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Linings of agglutinated Foraminifera from the Devonian: taxonomic and biostratigraphic implications.

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ABSTRACT – 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 geographical 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. *J. Micropalaeontol.* **18(1)**: 27–43, June 1999.

INTRODUCTION

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 μm). We believe that such a term is unwarranted as foraminifera are now known to form part of the sub-63 μm fauna (Gooday, 1986a, b; Pawlowski, 1991) and Burnett (1979) refers to foraminifera of the 10–15 μm 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, 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 the selection of sections was the prospectivity for acid-resistant fossils. Many of the sections had also previously yielded conodonts, and strong, reliable stratigraphic control is already in place. Samples yielding foraminiferal linings 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. This is followed by acid digestion in 50–70% HF for 1–4 days. Nitric acid (concentrated) was used when necessary for surface etching, the dissolution of fluorite salts and the destruction of amorphous organic matter. The residue was then separated through a 53 μm sieve and the coarse fraction was picked with a micropipette. Well-preserved specimens were selected for examination by conventional scanning electron microscopy or with an environmental electroscanner; the advantages of the environmental electroscanner have been outlined by Winchester-Seeto (1993a).

LOCALITY INFORMATION

Early Devonian

The majority of foraminiferal linings were recovered from Lower 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 and 2), yielded the most specimens. It is characterized by grey to dark grey, 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 Wyatt & Jell, 1980; Winchester-Seeto, 1993c).

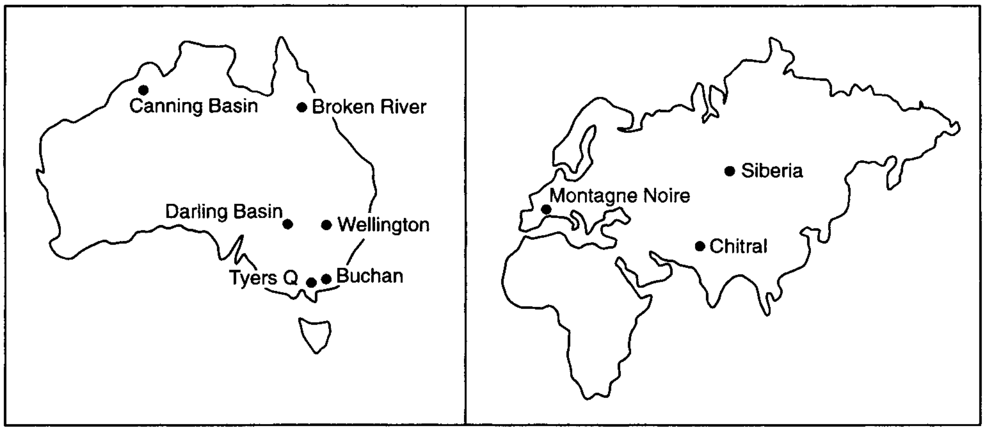


Fig. 1. Maps showing general position of localities investigated in this study.

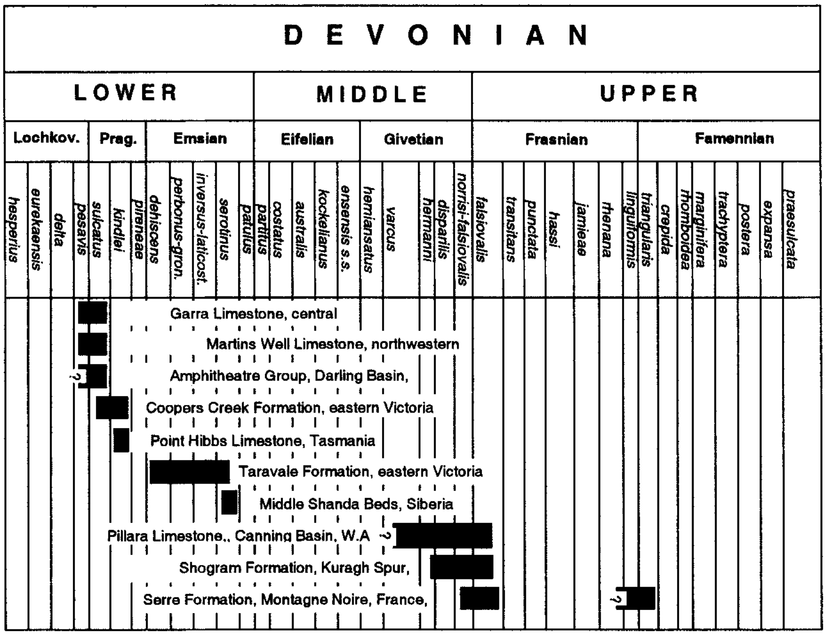


Fig. 2. Stratigraphic chart showing range of sections/bores detailed in this study, related to conodont zones.

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 grey to dark grey 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, unpubished 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 Rehfisch & Webb, 1993; Mawson & Talent, 1994).

Fossiliferous lime packstone characterizes the Point Hibbs Limestone, from Sanctuary Bay in southwestern Tasmania (Carey & Berry, 1988). The Sanctuary Bay section spans the *sulcatus–kindlei* conodont zones (Philip & Pedder, 1968; Winchester-Seeto, unpublished 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 358.4 m, 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 100 m 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 fairly 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 Late Devonian in age and in localities on three continents (see locality data). Although usually not of great abundance (about 10 per 50 g 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 — six of established species, seven compared with known species, six new species and five left in open nomenclature because of a 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 is undertaken in other parts of the world 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 (Heron-Allen, 1915; Petelin, 1970; Bender, 1995; 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.

