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

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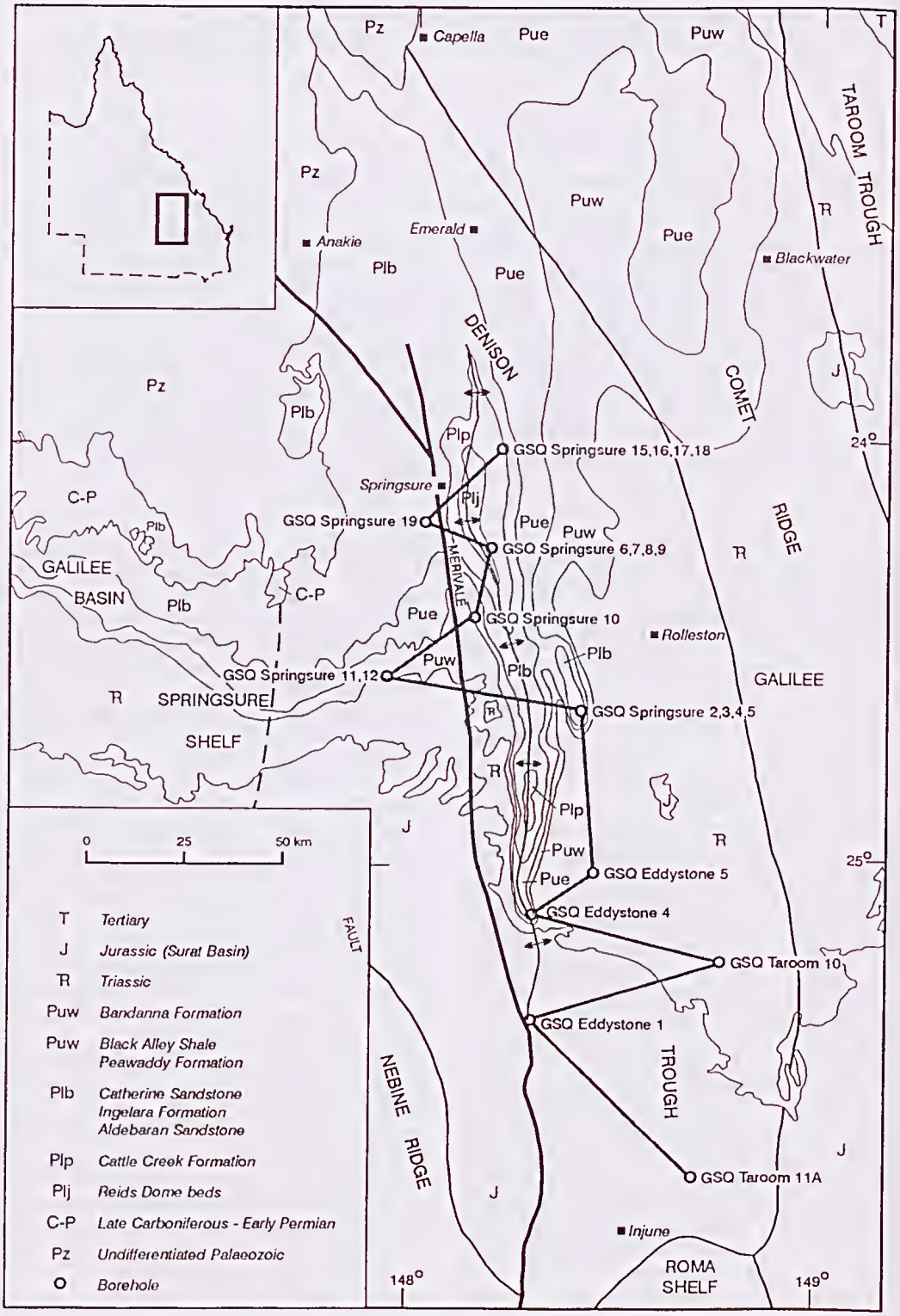
Eight biostratigraphic intervals are defined by the presence of foraminiferal index taxa in the Denison Trough lithostratigraphy. They are used to correlate 14 boreholes drilled in the flanks and periphery of the Springsure and Consuelo anticlines. The correlation is performed between intervals which 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


