FORAMINIFERA ZONATION IN THE PERMIAN STRATIGRAPHY OF THE DENISON TROUGH (BOWEN BASIN), CENTRAL QUEENSLAND

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Eight biostratigraphic intervals are defined by the presence of foraminiferal index taxa in the Denison Trough lithostratigraphy. They are used to correlate 14 boreholes drilled in the flanks and periphery of the Springsure and Consuelo anticlines. The correlation is performed between intervals which contain the index taxon and/or the key species associated. A species diversity diagram calculated in three sequences shows diversity peaks here interpreted as indicating climatic ameliorations. They correspond to the *Pseudonodosaria serocoldensis* Zone contained in the upper Sirius Member of the Cattle Creek Formation, Late Artinskian-Early Kungurian in age; to the *Pseudonodosaria borealis-Hillella marginodentata* Zone, contained in the Upper Ingelara-Catherine Sandstone Formations, of Kazanian age; and to the *Lunucammina maior* Zone contained in the Catherine Sandstone-Lower Peawaddy Formations of Late Kazanian-Midian age. The diachroneity shown through the biostratigraphic and lithostratigraphic correlation is not considered to unreasonably affect the chronological outcome.

RESULTS of research on Permian smaller foraminifera conducted in the Geological Survey of Queensland since the 1970s were published in the last decades (Palmieri 1983, 1988, 1990, 1994; Foster et al. 1985; Draper et al. 1990; Palmieri et al. 1994). This paper complements the illustrative work (Palmieri 1994) and constitutes the revised framework for the distribution of the Denison Trough foraminifers. The tentative correlation with the Novaya Zemlya Gusinozemelian Suite of Ufimian-Kazanian age (Kalashnikov et al. 1981) given in Palmieri (1983: fig. 4) is here revised after the recognition of Pseudonodosaria borealis Gerke and 12 other nodosariid species of foraminifera of Kazanian age in sediments of the Ingelara Formation, previously thought as correlatable with the Ufimian. Similarly index species names previously given by the author (Palmieri 1990; Draper et al. 1990) are here emended in agreement with the subsequent nomenclatorial work.

In the absence of fusulinid foraminifers the biostratigraphic value of the smaller Permian foraminifers of the Denison Trough was determined independently. It was then related, by recognition of affinity with or identity to foraminiferal species ranges, to stratigraphic schemes from other Permian basins of Australia. It is worth mentioning here the monograph on Permian Foraminifera of Tasmania (Conkin & Conkin 1993) which confirms, enlarges and refines their stratigraphic distribution. According to this study, in the opinion of the writer, in Tasmania the Malbina and Fern Tree Formations contain foraminifers similar to some respectively found in the Freitag and Ingelara Formations; the Berriedale and Mersey Formations contain foraminifers similar to those found in the Cattle Creek Formation; the Golden Valley Group and Darlington Limestone Formation contain foraminifers similar to those found in the Fossil Cliff Formation (Perth Basin); the Callytharra Formation (Carnarvon Basin); and the Nura Nura Formation (Canning Basin); and finally the Quamby Mudstone contains foraminifers similar to those found in parts of the Holmwood Shale (Perth Basin); the Carandibby and Nangetty Glacial Formation (Carnarvon Basin); and the Grant Group (Canning Basin), Western Australia. In the management of Australian Permian smaller foraminifers particular importance is also given to the results of foraminiferal research in the Early Permian 'arctic' basins: the Canadian Sverdrup Basin in Mamet & Pinard (1992); the Norwegian Barents Sea Basin in Groves & Wahlman (1997); and in the Late Permian Russian platform and trans-Caucasian areas (Pronina 1988, 1994, 1996). In other words it is implied here that even if constrained by a generally colder climate the rate of evolution of certain smaller foraminifers of Australia may have been comparable with the rate evolution of similar smaller foraminiferal faunas from the Boreal and Paratethyan regions. For the purpose of this paper and also because they were found to contain the foraminifers here discussed, only samples belonging to selected fully cored boreholes drilled by the Queensland Department of Mines are here considered. These boreholes, located on a broken



line, SSE-NNW directed and about 250 km long (Fig. 1), are: GSQ Taroom 11-11A; GSQ Eddystone 1; GSQ Taroom 10; GSQ Eddystone 4; GSQ Eddystone 5; GSQ Springsure 2, 3; GSQ Springsure 11, 12; GSQ Springsure 10; GSQ Springsure 6-9; GSQ Springsure 19; and GSQ Springsure 18. Stratigraphic drilling data and references are reported in Noon & Coote (1983). The lithostratigraphic boundaries adopted are those reported in Gray (1976, 1980) and those in Balfe (1982) with some modification in the Cattle Creek Formation. As a provisional, working stratigraphic scheme for the Denison Trough the one reported in Roberts et al. (1996) is used here (Fig. 2). A graphic correlation of the boreholes based on formations and on foraminiferal zones is given respectively in Figs 3 and 4. It is to be noted that the zonal intervals correlated with the type section may not contain the index taxon and in that case other key species have supported the correlation.

BIOSTRATIGRAPHY

This is a local biostratigraphic zonation based, where feasible, on first occurrence, in stratigraphic but not necessarily continuous order, of index species of foraminifers, usually selected among calcareous hyaline tests. Where these are not available, as for instance in Early Permian sequences, local range of selected agglutinating foraminifers are considered, as the final aim is to establish a local, workable chronostratigraphic scale. First and/or last appearance of index species gives then,



Fig. 2. Stratigraphic scheme for the Permian of the Denison Trough (modified after Roberts et al. 1996).

Fig. 1. Locality map.