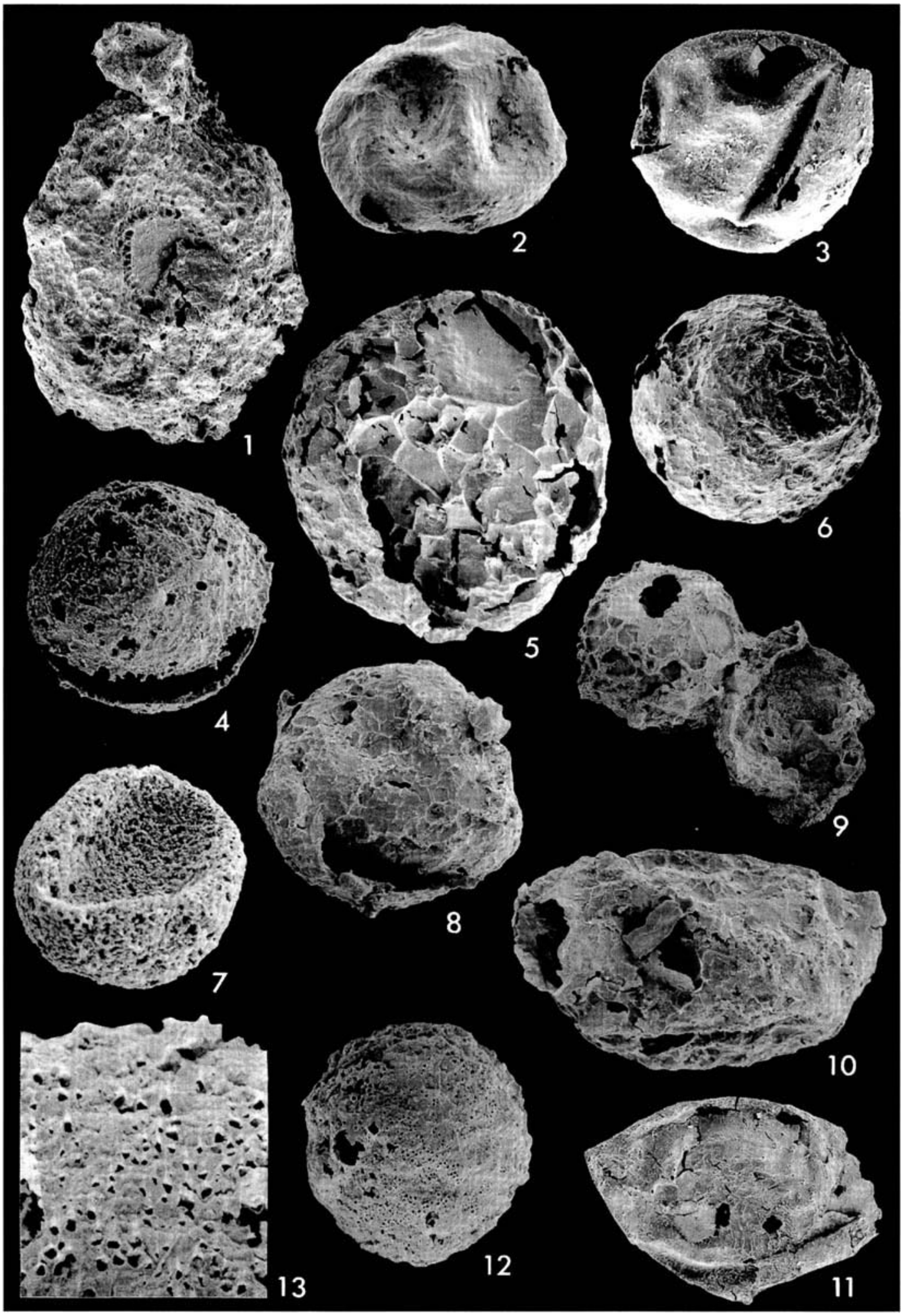
Thin sections of the sampled limestones and shales have proved of little use; the 'normal' foraminiferans are very rare and seldom found in thin section; and those that have been seen have no organic layer present, most likely due to the diagenetic changes in the often partly recrystallized sediments. 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 (Plate 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. (Plate 1, figs 12 and 13) 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 structures, wall thickness, number of apertures, all of which have previously been accepted as specific characters for normal-sized foraminiferans. Figure 3 lists the features used in



Explanation of Plate 1

fig.1. *Inaurus tubulata* Conkin, Conkin & Thurman, 1979, AMF102639, MSh. 1, ×300. **figs 2, 3**. *Psammosphaera cava* Moreman, 1930: **fig. 2**, AMF102640, GCR 37, ×300; **fig. 3**, AMF102641, GCR 117.3, ×450. **figs. 4–6, 8**. *Psammosphaera garraay* sp. nov.: **fig. 4**, paratype, AMF102642, GCR 37, ×400; **fig. 5**, paratype, AMF102643, RUN 76.6, ×350; **fig. 6**, paratype, AMF102644, GCR 605, ×400; **fig. 8**, paratype, AMF102646, MUNG 24.8, ×400. **fig. 7**. *Psammosphaera* sp., AMF102645, MUNG 76.2, ×400. **fig. 9**. *Sorosphaera* sp. cf. *S. confusa* Brady, 1879, AMF102647, Gel. Rd. 11T/81.7, ×300. **figs. 10, 11** .*Amphitremoida* sp. cf. *A. citroniforma* Eisenack, 1938: **fig. 10**, AMF102649, MUNG 24.8, ×400; **fig. 11**, AMF102648, KG 1 ×150. **figs 12, 13**. Gen. et sp. indet.; **fig. 12**, AMF102682, 16T/65.0, ×450; **fig. 13**, enlargement of fig. 12, ×2000. See text for abbreviations.