Pz
Capella
Pue
Puw
T
TAROOM TROUGH
R
Anakie
Emerald
Plb
Blackwater
DENISON
COMET
RIDGE
J
24°
Springsure
Plj
GSQ Springsure 15,16,17,18
GSQ Springsure 19
GSQ Springsure 6,7,8,9
MERIVALE
C-P
GALILEE
BASIN
GSQ Springsure 10
Rolleston
GSQ Springsure 11,12
SPRINGSURE
SHELF
GSQ Springsure 2,3,4,5
Plp
25°
GSQ Eddystone 5
GSQ Eddystone 4
GSQ Taroom 10
GSQ Eddystone 1
NEBINE RIDGE
TROUGH
GSQ Taroom 11A
Injune
ROMA SHELF
148°
149°
0 25 50 km
FAULT
T Tertiary
J Jurassic (Surat Basin)
R Triassic
Puw Bandanna Formation
Puw Black Alley Shale
Peawaddy Formation
Plb Catherine Sandstone
Ingelara Formation
Aldebaran Sandstone
Plp Cattle Creek Formation
Plj Reids Dome beds
C-P Late Carboniferous - Early Permian
Pz Undifferentiated Palaeozoic
Borehole

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,

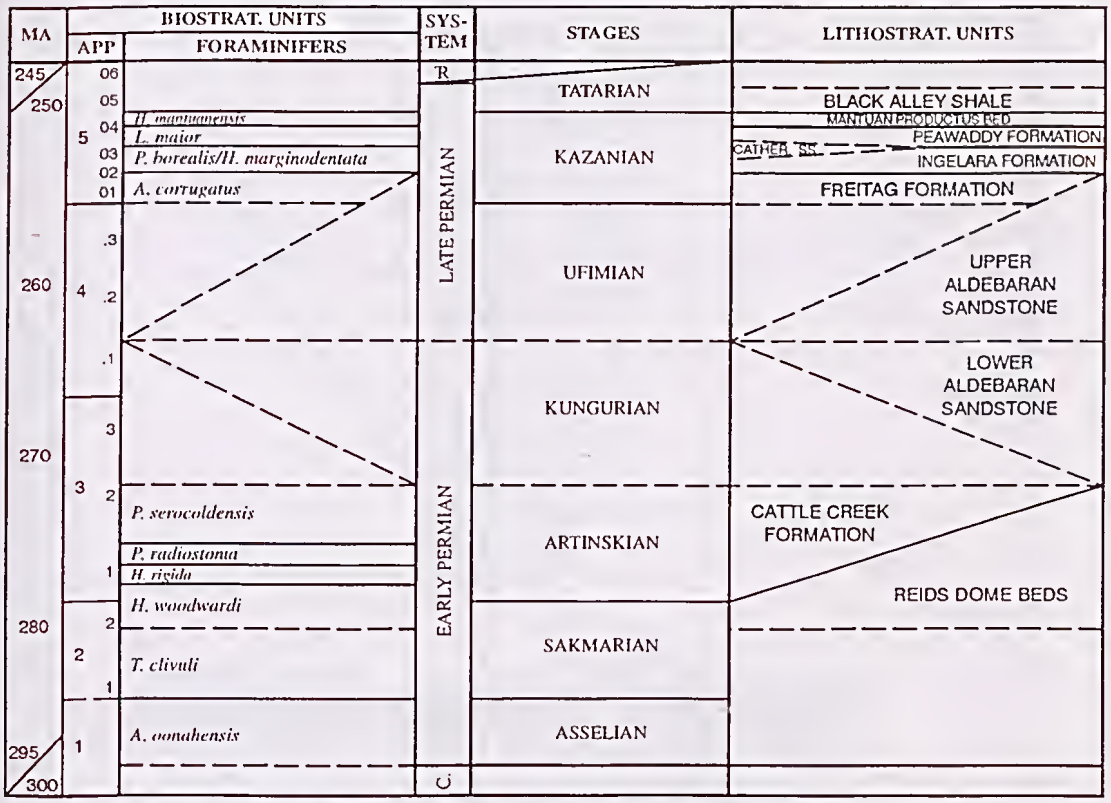


Fig. 2. Stratigraphic scheme for the Permian of the Denison Trough (modified after Roberts et al. 1996).

Fig. 1. Locality map.

