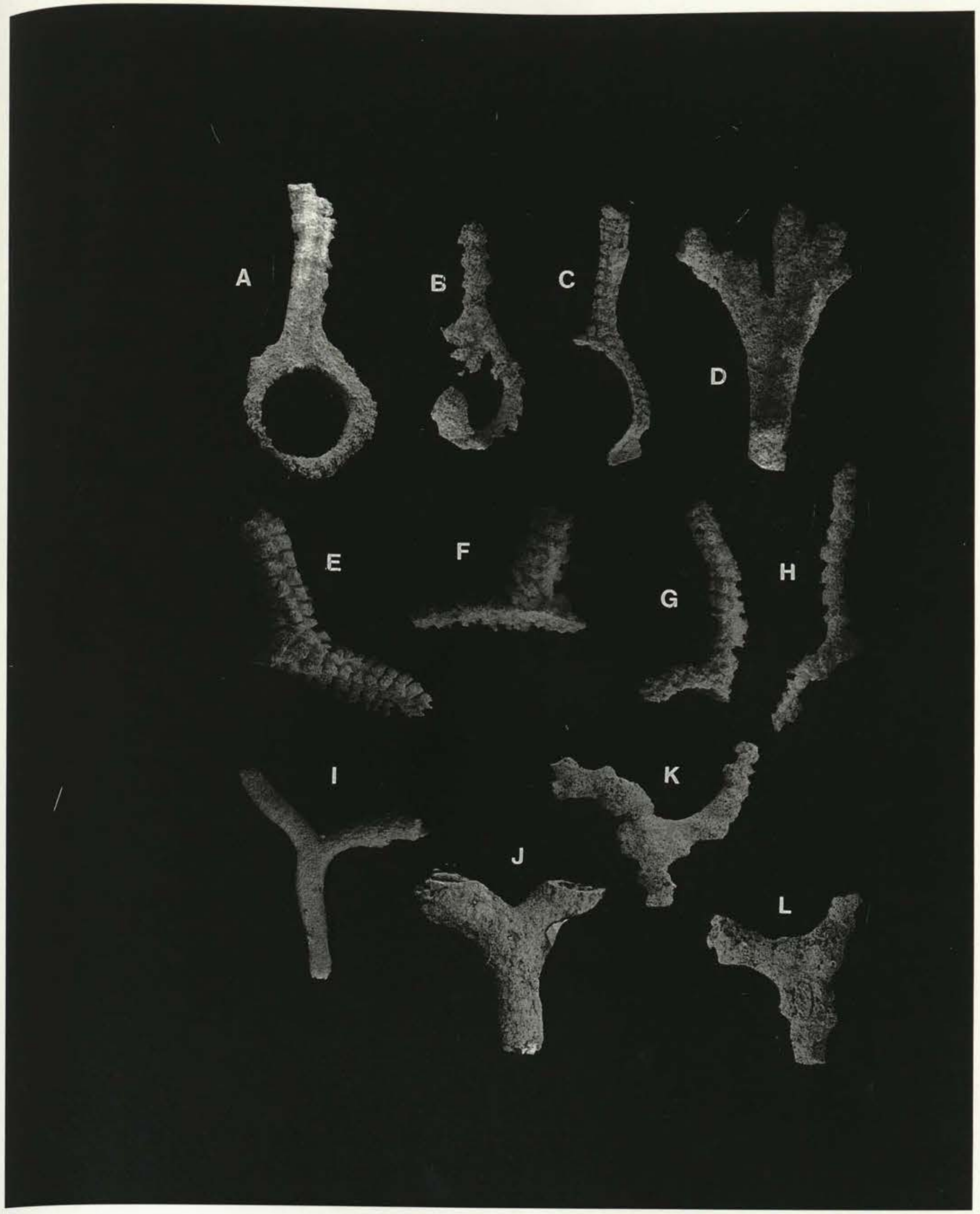


Plate 21. A – D, *Subbdelloidina spathula* n. sp. A, Holotype NMV P208056, x 65, YAR6/126. B, Paratype NMV P208057, x 65, YAR6/126. C, Paratype NMV P208058, x 72, YAR6/126. D, Paratype NMV P208059, x 60, YAR6/126. E – F, *Tikhinella* forma B. E, Figured specimen NMV P208060, x 60, TIM 18.9. F, Figured specimen NMV P208061, x 55, TIM 36.6. G, *Tikhinella* forma A, Figured specimen NMV P208062, x 140, D&P B. H – J, *Tikhinella* forma C. H, Figured specimen NMV P208063, x 150, D&P B. I, Figured specimen NMV P208064, x 80, ISIS 2.2. J, Figured specimen NMV P208065, x 100, D&P B. K, *Paracaligella* sp., Figured specimen NMV P208066, x 35, TIM 18.9. L – N, *Lucunammina* sp. L, Figured specimen NMV P208067, x 60, TIM 36.6. M, Figured specimen NMV P208052, x 70, TIM 69.9. N, Figured specimen NMV P208068, x 115, D&P B. O, *Tikhinella* forma E, Figured specimen NMV P208069, x 100, TIM 36.6.