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in this context, zonal levels not necessarily isochronous. They are, however, illustrative of environmental change. An example is given by *Ammodiscus corrugatus* whose whereabouts may be followed from the Freitag to the Peawaddy Formations: it is, however, important in detecting a shallow marginal marine environment of deposition for a Late Permian formation.

A broad biostratigraphic scheme for stadial subdivision is provided in Fig. 5: it is obvious that the Asselian and Sakmarian ranges do not concern the Denison Trough.

Figures 6–8 illustrate the diversity of the foraminiferal faunas as number of species with agglutinating, calcareous hyaline and calcareous imperforate per sample.

Finally, Figs 9–22 are foraminifers range charts for 14 of the 16 mentioned GSQ boreholes. These foraminifers are stored in the GSQ Microfossil Collection.

Howchinella woodwardi Zone

Synonymy. Assemblage Zone A1 (Palmieri 1983).

The index taxon is found in GSQ Springsure 9 at 171.6 m (31 m above the fresh water Reids Dome Beds) in mudstones of the Mostyndale Member, Cattle Creek Formation. Originally it was found in the upper Fossil Cliff Formation, Perth Basin, then in the upper Callytharra Formation, Carnarvon Basin, both of Late Sakmarian–Early Artinskian age. In GSQ Springsure 9 the zone interval is about 80 m. The assemblage comprises 25 species of which 5 are calcareous and 20 agglutinating. The calcareous *Protonodosaria tereta*, *Earlandia condoni* are known from the late Sakmarian–early Artinskian of Western Australia. The zone may represent sediments deposited following the first sea ingression in the Denison Trough.

Key species. Ammobaculites woolnoughi, Hyperammina elegantissima, Earlandia condoni, Protonodosaria tereta.

Distribution. GSQ Springsure 9: from 171.6 to 99.4 m, type section; GSQ Springsure 8: from 455.0 to 411.4 m; GSQ Eddystone 4: from 792.9 to 724.9 m; GSQ Taroom 10: from 1080.9 to 1035.4 m.



Fig. 5. Provisional biostratigraphic/evolutionary scheme for stadial subdivision from Asselian to Kazanian.

Howchinella rigida Zone

Synonymy. Assemblage Zone A2 (Palmieri 1983).

The index taxon appears in GSQ Springsure 9 at $_{0.9.4}$ m and is absent from 77.4 m. This interval

is found in GSQ Springsure 8 between 424.3 and 396.5 m. Of particular importance is the only presence of *Hemigordius schlumbergeri* in GSQ Springsure 9 at 91.4 m and *Meandrospira* sp. at 83.8 m. An Early Artinskian age is attributed to this interval.



Fig. 6. Foraminiferal diversity diagram (number of species/sample) for GSQ Taroom 10 ($O = agglutinating tests; X = calcareous hyaline/microgranular tests; <math>\Box = calcareous imperforate tests$).

Key species. Hemigordius schlumbergeri, Meandrospira sp., Nodosaria raggatti, Sacculinella australae, Mooreinella recurvata.

Distribution. GSQ Springsure 9: from 99.4 to 77.4 m, type section; GSQ Springsure 8: from 424.3 to 411.4 m; GSQ Springsure 7: from 411.4 to 361.6 m; GSQ Eddystone 4: from 724.3 to 713.4 m; GSQ Taroom 10: from 1035.4 to 961.2 m.

Pseudohyperammina radiostoma Zone

Synonymy. Assemblage Zone A3 (Palmieri 1983).

The index taxon appears in GSQ Springsure 7 at 356.5 m and continues until 288.3 m. The taxon, which has its origin in the Carnarvon Basin Byro Group, was found in the upper Holmwood Shales, Perth Basin, and the Noonkanbah Formation Canning Basin, Western Australia. In the Denison



Fig. 7. Foraminiferal diversity diagram for GSQ Springsure 2 and 3 (combined). Legend as per Fig. 6.

Trough this zone assumes a biofacies aspect and the index acts as a local marker. An Artinskian age is assigned to this zone. *Pseudohyperammina radiostoma* is found, occasionally in abundance, in mudstones of the Moorooloo Member of the Cattle Creek Formation.

Key species. Mooreinella bookeri, Thuramminoides sphaeroidalis.

Distribution. GSQ Springsure 8: from 46.9 to 33.5 m; GSQ Springsure 7: from 356.5 to 288.3 m, type section; GSQ Eddystone 4: at 713.4 m; GSQ Taroom: at 913.5 m (index taxon not found).



Fig. 8. Foraminiferal diversity diagram for GSQ Springsure 6-9 (combined). Legend as per Fig. 6.

Pseudonodosaria serocoldensis Zone

Synonymy. Assemblage Zones A4 & A5 (Palmieri 1983).

The index taxon has its origin in the Sirius Member of the Cattle Creek Formation. It was then found in the late Artinskian of all the other marine basins of Australia except Tasmania, however a key species of the zone (*Dentalina grayi*) is reported from the Berriedale Limestones (Conkin & Conkin 1993: p. 23, pl. 6, fig. 17). A profound change is manifested in or just before the zone with a steady increase in the number of calcareous hyaline foraminifers. Many appear for the first time together with the index taxon.

the Late Similar assemblages occur in of the Western Artinskian-Early Kungurian Australia basins, i.e. in the Carynginia Formation (Perth Basin), in the Byro Group (Carnarvon Basin), and in the Noonkanbah Formation (Canning Basin). In the Denison Trough the Pseudonodosaria serocoldensis Zone is part of the Sirius Member of the Cattle Creek Formation where it represents a significant marine ingression and amelioration of the climate from cold to cold temperate. The assigned age is late Artinskian to possibly early Kungurian.