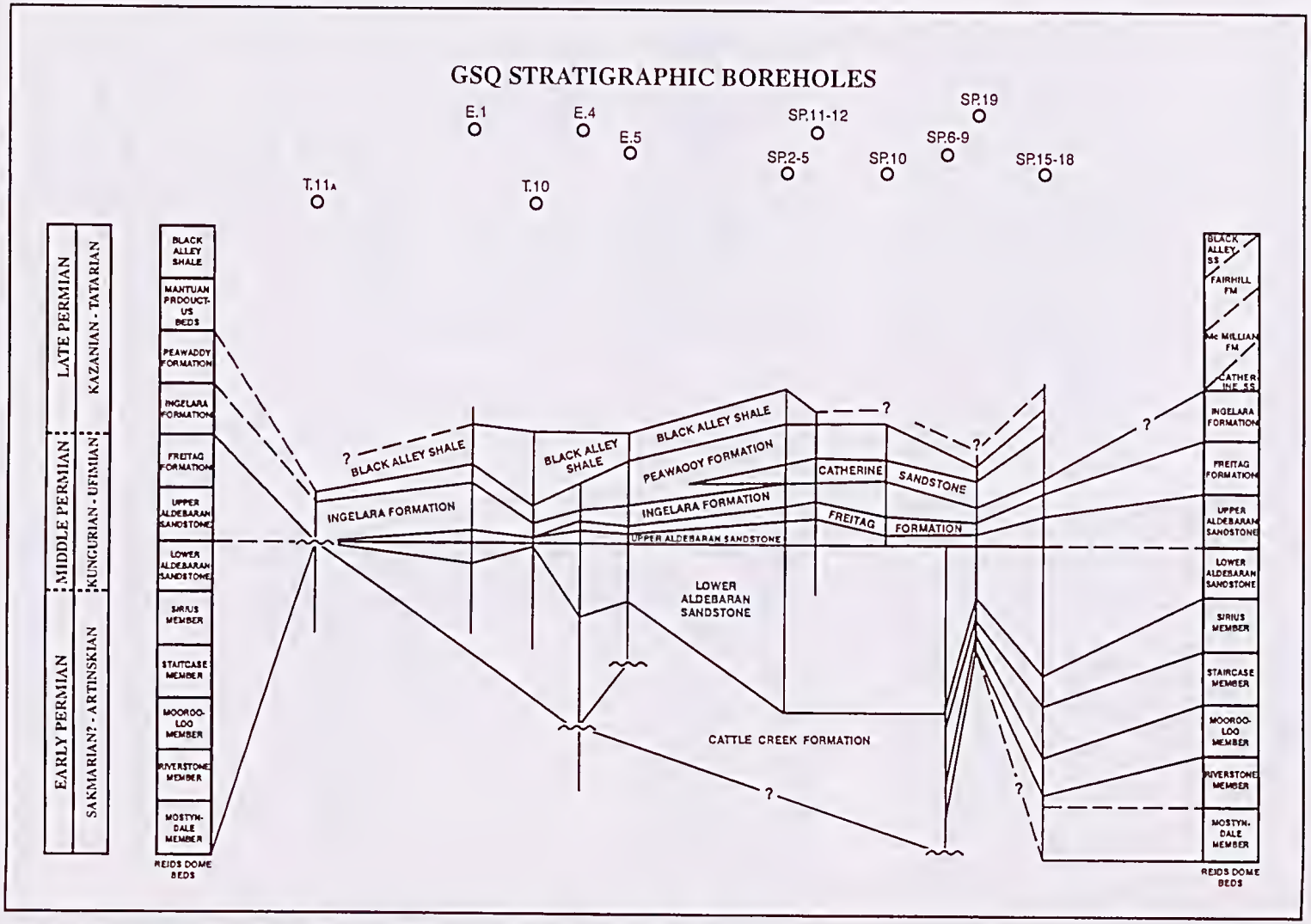


Fig. 3. Lithostratigraphic correlations between GSQ boreholes (after Gray 1976, 1980).