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. Criteria for determination of species.

this paper for specific separation. *Saccammina,* as defined by Loeblich & Tappan (1988) has a single aperture raised and on a long or short neck; here, however, we follow Hedley (1962) and Holbourn & Kaminski (1995), 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 24 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 kilometres (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 kilometres (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 UStA, and *Hyperammina* sp. cf. *H. sappingtonensis* has been 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–falsiovalis* 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 DESCRIPTIONS

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
Genus *Inauris* Conkin, Conkin & Thurman, 1979

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

Inauris tubulata Conkin, Conkin & Thurman, 1979
(Plate 1, fig. 1)

1979 *Inauris tubulata* Conkin, Conkin & Thurman: 4, plate 1, figs 1–10.

Material. One 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
Genus *Psammosphaera* Schulze, 1875

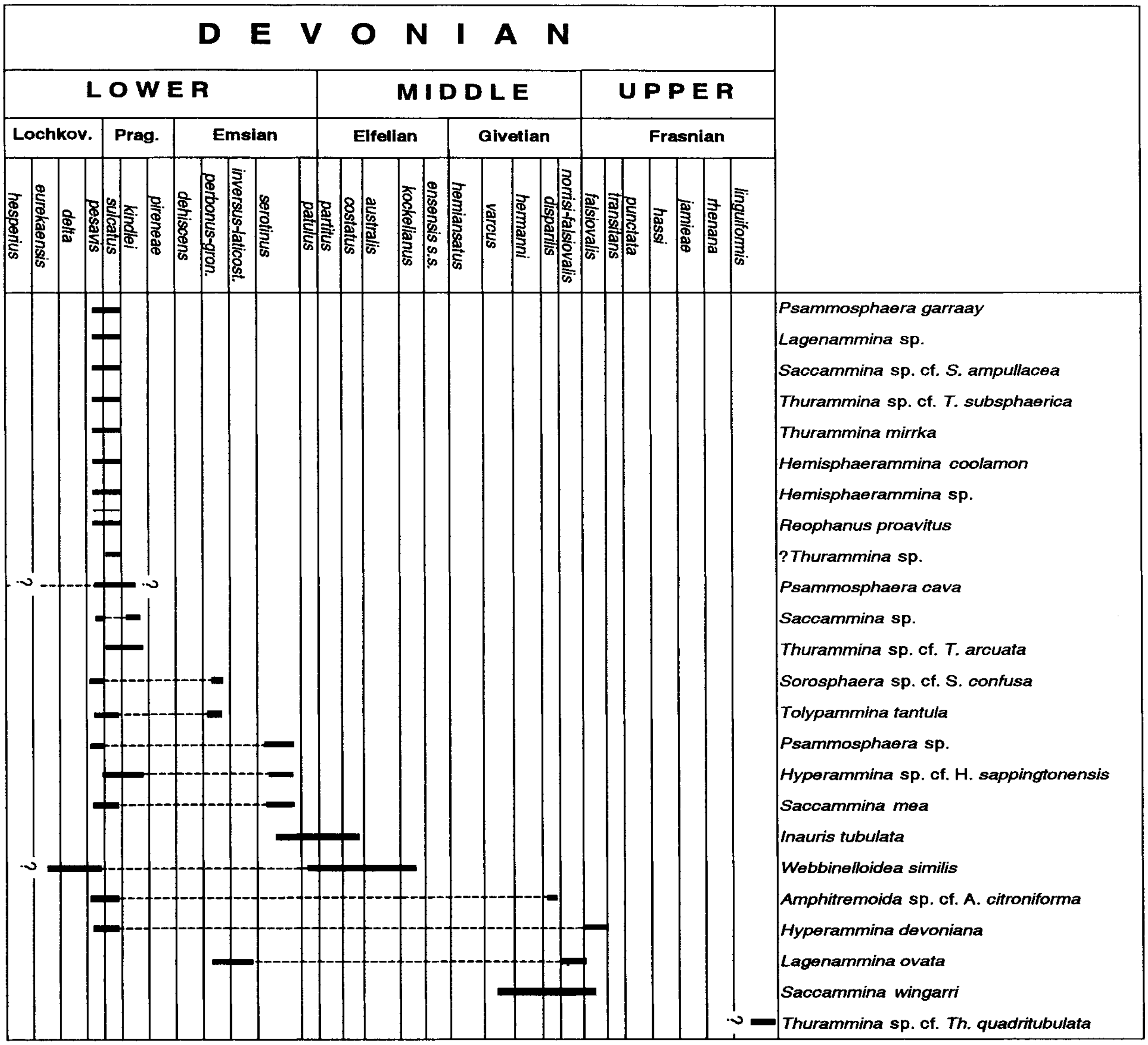


Fig. 4. Ranges of identified foraminifera, based on our studies and a literature search.