Key species. Dentalina grayi, Howchinella aulax, H. costata, H. hillae, Ichthyolaria sutilis, Nodosaria springsurensis.

Distribution. GSQ Springsure 6: from 222.6 to 194.2 m, type section; GSQ Eddystone 4: from 654.7 to 612.8 m.

Ammodiscus corrugatus Zone

Synonymy. Assemblage Zone B (Palmieri 1983).

The zone occur in the Freitag and Ingelara Formations of Late Permian age. As stated above this zone is facies controlled and is related to the establishment of agglutinating pioneering foraminifers along with transgressional seas. The index taxon was separated from the similar, but not identical, *Ammodiscus oonahensis* of the earliest Permian of Tasmania and South Australia where it may have a similar environmental meaning in periglacial seas. This index taxon has a major importance in the Denison Trough because it initiates the access of late Permian faunas from a southeastward direction. It is in fact often associated with *Hyperammina* cf. *hebdenensis*, which, together with *Glomospirella nyei* iteratively follows the sea incursions to the Northern Bowen Basin in the sediments of the Blenheim Formation. The zone is recognised in GSQ Springsure 3 from 256.0 to 227.6 m. In outcrop reaches about 100 m in thickness in the Freitag–Ingelara Formations section at Aldebaran Creek (South Branch) (Dickins & Malone 1973). The zone may encompass the Ufimian–Kazanian age.

Key species. Hyperammina cf. hebdenensis, Glomospirella nyei.

Distribution. GSQ Springsure 3: from 256.0 to 227.6 m, type section; GSQ Springsure 10: at 384.0 m; GSQ Springsure 18: at 499.7 m; GSQ

Springsure 19: from 765.3 to 737.0 m; GSQ Eddystone 5: from 760.3 to 754.1 m; GSQ Eddystone 1: from 789.7 to 786.4 m; GSQ Eddystone 4: from 215.9 to 213.6 m; GSQ Taroom 10: from 808.2 to 798.0 m; GSQ Taroom 11: from 222.5 to 217.2 m. All intervals belong to the Ingelara Formation.

Pseudonodosaria borealis-Hillella marginodentata Zone

Synonymy. Assemblage Zone C1 (Palmieri 1983). Pseudonodosaria minuta Zone (Palmieri 1990). Hillella marginodentata Zone (Palmieri 1994). Pseudonodosaria borealis Zone (Palmieri et al. 1994).



Fig. 9. Foraminifera distribution in GSQ Springsure 9. Range-chart of presence/absence by lowest appearance.

The zone is defined by the interval between the first occurrence of *Pseudonodosaria borealis* and the last occurrence of *Hillella marginodentata*. The index taxa appear in the same sample in GSQ Taroom 10 in the Ingelara Formation at 798.0 m, that is 10 m above the appearance of *Ammodiscus corrugatus* in the same borehole, and *Hillella marginodentata* is absent above 750.0 m. The zone was recognised in GSQ Springsure 3 between 227.6

and 150.4 m and in GSQ Springsure 18 between 483.7 and 448.3 m. In nearly all the other boreholes the zone is recognisable through the associated assemblage if one or both the index taxa are missing. The zone represents the first means of biostratigraphic correlation with Kazanian foraminifers faunas from the Russian Platform. It has no equivalent in Australia outside the Bowen Basin perhaps with the exception of the fora-

	HYPERAMMINA FUSTA	НОНСНІМЕСТА МООДИАКОІ	HYPERAMMINA FLETCHERI	NODOSARIA Sp. cf.N.RAGGATTI	PSEUDONODOSARIA ANTIQUA	SACCAMMINA 8P.	THURAMMINA SP.	HOHCHINELLA RIGIDA N. 8P.	HVPERAMMINA ELEGANTISSIMA	PROTONODOSARIA TERETA	AMMODISCUS MULTICINCTUS	GLOHOSPIRELLA SP. cf. G. UMBILICATA	HYPERAMMINA HEBDENENSIS	REOPHAN MINUTISSIMUS	I SACCAMMINA AMPULLA	REOPHAN BELFORDI	REOPHAK EMACIATUS	SACCULINELLA AUSTRALAE	THURAMMINOIDES SPHAEROIDALIS	ANHODISCUS NITIDUS	SACCAMMINA AMPULLACEA	TOLYPANMINA UNDULATA	GLOMOSPIRELLA CT. NYEI	AMMOBACULITES Cf. WANDAGEENSIS	TROCHAMMINA sp. indet.	I AMMOBACULITES NOOLNOUGHI	HODREINELLA BOOKERI	HOOREINELLA RECURVATA	" PSEUDOHYPERAMMINA RADIOSTOMA	
33.5											R.									i.							II.			33.5
36.9								•			ł	•			•	•		•			•	•	•	•	•	•	7	•	н.	36.9
44.5		•	•		•		•	•	•		1	•		•	•			•	F.		•	•	•	•	•	•	٠	•		44.5
46.9		•		•		7	•		•		1	•			٠	7	-	•	I.	II.	•	٠	•	•	•	٠	•	•		46.9
67.1		•				•	•	•	•	•	8	•		٠	•	٠	٠	•	L		•	•	٠	•	•	•		•	•	67.1
76.2		•	-	•	•	•	•	•	•	•	•			٠	٠	•	٠	•	8	•	•	•	•	•	•	•	•	:	•	76.2
91.4	•	•		•		•	•	•		•				•	•	٠	٠	•	1			•		•	1	1	-	ł.	•	91.4
103.7	•	•		•	•	•	•	٠	•	•	•	•			•	1	٠	•	H.	H.	•	•	:	-				Ŀ.	•	103.7
124.9	•	•	H.	•	•	٠	•	٠	٠	•			•	•	•		٠	٠	8		•	•				•	•	•	•	124.9
137.1	•	•		٠	•	٠	•	٠		•	I.		•	•		•	•	•				•	-	•	•	•	•	•	•	137.1
149.4		•		٠	•	٠	•	٠	٠	•	I.			٠	•	٠	٠	-				•		•	•	•	•	•	•	149.4
152.4		•	•	•	٠	٠	•	•	•	•		•	•				1		•	-		-	•	•	•	•	•	•	•	152.4
158.4	•	•		•	•	٠	•	٠	•	•		•											•	•	•	•	•	•	•	158.4
161.7	•	•		٠		٠	•	٠	•	٠	L		•	•						•	•	•	•	•	٠	•	•	•	•	101./
289.4	•	•		•	•	٠	•	•	•	•	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	289.4
304.8	•	•		•	•	•	•	•	•	•	•	•		•	٠	•	•	•	٠	•	•	•	•	•	•	•	•	•	•	304.8
319.9		•	•			•	•	•	•	•			-	•		•	٠	•	•	٠.	•	٠	•	•	•	•	•	•	•	319.9
350.4		•		•		•	•	•		•						•	•	•	•	•	•	•	•	•	•	•	•	•	•	350.4
380.3		•		•	•	•	•	•	•	•	•	-				•	•	•	•	•	•	•	•	•	•	•	•	•	•	380.3
396.5		•		•	•	•	•	•	•	•				•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	/11 /
411.4		•		•	•	•	•				•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	411.4
424.3								•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	424.3
441.9					-	7	7																							441.9