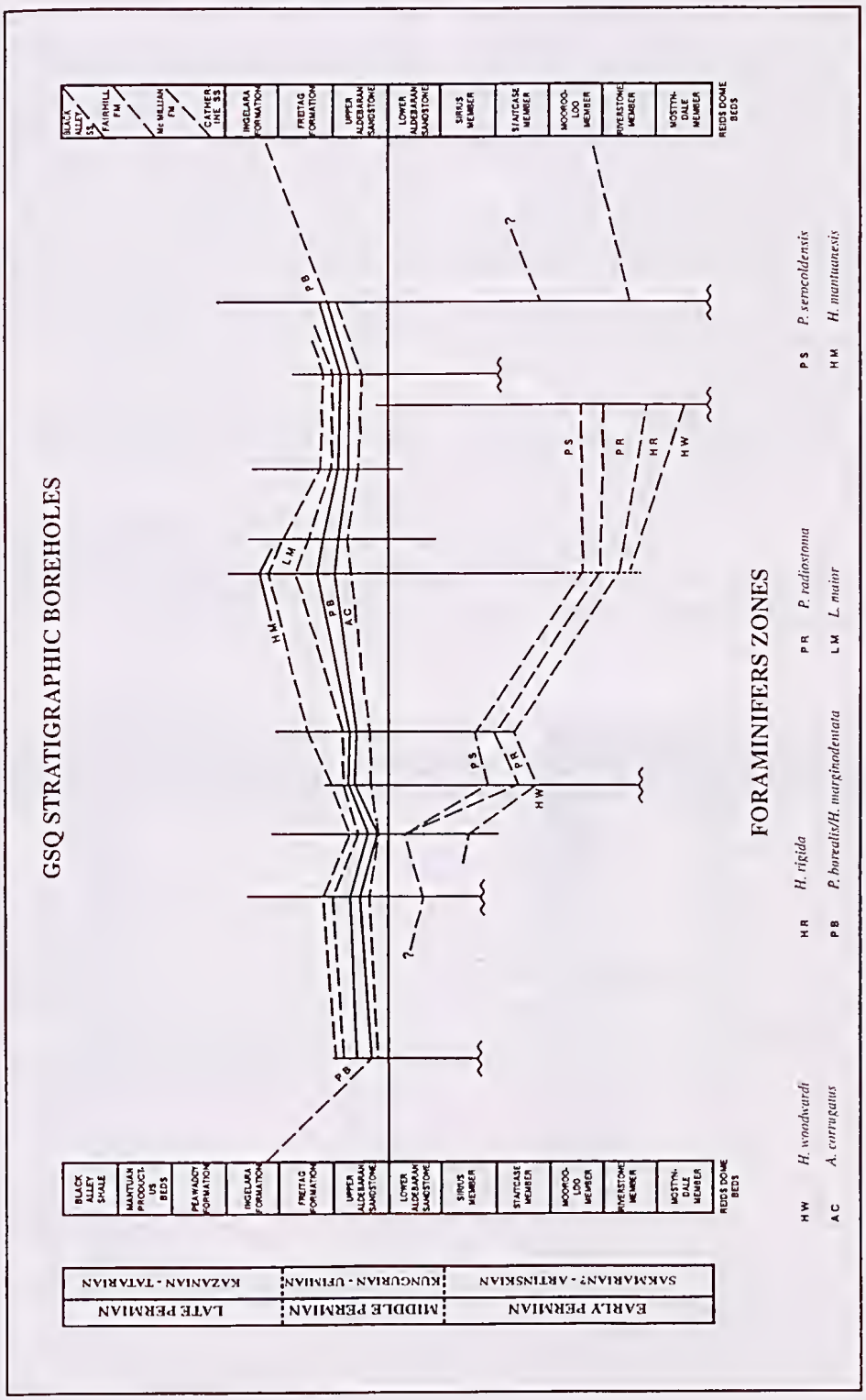


Fig. 4. Biostratigraphic correlations between GSQ boreholes based on foraminiferal zones (modified after Palmieri 1983).

in this context, zonal levels not neeessarily isoehronous. 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 biostratigraphie 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 speeies with agglutinating, ealeareous hyaline and ealeareous imperforate per sample.

Finally, Figs 9–22 are foraminifers range eharts for 14 of the 16 mentioned GSQ boreholes. These foraminifers are stored in the GSQ Mierofossil 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 speeies of which 5 are ealeareous and 20 agglutinating. The ealeareous *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 seetion; 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.