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 (Moreman, 1930; Dunn, 1942; Mound, 1968), although varying wall thickness, test size and the 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 the original wall texture. Loeblich & Tappan (1988: 28) state 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
(Plate 1, figs 2 and 3)

1930 *Psammosphaera cava* Moreman: 48, plate 6, fig. 12.
1942 *Psammosphaera cava* Moreman; Dunn: 322, plate 42, fig. 6.
1985 *Psammosphaera cava* Moreman; Gnoli & Serpagli: 214, plate 1, figs. 19, 20.
1994 *Psammosphaera* spp. Winchester-Seeto & Bell: 202, figs 2.7, 2.9. 2.14; non 2.8, 2.10, 2.12.
1996 *Psammosphaera cava* Moreman; Bell: 88, fig. 6J.

Material. Fifteen 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, Queensland, *sulcatus* Conodont Zone; Coopers Creek Formation, Victoria, *kindlei* Conodont Zone; Sardinia, Upper Pridolian, *eosteinhornensis* Conodont Zone to Early Lochkovian; basal Niagaran, Silurian, Missouri, USA.
Dimensions. Diameter, 69–140 μm (av. 97 μm for nine 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).

Psammosphaera 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 (Plate 1, fig. 3) and a slightly pitted surface (Plate 1, fig. 2).

Psammosphaera 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 (Eisenack, 1932; Stewart & Priddy, 1941; Browne & Schott, 1963; McClellan, 1966; Kristan-Tollmann, 1971b; Mabillard & Aldridge, 1982) and into the Devonian (Gnoli & Serpagli, 1985; Bell, 1996) and perhaps into the Upper Carboniferous (Pennsylvanian) as *P. gracilis* Ireland (Toomey, 1974) [Mound (1968) and Kristan-Tollmann (1971b) synonymized *gracilis* with *cava*]. Browne & Schott (1963) and Kristan-Tollmann (1971b) give extensive synonymies for this species.

Psammosphaera garraay n. sp.
(Plate 1, figs 4–6, 8)

1994 *Psammosphaera* spp. Winchester-Seeto & Bell: 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. A species of *Psammosphaera* represented by an organic lining with a reticulated wall.
Holotype. AMF87212, Fig. 2.8 Winchester-Seeto & Bell (1994: 202).
Material. Thirteen 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).
Type locality and horizon. RUN 44.4, 42.2 m above the base of the RUN section of the Garra Limestone, central NSW, Australia.
Description. Test free; globular; organic foraminiferal lining, wall reticulated; no apparent apertures.
Distribution. Garra Limestone, Wellington, NSW, *pesavis–sulcatus* conodont zones; Martins Well Limestone, Broken River area, Queensland, *sulcatus* Conodont Zone.
Dimensions. Diameter, 71–144 μm (ave. 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.

Psammosphaera sp.
(Plate 1, fig. 7)

Material. Two 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; an organic foraminiferal lining; 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.

Genus *Sorosphaera* Brady, 1879
Type species. *Sorosphaera confusa* Brady, 1879
Sorosphaera sp. cf. *S. confusa* Brady, 1879
(Plate 1, fig. 9)

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

Material. Two 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. Before 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 (1971a) 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 (1971a) 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
Genus *Amphitremoida* Eisenack, 1938
Type species. *Amphitremoida citroniforma,* Eisenack, 1938
Amphitremoida sp. cf. *A. citroniforma* Eisenack, 1938
(Plate 1, figs 10 and 11)

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

Material. Four 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 (ave. 248 μm); minimum diameter, 68–200 μm (ave. 125 μm); D_{max}/D_{min}, 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 northwest 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.

Genus *Lagenammina* Rhumbler, 1911
Type species. *Lagenammina laguncula* Rhumbler, 1911
Lagenammina ovata Bell, 1996
(Plate 2, figs 1 and 2)

1996 *Lagenammina ovata* Bell: 92, fig. 7O, P.

Material. Two 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.
(Plate 2, figs 3-5)

Material. Three 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 preservational differences.

Genus *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. Plate 2, fig. 6).