Fig. 10. Foraminifera distribution in GSQ Springsure 8. Range-chart of presence/absence by lowest appearance.

minifers faunas from the Kulnura Marine Tongue of the Northern Sydney Basin. New nodosariid and lagenid species make their first appearance. The zone represents in the type section of GSQ Taroom 10 a suite of sediments deposited in Kazanian age. Generally the interval belongs to the upper Ingelara Formation, however, it encompasses on the fringe of the Springsure Shelf sediments which have been attributed (Gray 1976) to the Catherine Sandstone. Where the Catherine

	AMMODISCUS MULTICINCTUS	AMMODISCUS NITIDUS	I HYPERAMMINA HEBDENENSIS	MODREINELLA RECURVATA	REOPHAK BELFORDI	SACCAMMINA AMPULLA	SACCULINELLA AUSTRALIS	GLOHOSPIRELLA CT. NYEI	HIPPOCREPINELLA BIAPERTA	HYPERAMMINA FLETCHERI	REDPHAK EMACIATUS	THURAMMINOIDES SPHAEROI DALIS	HOUCHINELLA WOODWARDI	MOOREINELLA BOOKERI	NODOSARIA SP. Cf. G. RAGGA TTI	HYPERAMMINA COLEVI	I REOPHAX SUBASPER	TROCHAMMINA sp. indet.	EARLANDIA CONDONI	GLOMOSPIRELLA Sp. cf.G.U MBILICATA	PSEUDOHYPERAMMINA RADIO STOMA	HYPERAMMINA ACICULA	
229.8																							229.8
243.8	•		•	•	•	•	•	•	•		•	•	•	•	•		•	•	•	•	•	7	243.8
274.2	÷.	÷	÷		1	•	•	•	•		•	÷	•	•	÷		•	•	•	•	•	•	274.2
288.3				÷							1	ų.	:	:	ų.		:	Ċ	:	:	÷.	:	288.3
305.0			i.							i.		É.				÷.	÷			÷	I.		305.0
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340.0			-							• •													340.0
344.3			•				•		7		П	7		8							I.		344.3
350.5	-	7	•	•	Ξ.	•	•	7		7	7	•	•	7			•	•		7	I.	•	350.5
356.5			•	•	•	•	•				•		•				•	•				•	356.5
301.0	•	•	•	•	•	•	•	•	•	•	•		•	•	•		•	-	•	•	•	•	361.6
383 1	•	•	•	•	•	•	•		•	•	•		•	•	-		-		•	•	•	•	376.4
396.5	-	-	-	•	•	•	•	-	•	4	•		•	-				•	•	•	•	•	396 5
411.4				•	•	•	•		•		•		•			•	•	•	•	•	•	•	411 4
423.9					÷	÷					-		-		•	•	•	•	•	•	•		423.9
440.4						-			i.						•	•	•	•	•	•	•	•	440.4
455.6									-	-													455.6

Fig. 11. Foraminifera distribution in GSQ Springsure 7. Range-chart of presence/absence by lowest appearance.

Sandstone does not exist it continues in the lowermost Peawaddy Formation. Roberts et al. (1996) assign an absolute age of 253.4 ± 3.2 to a sample taken at about 480 m in GSQ Springsure 18.

Key species. Eocristellaria initialis, Howchinella striatosulcata, Lingulinodosaria arctica, Nodosaria draperi.

Distribution. GSQ Taroom 11: from 217.2 to 172.3 m; GSQ Taroom 10: from 798.0 to 750.9 m, type section; GSQ Eddystone 4: from 118.7 to 100.7 m; GSQ Eddystone 1: at 786.4 m; GSQ Eddystone 5: at 745.8 m; GSQ Springsure 19: from 737.4 to 657.4 m; GSQ Springsure 18: from 483.7 to 448.3 m; GSQ Springsure 10: from 384.0 to 373.9 m; GSQ Springsure 3: from 227.6 to 150.4 m.

Lunucammina maior Zone

Synonymy. Assemblage Zone C2 (Palmieri 1983). Lunucammina maioris Zone (Palmieri 1990). Lunucammina maioris Zone (Draper et al. 1990).