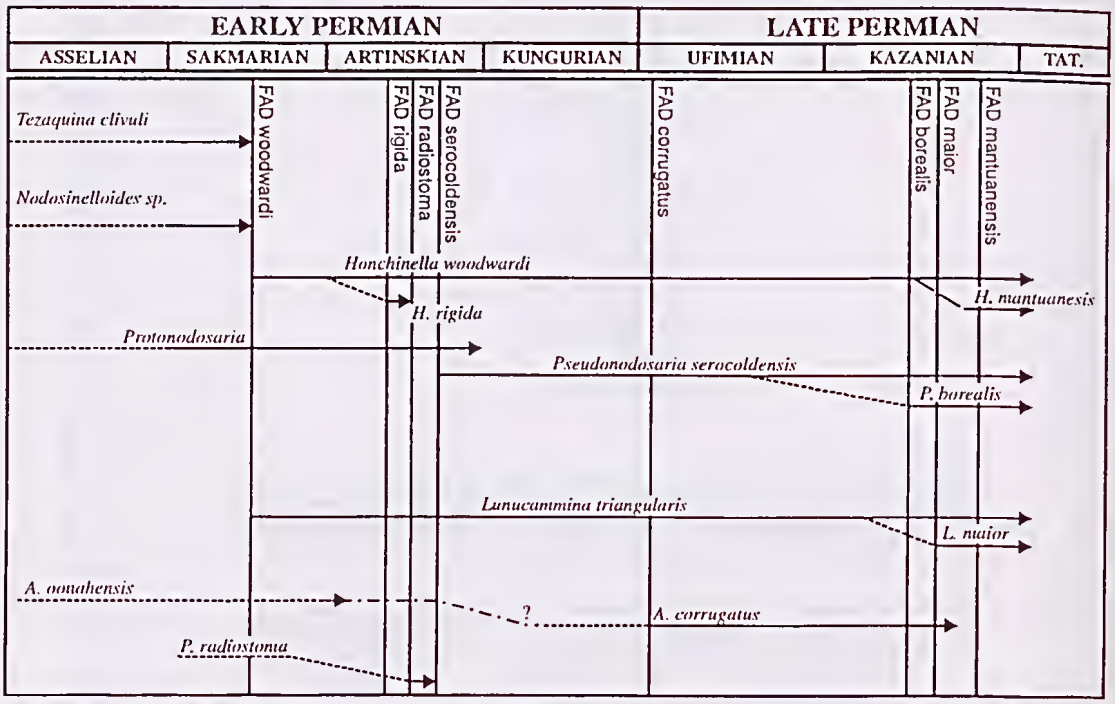


Fig. 5. Provisional biostratigraphic/evolutionary scheme for stadial subdivision from Asselian to Kazanian.

Howchinella rigida Zone

Synonymy. Assemblage Zone A2 (Palmieri 1983).

The index taxon appears in GSQ Springsure 9 at 99.4 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.