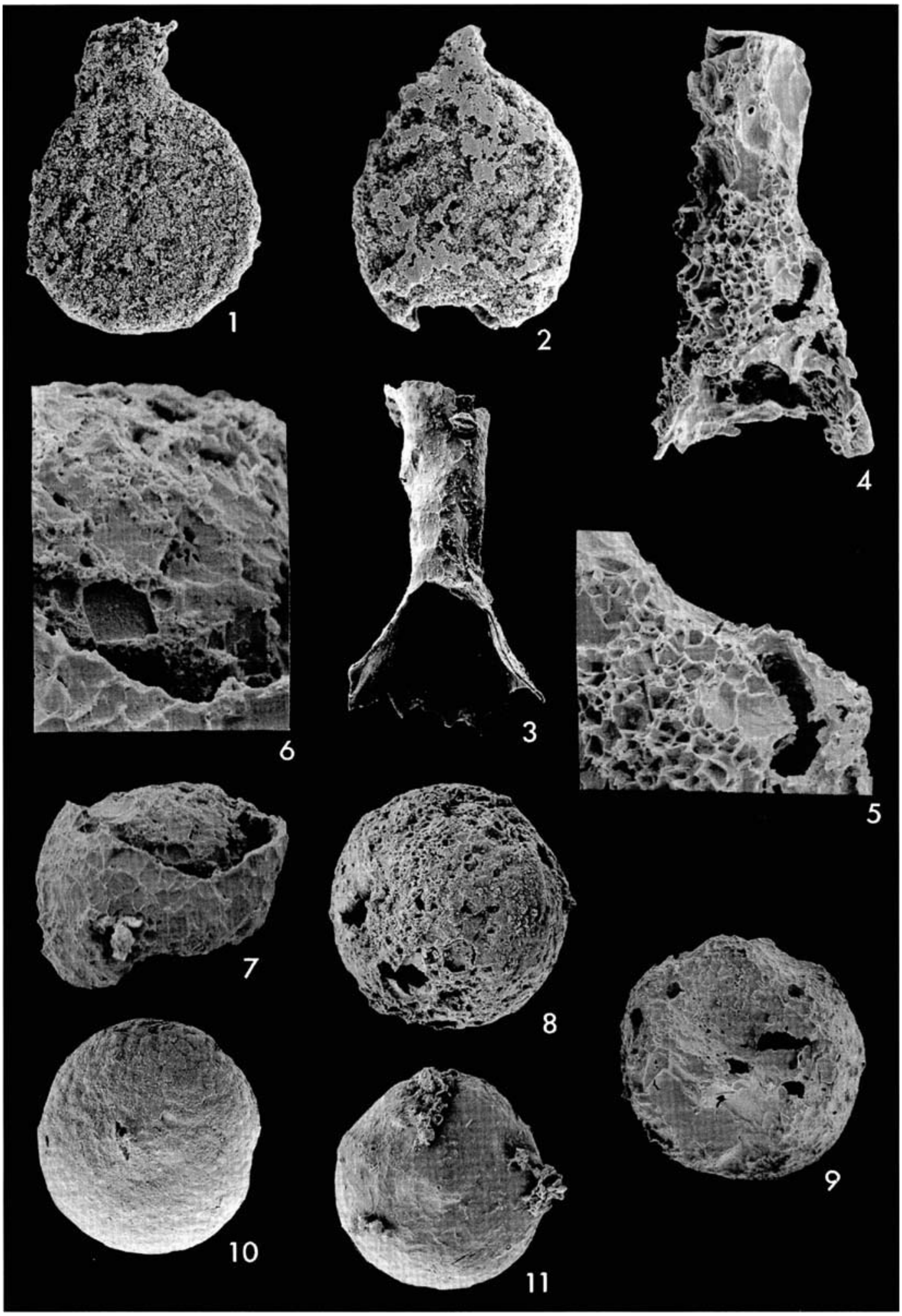
Saccammina mea n. sp.
(Plate 2, figs 6–9)

1994 *Saccammina* spp. Winchester-Seeto & Bell: 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. A species of *Saccammina* represented by an organic foraminiferal lining with a reticulated wall surface and aperture not raised.
Holotype. AMF102656, Plate 2, fig. 8.
Material. Eleven 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).
Type locality and horizon. RUN 44.4, 42.2 m above the base of the RUN section of the Garra Limestone, central NSW, Australia.
Description. Test free; globular; wall surface reticulate; a single large round aperture, flush with the test surface.
Distribution. Garra Limestone, Wellington, NSW, *pesavis–sulcatus* conodont zones; Martins Well Limestone, Broken River, Queensland., *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 nine 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.

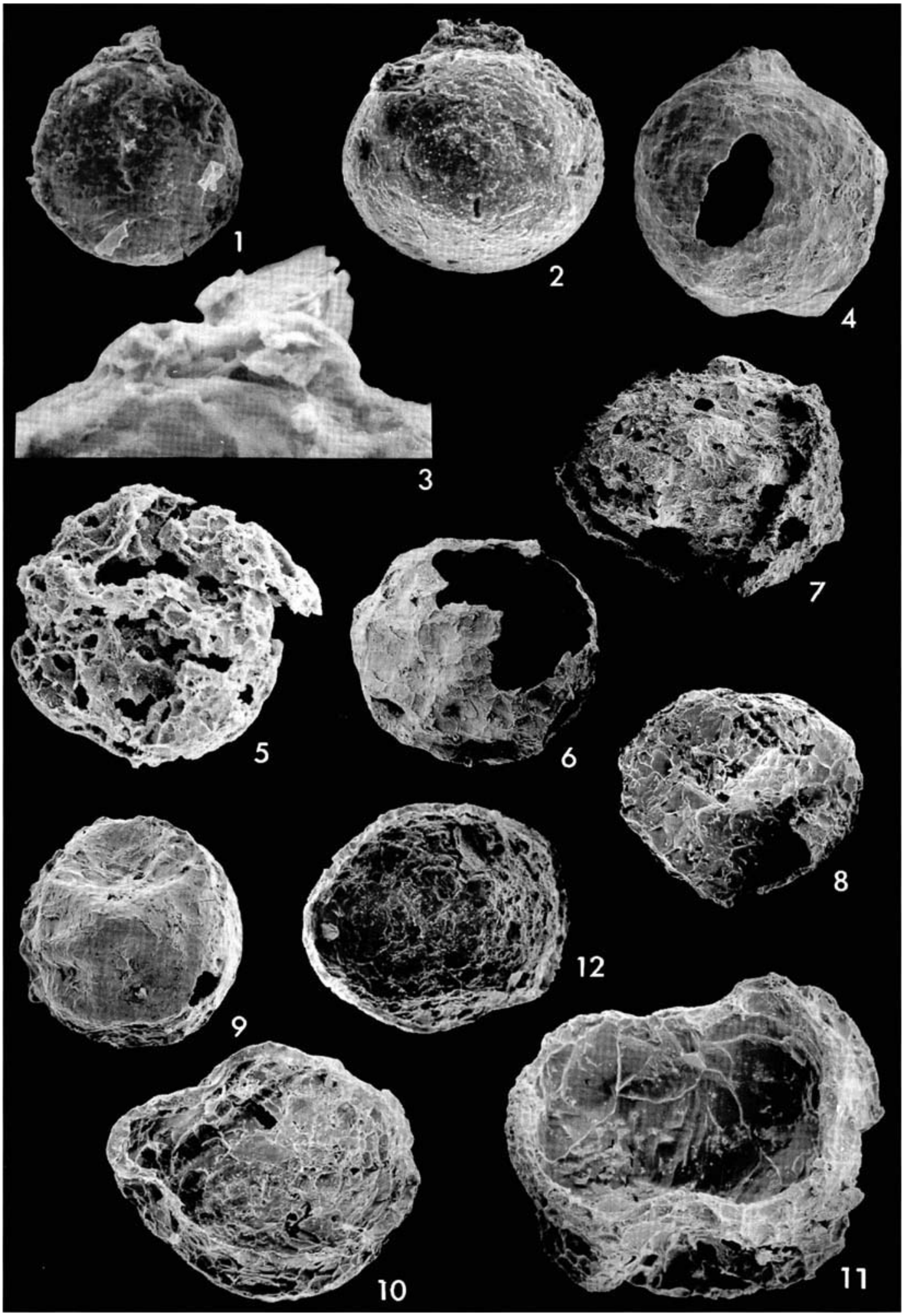
Saccammina wingarri n. sp.
(Plate 3, figs 1-3)