The index taxon appears at 141.2 m in GSQ Springsure 3 and becomes absent at 59.0 m. It represents the continuity of iterative evolution of foraminifers in the late Kazanian–Murgabian, with the initial development of relatively larger lunu-camminids possibly in response to shallowing of marine waters and the incoming of restricted conditions. The zone is represented in the Catherine Sandstone and Peawaddy Formation. Particular importance is given to the presence of the species *Pilammina* sp., now under study by the author.

185.9 194.2		HVPERAMMINA FLETCHERI	AMMODISCUS MULTICINCTUS	AMMODISCUS NITIDUS	AMMOVERTELLINA GLOMOSPIRO	GLOHOSPIRELLA SP. cf.G. UMB	MOOREINELLA RECURVATA	PSAMMOSPHAERA PUSILLA	REOPHAN ASPER	REOPHAN MINUTISSIMUS	SACCAMMINA AMPULLA	SACCULINELLA AUSTRALIS	THURAMMINDIDES SPHAERDIDA	TOLYPAMMINA UNDULATA	HONCHINELLA HILLAE	HOUCHINELLA HOODHARDI	ICHTHVOLARIA LIMPIDA	NODOSARIA SP. Cf. N. RAGGATT	MOOREINELLA BOOKERI	ICHTYOLARIA SUTILIS	PSEUDONODOSARIA SEROCOLDE	AMMOBACULITES Cf. WANDAGE	DENTALINA GRAVI	GLOHOSPIRELLA CT. NYEI	HOWCHINELLA AULAX	NODOSARIA RAGGATTI	PSEUDOTRISTIX 8p. 1	SACCAMMINA ARENOSA
201.1 205.7 206.4 216.4 222.6 231.6 237.9 257.7 277.3 278.2	L85.9 L94.2 201.1 205.7 206.4 216.4 222.6 231.6 237.9 257.7 277.3 278.2	· · · · · · · · · · · · · · · · · · ·	·	- 100 100 - 10						· · · · · · · · · · · · · · · · · · ·		· · · · · · · · · · · · · · ·				· · · · · · · · · · · · · · · · · · ·					· · · · · · · · · · · · · · · · · · ·			······			· · · · · · · · · · ·	

Fig. 12. Foraminifera distribution in GSQ Springsure 6. Range-chart of presence/absence by lowest appearance.

This species occurs in: GSQ Springsure 3 at 59.0 m (lowermost Peawaddy Formation); GSQ Taroom 10 at 734.9 m (lowermost Peawaddy Formation); an outcrop sample of the Flat Top Formation, southeast Bowen Basin, and of the Gigoomgan Limestone, Gympie Basin.

THURAHHINOIDES SPHAEROIDALHHANHH	
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SIJIIUS AIMAJOVHTHDI	
ATATEODIVEAL AIRAJOYHTHOI	· · · · · · · · · · · · · · · · · · ·
ANITAZZAND AINALOVHTHOI	•••••
HONCHINELLA INCISA	· • • • • • • • • • • • • • • • • • • •
HONCHINELLA INPOLITA	· · · · · · · · · · · · · · · · · · ·
.q= 23TIA903H	· · · · · · · · · · · · · · · · · · ·
EDCRISTELLARIA INITIALIS	· · · · · · · · · · · · · · · · · · ·
аяван антлатизо	••••• <u>•</u> ••••••••
CALCIVERTELLA ADHAERENS	• • • • • • • • • • • • • • • • • • •
CALCITORNELLA HEATHI	••••••••••••••••••••••••••••••••••••••
SHHOVERTELLINA GLOHOSPIROIDES	· · · · · · · · · · · · · · · · · · ·
HEANDROSPIRA	•••••• = •••••• §
LUNUCAHHINA ANING	· • • • • • • • • • • • • • • • • • • •
нонснінегге ноорневої	• • • • • • • • • • • • • • • • • • •
TROCHAHHINA LAEUIS	• • • • • • • • • • • • • • • • • • •
ATAJUONU ANIHHAAYJOT	• • • • • • • • • • • • • • • • • •
-де женаозя	· · · · · · · · · · · · · · · · · · ·
NODOSARIA SPRINGSURENSIS	· · · · · · · · · · · · · · · · · · ·
ISTARSO AISAROON	· · · · · · · · · · · · · · · · · · ·
ADIAHIJ AIMAJOYHTHJI	······
HONCHINELLA STRIATOSULCATA	
HONCHINELLA HILLAE	····· ··· · · · · · · · · · · · · · ·
HONCHINELLA COSTATA	· · · · · · · · · · · · · · · · · · ·
номентиегсы высых	
HILLELLA HARGINODENTATA	1 · · · · · · · · · · · · · · · · ·
GLOHOSPIRELLA PP.CT.G. UMBILICATA	· · · · · · · · · · · · · · · · · · ·
CLOHOSFIRELLA NYEI	
GLOHOSPIRA ADHERENS	SSC
АЗОАЛИТИА АНТИКАЗОВА	
HYPERANNINA CI. HEBDENENSIS	
HIPPOCREPINELLA BIAPERTA	
PSEUDONODOSARIA BOREALIS	
HADEBOHNING HEBDENENIZ	istr
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Key species. Calvezina sp., Dentalina habra, Ichthyolaria laevicostata, Howchinella incisa, Pilammina sp., Trochammina laevis.

Distribution. GSQ Springsure 3: from 141.2 to 59.0 m, type section; GSQ Springsure 2: at

243.0 m; GSQ Springsure 10: from 242.1 to 145.0 m; GSQ Springsure 19: from 657.0 to 655.0 m; GSQ Eddystone 4: at 734.4 m; GSQ Eddystone 1: from 774.2 to 759.0 m; GSQ Eddystone 4: at 99.2 m; GSQ Taroom 10: at 734.9 m; GSQ taroom 11: at 141.2 m.