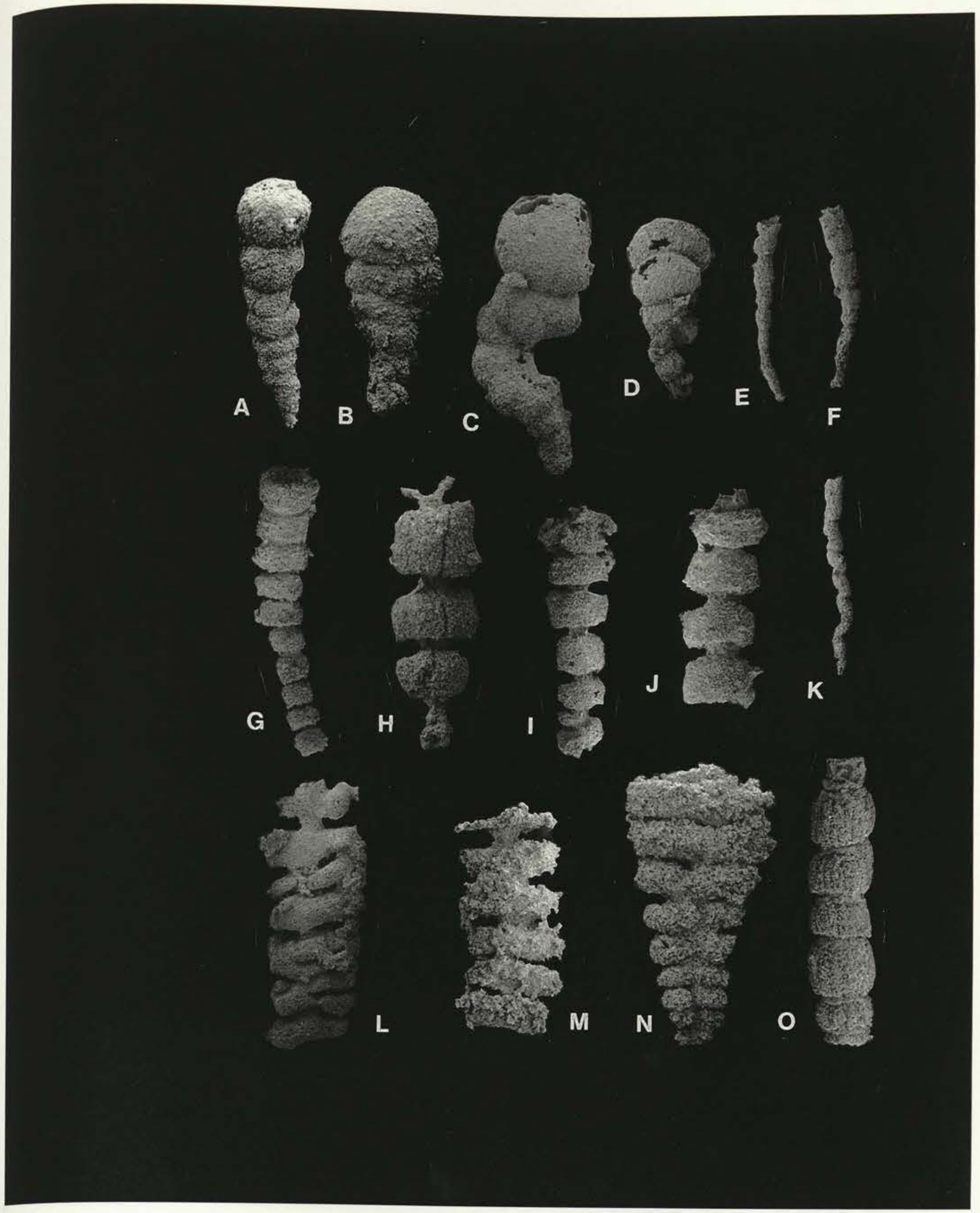


Plate 22. A – E *Hyperammina leptalea* n. sp. A, Holotype NMV P208072, x 60, DSC 230. B, closeup of proloculum of Holotype, x150. C, Paratype NMV P208073, x 80, DSC 230. D, Paratype NMV P208074, x 70, DSC 230. E, Paratype NMV P208075, x 65, DSC 230. F, G *Sorosphaera tricella* Moreman. F, Figured specimen NMV P208070, x 24, WERR 16.2. G, Figured specimen NMV P208071, x 24, QU 166. H, *Psammosphaera cava* Moreman, Figured specimen NMV P208076, x 130, DSC 230. I, *Psammosphaera aspera* Summerson, Figured specimen NMV P208077, x 24, QU 233. J, *Lituotuba exserta* Moreman., Figured specimen NMV P208078, WERR 16.2, x 400.