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



Explanation of Plate 2

figs 1, 2. *Lagenammina ovata* Bell, 1996: **fig. 1**, AMF102650, KG 17, ×350; **fig. 2**, AMF102651, KG 17, ×450. **figs 3–5**. *Lagenammina* sp.: **fig. 3**, AMF102652, GCR 262, ×500; **fig. 4**, AMF102653, MUNG 24.8, ×350; **fig. 5**, enlargement of fig. 4, ×700. **figs 6–9**. *Saccammina mea* sp. nov.: **fig. 6**, enlargement of fig. 7, ×1500; **fig. 7**, paratype, AMF102654, MUNG 24.8, ×400; **fig. 8**, holotype, AMF102656, RUN 44.4, ×450; **fig. 9**, Paratype, AMF102655, GCR 106, ×400. **figs 10, 11**. *Saccammina* sp.: **fig. 10**, AMF102657, RUN 207, ×400; **fig. 11**, AMF102658, BOO 13.1, ×400. See text for abbreviations.



Explanation of Plate 3

figs 1–3. *Saccammina wingarri* sp. nov.: **fig. 1**, holotype, AMF102659, PD 166 388.4, ×400; **fig. 2**, paratype, AMF102660, LSA 113, ×400; **fig. 3**, enlargement of neck of holotype, ×1400. **fig. 4**, *Saccammina* sp. cf. *S. ampullacea* (Crespin, 1961), AMF102661, MUNG 8.4, ×350. **fig. 5**. *Thurammina* sp. cf. *T. subsphaerica* Moreman, 1930: AMF102662, MUNG 71.5, ×350. **figs 6, 7**. *Thurammina mirrka* sp. nov.: **fig. 6**, paratype, AMF102663, GCR 401.8,×300; **fig. 7**, holotype, AMF102664, GCR 412.2, ×400. **fig. 8**. *Thurammina* sp. cf. *T. arcuata* Moreman, 1930, AMF102665, GCR 37, ×350. **fig. 9**. *Hemisphaerammina* sp, AMF102666, GCR 117.3, ×350. **figs 10–12**. *Hemisphaerammina coolamon* sp. nov.: **fig. 10**, paratype, AMF102667, MUNG 24.8, ×400; **fig. 11**, holotype, AMF102668, MUNG 6.3, ×400; **fig. 12**, paratype, AMF 102669, MUNG 24.8, ×350. See text for abbreviations.

Diagnosis. A species of *Saccammina* represented by an organic foraminiferal lining with a smooth wall surface and raised aperture.
Holotype. AMF102669, Plate 3, fig. 1
Material. Three specimens from PD 166/388.4 m and from LSA (sample 113).
Type locality and horizon. PD 166, 388.4 m, Pillara Limestone, Pillara Range, Canning Basin, WA, Late Givetian–Early Frasnian, ?*varcus* Conodont Zone.
Description. Test free; globular; wall surface smooth; aperture rounded and raised on a short neck.
Distribution. Pillara Limestone, Pillara Range, Canning Basin, WA, *disparilis-asymmetricus* conodont zones; Serre Formation, Montagne Noire, France, *asymmetricus* Conodont Zone.
Dimensions. Diameter of chamber, 80–124 μm; diameter of neck, 23–40 μm; length of neck, 6–12 μm; $D_{neck}/D_{chamber}$, 0.3; $L_{neck}/D_{chamber}$, 0.1.
Remarks. The very short, protruding neck (less than 10% of the 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 to erect a new species.

Saccammina sp. cf. *S. ampullacea* (Crespin 1961)
(Plate 3, fig. 4)

1994 *Saccammina* spp. Winchester-Seeto & Bell: 202, figs 4.3, 4.5, 4.6.