106.6 1113.3 114.3 114.7 114.7 114.7 115.2 1116.7 1116.7 1116.7 121.9 252.5 257.0

.q= AISAJUTKETOBOJO ICHTYOLARIA SUTILIS CALCITORNELLA STEPHENSI HOOKEINERRY = D. HAPLOPHRAGHOIDES =p. SHHODISCOS HOFLICINCIOS TREPEILOPSIS AUSTRALIENSIS SPANDELINOIDES 8P. PLUMHERINELLA Sp. HAICHELINA - TINGULONODOSARIA = P. ICHTYOLARIA LIMPIDA HONCHINELLA HOODWARDI HEHIGORDIUS HARLTONI EOCRISTELLARIA INITIALIS CALCITORNELLA ELONGATA HONCHINELLA HANTUANENSIS CKYPTOSEPTIDA CASEVI AJJIZUS ANIHHAHTADA HYPERAMMINA CT. HEBDENENSIS PSEUDOTRISTIX =p. 4 AJJUAHA ANINHADDAR PSEUDONODOSARIA BOREALIS ORTHOUERTELLA PROTEA NODOSARIA SPRINGSURENSIS ITTADDAS AISAROOON NODOSARIA DRAFERI HONCHINELLA STRIATOSULCATA HONCHINELLA PARRI HONCHINELLA INCISA HOWCHINELLA COSTATA HONCHINELLA AULAX GLOHOSPIRELLA NYEI CLOHOSPIRA =p. CLOHOSPIRA ADHAERENS DENTALINA HABRA IVAND ANIJATNED CALCIVERTELLA ADHAERENS сыссттовиесся невтні витерияяор гиретия АТАЈИДИИ АИІМНАЧУЈОТ HAPERAHHINA FLETCHERI ANHOVERTELLINA GLOHOSPIROIDES



Howchinella mantuanensis Zone

Synonymy. Assemblage Zone C3 (Palmieri 1983).

The index taxon represent the last stage of the evolutionary lineage of the howchinellid in the Permian of Australia and it may feature a certain amount of endemism. Abundant Agathammina pusilla and Cryptoseptida caseyi give affinity with association of Midian age (Pronina 1988). The zone include sediments of the Mantuan Productus Bed and the very first glauconitic sandy siltstone of the Black Alley Shale. The latter represents the last stage of a shallow restricted marine environment with the area subjected to uplift and consequent creation of a lacustrine environment.

Key species. Agathammina pusilla, Cryptoseptida caseyi, Hemigordius harltoni, Maichelina sp., Plummerinella sp.

Distribution. GSQ Springsure 2: from 115.7 to 114.3 m, type section.

CONCLUSION

Sediments drilled in the Denison Trough (a Sub-Basin of the Bowen Basin) can be subdivided in foraminiferal zones which serve to independently correlate the stratigraphy of the boreholes. The

	AMMODISCUS CORRUGATUS	AMHODISCUS MULTICINCTUS	AMHODISCUS NITIDUS	GLOMOSPIRELLA Sp. cf. G. UMBILICAT	HYPERAMMINA Cf. HEBDENENSIS	PSEUDONODOSARIA BOREALIS	THURAMMINDIDES SPHAERDIDALIS	GLOMOSPIRELLA NYEI	NODOSARIA RAGGATTI	REOPHAX sp.indet.	I SACCAMMINA AMPULLA	HYPERAMMINA FLETCHERI	ТОСУРАНИТИА UNDULATA	HAPLOPHRAGHOIDES SP.	TROCHAMMINA LAEVIS	I AMMOBAGULITES Cf. MANDAGEENSIS	AMMOVERTELLINA GLOMOSPIROIDES	AMMOVERTELLA SP.			
145.0	1	•			•								1		1			1	145.	0	
161.2			•	•		•	•		•	•	•	-				•		-	150.	3	
239.4	•	•	•	•	1	•	•	•	•	•	•	1	-	•		•	•	•	239	4	
241.4		÷	•	•		•	•	÷	•	÷	•			÷	÷	÷	•	•	241	4	
242.1		-					:	1			•		•	ł	1		•	•	242.	1	
243.7															-			:	243.	7	
373.9												-	-						373.	9	
384.0											-								384.	0	

Fig. 15. Foraminifera distribution in GSQ Springsure 10. Range-chart of presence/absence by lowest appearance.

amount of diachroneity perceived, which has to be expected when considering the migration and the settlement of the fauna, does not seem to have reached unreasonable proportion. This simple biostratigraphic scheme may work as a basis for further and more refined research, perhaps requiring the establishment of field stratigraphic sections for multidisciplinary studies, including the correlation with coeval section of the Boreal Hemisphere. For example, the record of the first occurrence of a species of the genus *Pilammina* here reported may point to such achievement.