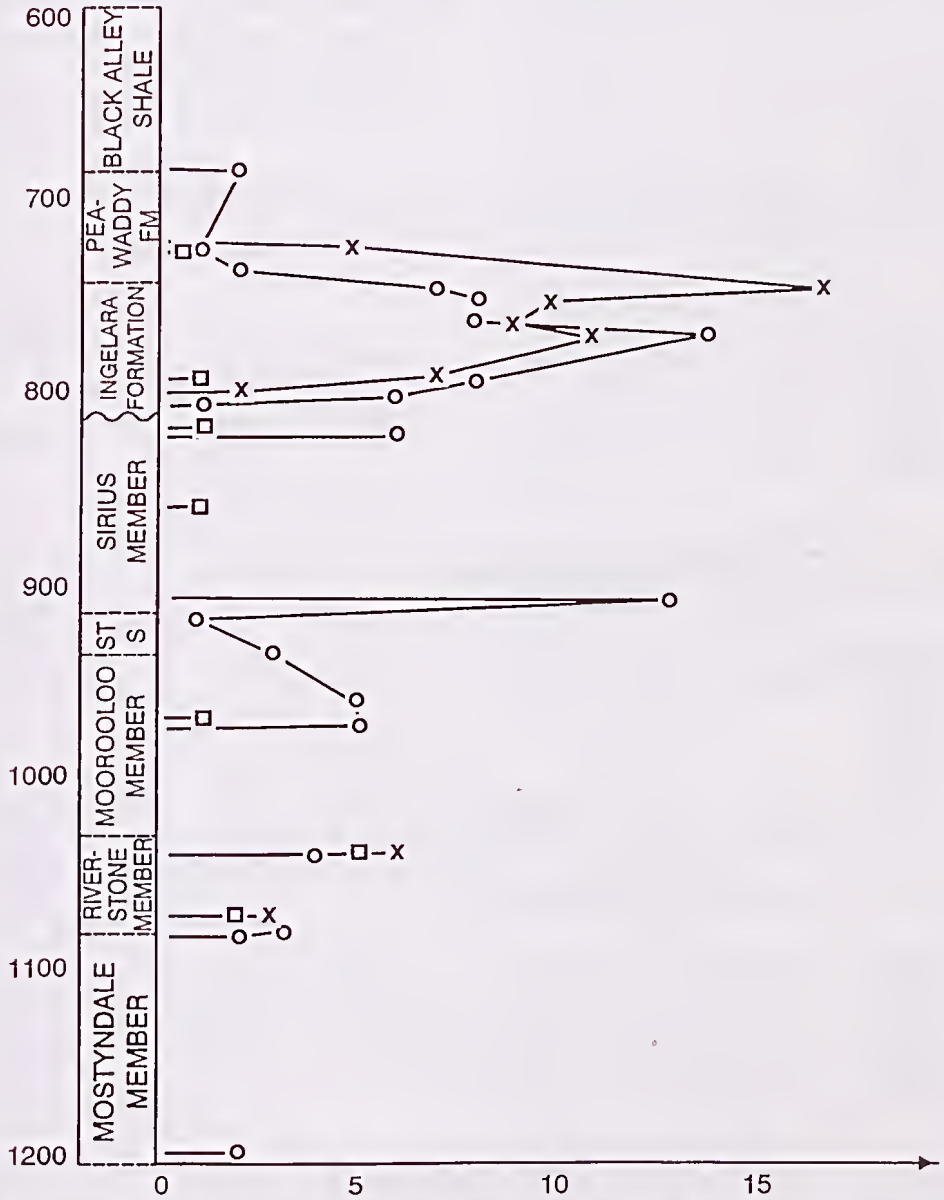


Fig. 6. Foraminiferal diversity diagram (number of species/sample) for GSQ Taroom 10 (O = agglutinating tests; X = calcareous hyaline/microgranular tests; □ = calcareous imperforate tests).

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

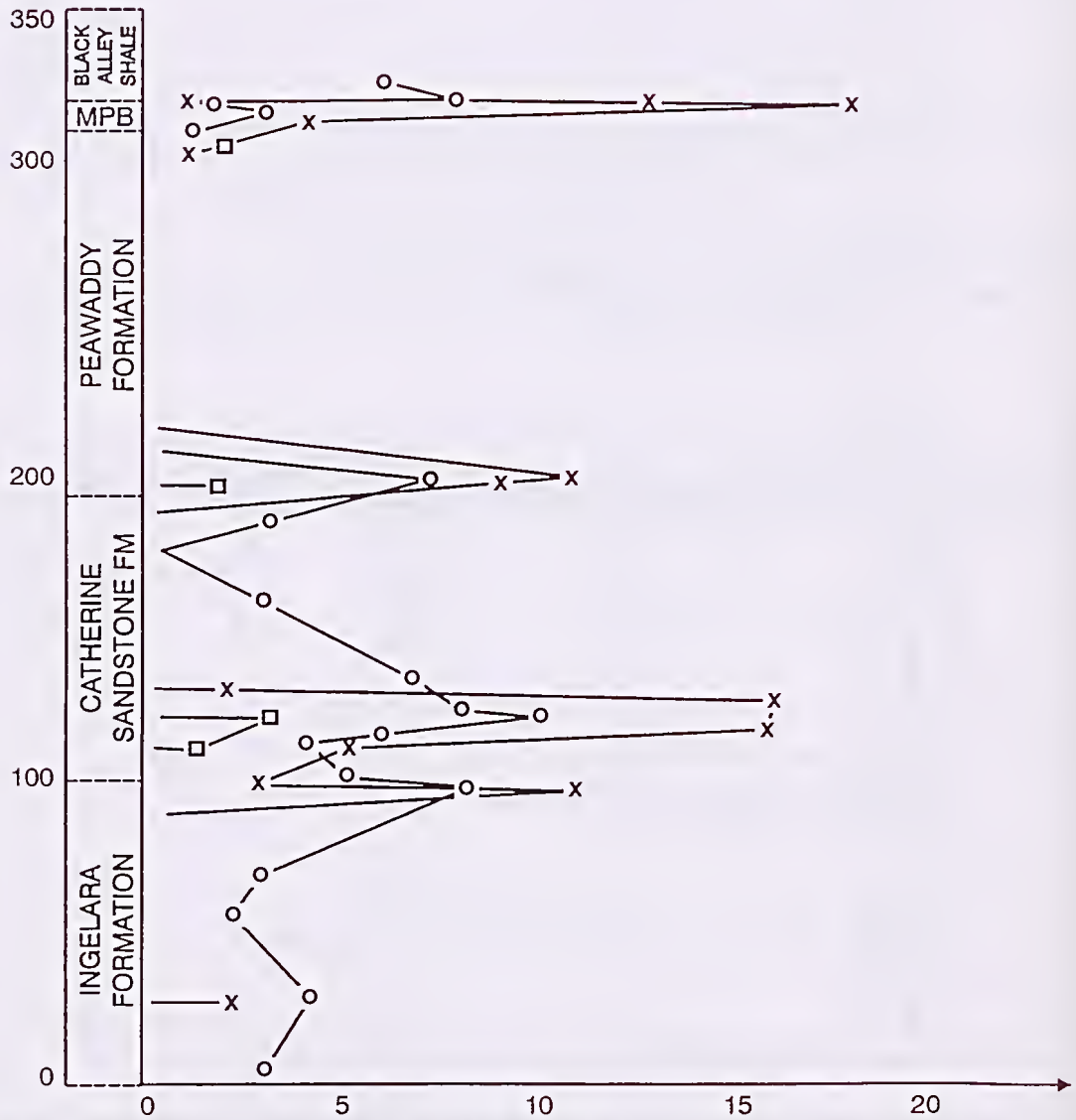


Fig. 7. Foraminiferal diversity diagram for GSQ Springsure 2 and 3 (combined). Legend as per Fig. 6.