Material. Three 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 two 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.
(Plate 2, figs 10 and 11)

Material. Three 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; an organic foraminiferal lining; 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.

Genus *Thurammina* Brady, 1879
Type species. *Thurammina papillata* Brady, 1879

Thurammina mirrka n. sp.
(Plate 3, figs 6 and 7)

Derivation of name. From the Australian Aboriginal word *mirrka*, meaning cave, referring to the Wellington Caves near the type locality (Ngiyampaa language).
Diagnosis. A species of *Thurammina* represented by an organic foraminiferal lining with rough wall and with aperture flush with surface.
Holotype. AMF102664, Plate 3, fig. 7.
Material. Four specimens from RUN (sample 237.6) and GCR (samples 106, 401.8, 412.2).
Type locality and horizon. GCR 412.2, 410.1 m above the base of the GCR section of the Garra Limestone, central NSW, Australia.
Description. 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.
Distribution. Garra Limestone, Wellington, NSW, *pesavis–sulcatus* conodont zones.
Dimensions. Diameter of chamber, 70–110 μm (ave. 92 μm for four specimens).
Remarks. Although the main feature of *Thurammina* are the apertures raised on papillae (Loeblich & Tappan, 1988), we place this new species with *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
(Plate 4, fig. 1)

1942 *Thurammina quadritubulata* Dunn: 334, Plate 43, fig. 22
1961 *Thurammina quadritubulata* Dunn; Blumenstengel: p. 318

Material. One specimen from LSC (sample 1.6 m 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
(Plate 3, fig. 8)

Material. Five 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; Stewart & Priddy, 1941; Dunn, 1942; McClellan, 1966).

Thurammina sp. cf. *T. subsphaerica* Moreman, 1930
(Plate 3, fig. 5)

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

Material. Three 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, Queensland, *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 0.5 μ, has not been observed before. *Thurammina subsphaerica* has been recorded from the Silurian of Illinois by Dunn (1942).

Thurammina sp.
(Plate 4, figs 2 and 3)

Material. One specimen from MW (sample 25.4).
Distribution. Martins Well Limestone, Broken River, Queensland, *sulcatus* Conodont Zone.
Description. Test free; an organic foraminiferal lining; '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
Genus *Hemisphaerammina* Loeblich & Tappan, 1957
Type species. *Hemisphaerammina batalleri* Loeblich & Tappan, 1957

Hemisphaerammina coolamon n. sp.
(Plate 3, figs 10–12)

1994 *Hemisphaerammina* sp. Winchester-Seeto & Bell: 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. A species of *Hemisphaerammina* represented by an organic foraminiferal lining with a reticulated wall surface.
Holotype. AMF102668, Plate 3, fig. 11
Material. Five specimens from MUNG (samples 6.3, 24.8) and MW (sample 49).
Type locality and horizon. MUNG 6.3, 6.2 m above the base of the MUNG section of the Garra Limestone, central NSW, Australia.
Distribution. Garra Limestone, Wellington, NSW, *pesavis–sulcatus* conodont zones; Martins Well Limestone, Broken River, Queensland, *sulcatus* Conodont Zone.
Description. Test apparently formerly attached; hemispherical chamber with a basal membrane; a thick flat attachment surface; wall surface reticulate; no apparent aperture.
Dimensions. Diameter of chamber, 83–116μm (Av. 90.5 μm for five 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 & Tappan (1988) have synonymized these two genera. A number of our specimens only show a partial basal membrane.

Hemisphaerammina sp.
(Plate 3, fig. 9)

1994 *Hemisphaerammina* sp. Winchester-Seeto & Bell: 205, fig. 4.6.

Material. Two specimens from MUNG (sample 8.4) and GCR (sample 117.3).
Distribution. Garra Limestone, Wellington, NSW, *pesavis–sulcatus* conodont zones.
Description. Test an organic foraminiferal lining; 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.

Genus *Webbinelloidea* Stewart & Lampe, 1947
Type species. *Webbinelloidea similis* Stewart & Lampe, 1947
Webbinelloidea similis Stewart & Lampe, 1947
(Plate 4 fig. 13)

1947 *Webbinelloidea similis* Stewart & Lampe: 535, pl. 78, fig. 8.
1970 *Webbinelloidea similis* Stewart & Lampe; Conkin & Conkin: 4–14, pl. 1, figs 1–31; pl. 2, figs 1–27; pl. 3, figs 1–16; pl. 4, figs 1–35.
1984 *Webbinelloidea similis* Stewart & Lampe; Malec: 560–561, pl. 1, figs 1–20; pl. 2 figs 1–12.
1985 ?*Webbinelloidea* sp. Stewart & Lampe; Gnoli & Serpagli: 214, pl. 1, fig. 21.
1988 *Webbinelloidea similis* Stewart & Lampe; Malec & Studencki: 84–85, pl. 1, figs 13, 15–18; pl. 2, figs 1–4; pl. 3, figs 1–5.
1992 *Webbinelloidea similis* Stewart & Lampe; Malec: 282, pl. 1, fig. 6; pl. 2, figs 6, 10; pl. 3, figs 6, 9; pl. 4, figs 1–9.
1994 *Hemisphaerammina* sp. Winchester-Seeto & Bell: 205, fig. 4.8.

For further synonyms see, Conkin & Conkin (1970).