ACKNOWLEDGEMENTS

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	AMMODISCUS CORRUGATUS	AMMODISCUS MULTICINCTUS	GLOMOSPIRELLA NYEI	HYPERAMMINA FLETCHERI	THURAMMINDIDES SPHAERDIDALIS	TOLYPAMMINA UNDULATA	AMMODISCUS NITIDUS	CALCITORNELLA HEATHI	HOWCHINELLA COSTATA	HOWCHINELLA HILLAE	HOWCHINELLA IMPOLITA	HOWCHINELLA INCISA	HOWCHINELLA PARRI	HOWCHINELLA STRIATOSULCATA	HOWCHINELLA NOODWARDI	HYPERAMMINA Cf. HEBDENENSIS	I ICHTHYOLARIA CRASSATINA	ICHTYOLARIA LIMPIDA	I ICHTYOLARIA SUTILIS	LINGULONODOSARIA SP.	NODOSARIA DRAPERI	NODOSARIA RAGGATTI	PSEUDONODOSARIA BOREALIS	I REOPHAX sp.indet.	HILLELLA MARGINO DENTATA	HOWCHINELLA AULAX		
48.3																											448.3	
70.0																											470.0	
79.6																7									7		479.6	
83.7																								7			483.7	
			-		-	-																					100 7	

Fig. 16. Foraminifera distribution in GSQ Springsure 18. Range-chart of presence/absence by lowest appearance.

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	AMMODISCUS MULTICINCTUS	AMMODISCUS NITIDUS	HYPERAMMINA FLETCHERI	REOPHAK SUBASPER	SACCAMMINA sp.	H HYPERAMMINA PULUILLA	AMMODISCUS CORRUGATUS	GLOMOSPIRELLA NVEI	HYPERAMMINA Cf. HEBDENENSIS	EOCRISTELLARIA INITIALIS	HOHCHINELLA AULAX	HOWCHINELLA STRIATOSULCATA	HOUCHINELLA HOODHARDI	ICHTYOLARIA SUTILIS	NODOSARIA RAGGATTI	PSEUDONODOSARIA BOREALIS	AMMOVERTELLINA GLOMOSPIROIDES	AMMOVERTELLA SP.	GLOMOSPIRELLA SP. Cf. G. UMBILICATA	REOPHAX BELFORDI	ТОСУРАНИТИА ИNDULATA	TROCHAMMINA LAEVIS	I AMMOBACULITES SP.	REOPHAX 8p.	TROCHAMMINA sp. indet.	
503.0																										503.0
513.8																										513.8
513.9																										513.9
514.6			•	•			•																			514.6
572.0			•						7									7								572.0
605.0	•	•																								605.0
610.3		•		•	•	• •	•		-		•															610.3
613.0	- 7		-	•			•	•			•															613.0
654.4	•	•		•	•	•		•		•	•															654.4
655.0				•		•		•		•									7				-	-		655.0
657.0		-	-						-																	657.0
657.4		-														-		-	-							6 mm 1
										•	-						•				7					657.4
737.0		•		:						:	-	:	:	:	:	ļ	i	÷	ļ	•	:	-	:	:	:	657.4 737.0
737.0 737.4		•		•								•		:	:	•	i			•	•••••••••••••••••••••••••••••••••••••••	•	••••••	•	•	657.4 737.0 737.4
737.0 737.4 765.3		• • • •		• • • •				•		••••	•	•	•••			•				••••••	•••••	• • • •	• • • •	•••••	• • • •	657.4 737.0 737.4 765.3
737.0 737.4 765.3 1131.2				• • • • •	-			·		•••		•••	•••			· · · ·			• • • •	• • • • •			• • • •	• • • •	• • • • •	657.4 737.0 737.4 765.3 1131.2
737.0 737.4 765.3 1131.2 1160.0			•		-			· · · · · ·		· · ·	· · · · · · ·	· · · · · · ·	•••			· · · · ·				• • • • • •	· · · · · ·				• • • • •	657.4 737.0 737.4 765.3 1131.2 1160.0

Fig. 17. Foraminifera distribution in GSQ Springsure 19. Range-chart of presence/absence by lowest appearance.

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	AMMODISCUS NITIDUS	PSEUDONODOSARIA SEROCOLDENSIS	HVPERAMMINA HEBDENENSIS	UERISPIRA JELLI	AMMODISCUS CORRUGATUS	HYPERAMMINA FLETCHERI	HYPERAMMINOIDES ELEGANS	NODOSARIA RAGGATTI	THURAMMINOIDES SPHAEROIDALIS	AMMOBACULITES ECCENTRICUS	SACCAMMINA AMPULLA	TOLYPAMMINA UNDULATA	PSEUDONODOSARIA BOREALIS	TROCHAMMINA LAEVIS	CALCITORNELLA ELONGATA	CALCITORNELLA HEATHI	HOWCHINELLA WOODWARDI	LUNUCAMMINA MAIOR		
734.4		•							•	•	•	•							734.4	
745.8	•	•	•	•	•	•	·	•			:				•	•	•	•	745.8	
754.1	•	•	•	•				:					•	•	:	•	•	•	754.1	
760.3		•	•	•						•	•	•	•	•	•	٠	•	•	760.3	
1220.6	-				•	•	•	•	•	•	•	٠	•	•	•	•	•	•	1220.6	
1279.1			•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	12/9.1	

Fig. 18. Foraminifera distribution in GSQ Eddystone 5. Range-chart of presence/absence by lowest appearance.

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	HONCHINELLA AULAX	HOWCHINELLA WOODWAR	TROCHAMMINA Sp.	UERISPIRA JELLI	CALCITORNELLA HEATH	I AMMODISCUS CORRUGA	GLOMOSPIRELLA NYEI	ICHTHYOLARIA SUTIL	HAMADISCUS MULTICI	HYPERAMMINA FLETCH	HILLELLA MARGINODE	HOWCHINELLA COSTATA	HAPLOPHRAGMOIDES SI	TROCHAMMINA LAEVIS	Тосуранития имриса	THURAMMINOIDES SPH	H AMMODISCUS NITIDUS	HYPERAMMINA Cf. HE	GLOMOSPIRA Sp.	PSEUDONODOSARIA BO			
601.8 652.4 657.8 673.2 701.3 709.8 719.3 720.7 724.9 743.0 759.0 767.7 774.2 783.5 786.4 787.5						· ·															6 6 6 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7	01.8 52.4 57.8 73.2 01.2 09.1 19.2 20.2 24.2 43.1 59.2 67.2 74.2 83.2 86.2 87.2 89.2	84823837900725457
930.0 933.0 948.6		•	•				•	•					•	• • • •	•				• • • •	•••••••••••••••••••••••••••••••••••••••	999)30.)33.)48.	000

Fig. 19. Foraminifera distribution in GSQ Eddystone 1. Range-chart of presence/absence by lowest appearance.