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, Thurammina-oides 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).

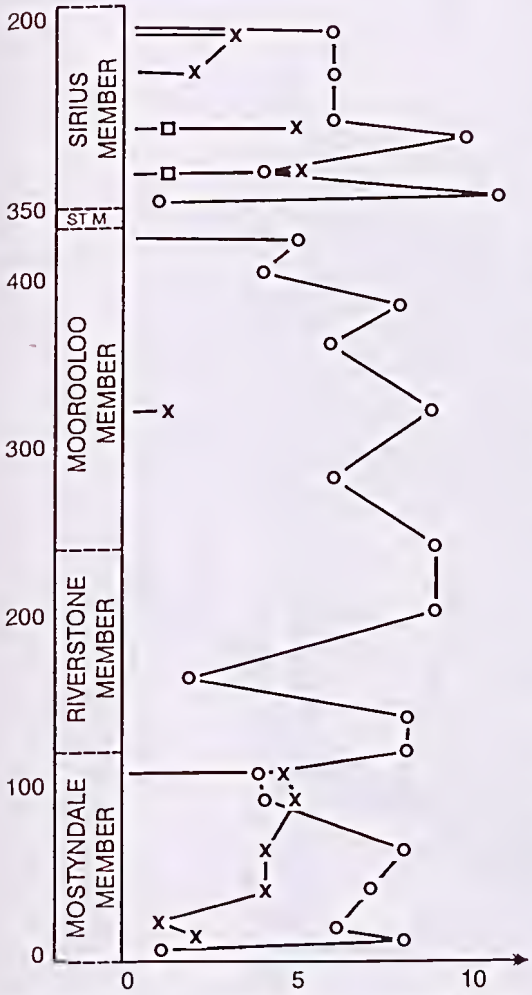


Fig. 8. Foraminiferal diversity diagram for GSQ Springsure 6–9 (combined). Legend as per Fig. 6.

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.

Similar assemblages occur in the Late Artinskian–Early Kungurian of the Western 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 elimate 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 oonaluensis* 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).