Material. One specimen, from RUN (sample 199.3).
Distribution. Garra Limestone, Wellington, NSW, *pesavis* Conodont Zone; Góry Świetokrzyskie Mountains, Poland, Upper Emsian–Lower Eifelian; Columbus Formation, USA, *patulus–costatus* conodont zones; Delaware Formation, USA, *kocklianus* Conodont Zone; Corti Baccas third 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 workers 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 fairly 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 USA (Conkin & Conkin, 1981, with synonymy), and in Poland occurs in the Lower–Middle Devonian (Malec, 1992).

Genus *Hyperammina* Brady, 1878
Type species. *Hyperammina elongata* Brady, 1878
Hyperammina devoniana Crespin, 1961
(Plate 4, figs 11 and 12)

1961 *Hyperammina devoniana* Crespin: 1961; 406, pl. 64, figs 1–6.
1994 *Hyperammina* spp. Winchester-Seeto & Bell: 202, figs 2.1, 2.2.

Material. Four 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 River, Queensland, *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 believe that Crespin's 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
(Plate 4, figs 4–8)

1994 *Hyperammina* spp. Winchester-Seeto & Bell: 202, figs 2.3, 2.4, 2.5?

Material. Two 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 River, Queensland, *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 (ave. 219.5 μm); diameter of proloculum, 35–104 μm (ave 57 μm).
Remarks. This species is characterized 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 (Plate 4, fig. 8) or become flaring (Plate 4, fig. 5) and even shows the characteristic 'hourglass' constriction of *Hyperammina* (Plate 4, fig. 6). Conkin & Conkin (1964) determined that *H. sappingtonensis* existed as both micro- and megalospheric forms. Specimens observed in this study have prolocular sizes which fit fairly easily into the size ranges given

Explanation of Plate 4

fig. 1. *Thurammina quadritubulata* Dunn, 1942, AMF102670, LSC 1.6 m below 12b, ×400. **figs 2, 3**. *Thurammina* sp.: **fig. 2**, AMF102671, MW 13.7, ×400; **fig. 3**, enlargement of fig. 2, ×900. **figs 4–8**. *Hyperammina* sp. cf. *H. sappingtonensis* Gutschick, 1962: **fig. 4**, AMF102674, KE DDH1 448.51, ×300; **fig. 5,** AMF102672, MSh 2, ×400; **fig. 6**, AMF102675, MSh 2, ×400; **fig. 7**, AMF102673, Pt. Hibbs 68669, ×400; **fig. 8**, AMF102676, MW 39.9, (×300). **fig. 9**, *Reophanus proavitus* sp. nov., holotype, AMF102677, GCR 105, ×200. **fig. 10**. *Tolypammina tantala* Bell, 1996, AMF102678, GCR 53.7, ×120. **Figs 11, 12**. *Hyperammina devoniana* Crespin, 1961: **fig. 11**, AMF102679, MW 39.9, ×300; **fig. 12**, AMF102680, GCR 38, ×200. **fig. 13**. *Webbinelloidea* sp. cf. *W. similis* Stewart & Lampe, 1947, AMF102681, RUN 199.3, ×300. See text for abbreviations.

for this species. In the megalospheric forms the ratio of prolocular diameter to length of specimen is one to three or four, whereas 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* Blumenstegal 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
Genus *Tolypammina* Rhumbler, 1895
Type species. *Hyperammina vagans* Brady, 1879

Tolypammina tantula Bell, 1996
(Plate 4, fig. 10)

1994 *Hyperammina* spp. Winchester-Seeto & Bell: 206, figs 3.12, 3.13.
1996 *Tolypammina tantula* Bell: 99, figs 10C-E.

Material. Two 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
Genus *Reophanus* Saidova, 1970
Type species. *Hormosina ovicula* Brady, 1879

Reophanus proavitus n. sp.
(Plate 4, fig. 9)

1994 *Reophax* sp. Winchester-Seeto and Bell: 206, figs 3.7, 3.8.

Derivation of name. From the Latin word *proavitus*, meaning ancestor.
Diagnosis. A species of *Reophanus* represented by an organic foraminiferal lining with smooth surface.
Holotype. AMF102677, Plate 4, fig. 9.
Material. Three specimens from RUN (sample 85.7) and GCR (samples 105, 290.9).
Type locality and horizon. GCR 105, 105 m above the base of the GCR section of the Garra Limestone, Wellington, central NSW, Australia.
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.
Description. 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.
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. oviculus*), 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.
(Plate 1, figs 12 and 13)

Material. Three specimens from Gel. Rd. (sample 16T/65).
Distribution. Taravale Formation, eastern Victoria, *serotinus* Conodont Zone.
Description. Test free; an organic foraminiferal lining; 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. Although 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.

SUMMARY

The present study of Devonian (Lochkovian to Frasnian) organic foraminiferal linings recognizes 24 species, of which six are new. Organic foraminiferal linings show potential for inter- and intra-continental biostratigraphic correlations as some species have a wide geographical, but stratigraphically limited, range.

This study is the first to integrate taxonomic and biostratigraphic information from foraminiferal linings with that of intact agglutinate foraminiferans from Palaeozoic sequences. This recognition of the significance of the linings opens up a new source of foraminiferal fossils from which to draw information. Thus we now have the potential to not only examine the full size range of foraminiferans and to gain a more complete understanding of the range of variation within these organisms, but also to appreciate the influence of environmental factors on their physiology and distribution.

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