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	99.2	118.7	2.171	213.6	215.9	1.924	552.5	584.6	612.8	654.7	654.7	670.4	4.269	1. 607	720.3	724.9	280.6	789.5	792.9	879.4	6.816	
SISNELLANTEUR SIZAOLIENSIS																						
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SELLERE ALRADOVHTHOL	-	• •	• •	• •	• •	• •	• •	•	• •	•••	• •		• •	•	• •	•	• •	• •	•	• •	•	
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PSEUDONODOSARIA BOREALIS		-				: :								:		•			:	: :		
HILLELLA HARGINODENTATA	-		-												11	:				11		
TIDOLARIA INFOLIA																						
HONCHINELLA COSTATA		. 1			•																	
CLOHOSPIRELLA NYEI	-	-		-	-																	
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HYPERANHINA CT. HEBDENENSIS			•	•		•	• •	•	• •	• •	• •	•	• •	•	• •	•	• •	• •	•	• •	•	JCc
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PSEUDONODOSARIA SEROCOLDENSIS	• •	•	• •	• •	•	• •	• •	•	- ·	-	• •	•	• •	•	• •	•	• •	•	•	• •	•	dd
PROTOHODOSARIA IRHIHEHSIC	• •	•	• •	• •	•	• •	• •	•	• •	-	• •	•	•••	•	• •	•	• •	•	•	• •	•	G
CALCIVERTELLA #P.CT. C. ADHERENS	• •	•	• •	• •	•	• •	• •	•	• •		• •	•	• •	•	• •	•	• •	•	•	• •	•	est
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ICHTHYOLARIA LINAIDA		-	• •	• •		• •						-	·		• •	•	• •		•			10
AUDITHA AISAZOGONOGUJEª			•••	• •								<u> </u>							:			S
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REOPHAN HINUTISSITUS	• •	•	• •	• •	• •		•••	-	• •	-	• •	-	-	-	-	•	• •	•	•	• •	•	12
HOOREINELLA RECURVATA	• •		•••	• •	• •	• •	• •	•	• •	•	• •	• •	1		-	•	• •	•	•	• •	•	36
HOOREINELLA BOOKERI	• •	•	• •	• •	• •		• •		• •		•••	• •	-	• •	•	• •	•	•	•	• •	•	an
CLOBIVALVULA BULLOIDES	• •	•	• •	• •	• •		• •	•	• •	-	•	• •	• •	• •		• •	•	•	•	• •	•	R
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Range-chart of presence/absence by lowest appearance. Foraminifera distribution in GSQ Taroom 10. Fig. 21.

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-de MNINHAJI9 HONCHINELLA HANTUANENSIS -de SEGIONITEGNUS NODOSARIA SPRINGSURENSIS ICHTHYOLARIA SUTILIS HONCHINELLA STRIATOSULCATA HONCHINELLA HILLAE -de WRITULIUNG HONCHINELLA INCISA GLOHOSPIRELLA =p.cf. G.UMBILICATA PSAHHOSPHAERA PUSILLA HOOKEINERTH =D - THEULONODOSARIA =P. ICHTHYOLARIA LIMPIDA ANITARZAND AIMAJOYHTHDI EDCRISTELLARIA INITIALIS SHHOVERTELLINA GLOHOSPIROIDES ANHOBACULITES ECCENTRICUS PSEUDONODOSRIA BOREALIS ITTADDAS AISA2000M HODDSARIA DRAPERI D. ... HONCHINELLA AULAX HILLELLA HARGINODENTATA DENTALINA GRAVI SACCANNINA NENISPHAERICA ICHTHYOLARIA IMPOLITA HYPERAMMINA CI. HEBDENENSIS CLOHOSPIRELLA NYEI SUTADUARDO SUDEIDONNA THURAHHINOIDES SPHAEROIDALIH HYPERRHHINA HEBDENENSIS TROCHANNINA PULVILLA HEANDROSPIRA =P.1 аллична антинарраг PROTONODOSARIA TERETA PROTONODOSARIA IRWINENSIS ORTHOUERTELLA PROTEA ITTADDAS.N. 10.4. AISA2000N GLOHOSPIRA ADHAERENS ATUNIH AIGNAJAR3 CALCITORNELLA HEATHI CALCITORNELLA ELONGATA SUTONIDITUNH SUDSIGONHA АТАЈИДИИ АНІННАЧУЈОТ LUNUCAHNINA TRIANGULARIS HYPERAHMINA ELEGANTISSINA нонснінєгги поорникої HEHICORDINS HARLTONI CALCIVERTELLA ADHERENS иновесисттея моогноиент -de UNINHUSSUS HOOSEINERTH BOOKERI HYPERANNINA FLETCHERI GLOHOSFIRELLA CT. NYEI SUDITIN SUDSIDONNA

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Fig. 22. Foraminifera distribution in GSQ Taroom 11. Range-chart of presence/absence by lowest appearance.

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Palmieri, V. 1998. "Foraminifera zonation in the Permian stratigraphy of the Denison Trough (Bowen Basin), Central Queensland." *Proceedings of the Royal Society of Victoria. New series* 110(1/2), 173–195.

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