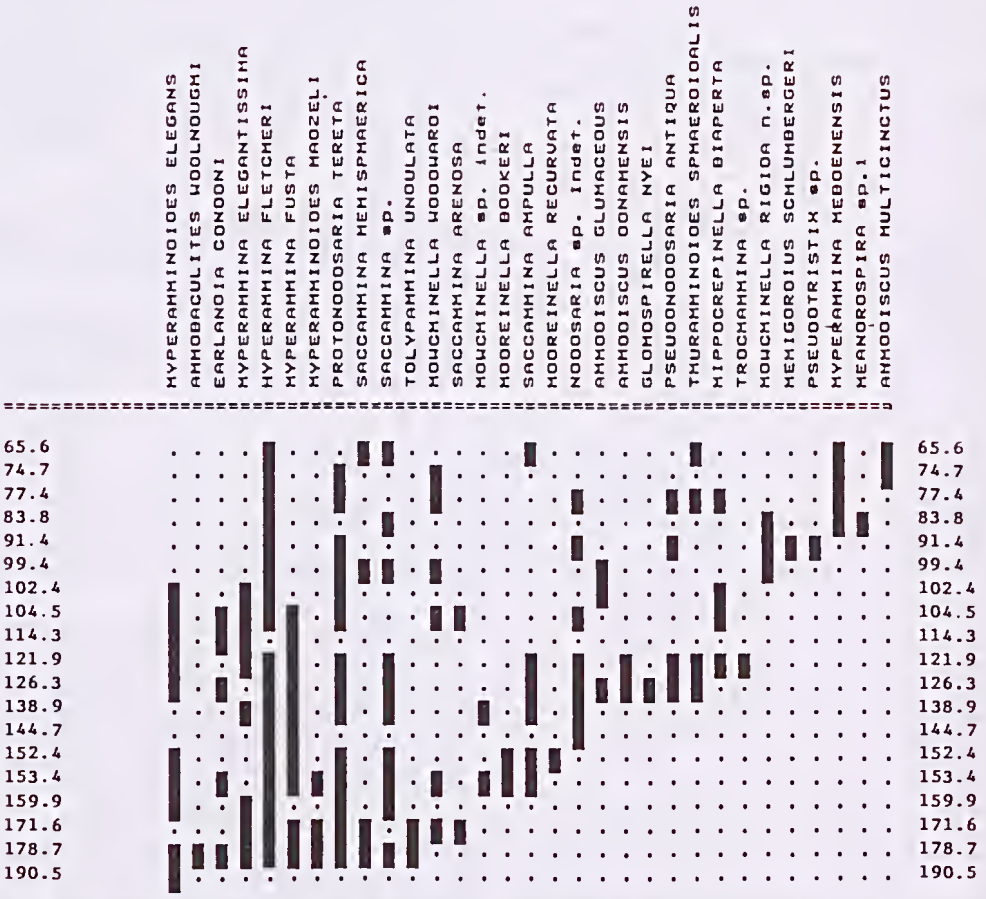


Fig. 9. Foraminifera distribution in GSQ Springsure 9. Range-chart of presence/absence by lowest appearance.

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 exeeption of the fora-

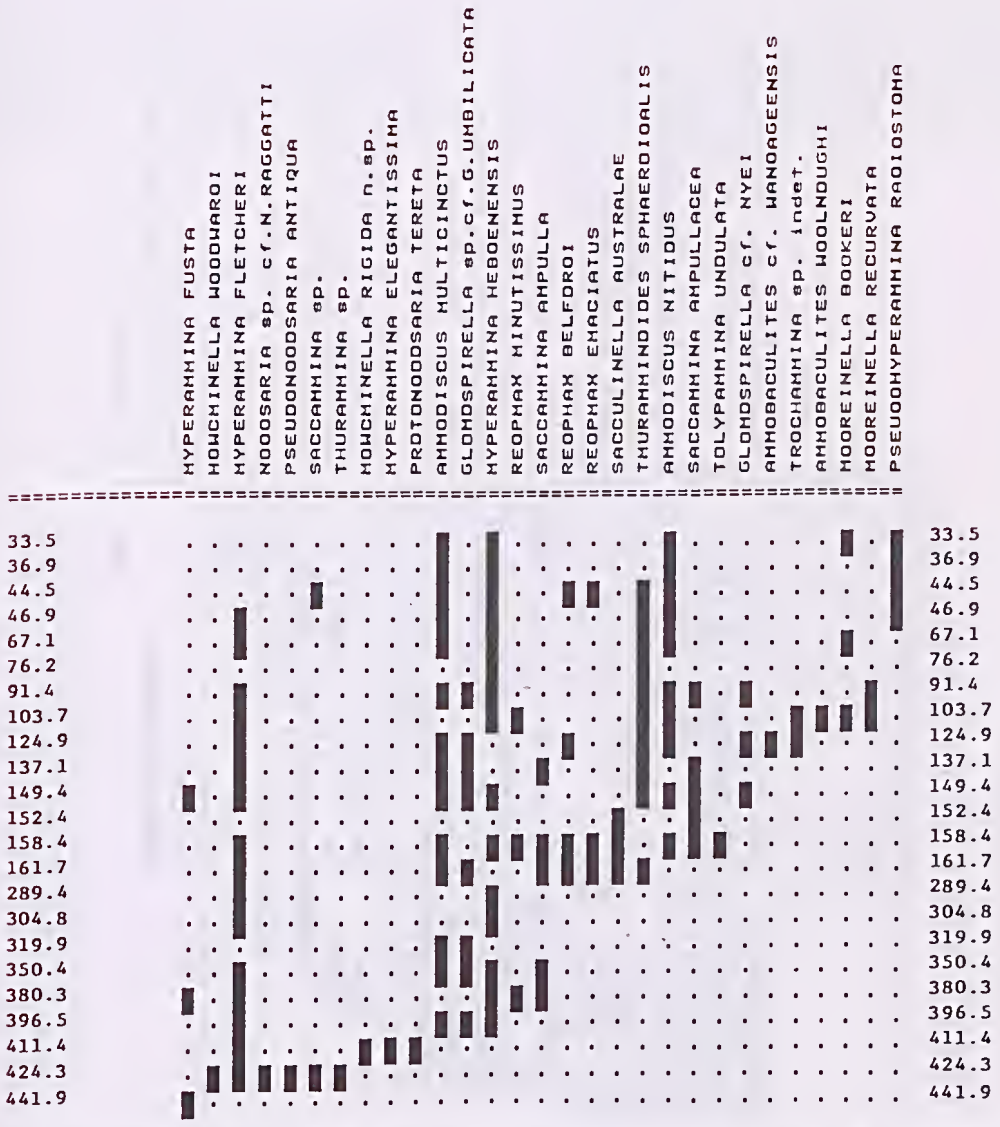


Fig. 10. Foraminifera distribution in GSQ Springsure 8. Range-chart of presence/absence by lowest appearance.

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

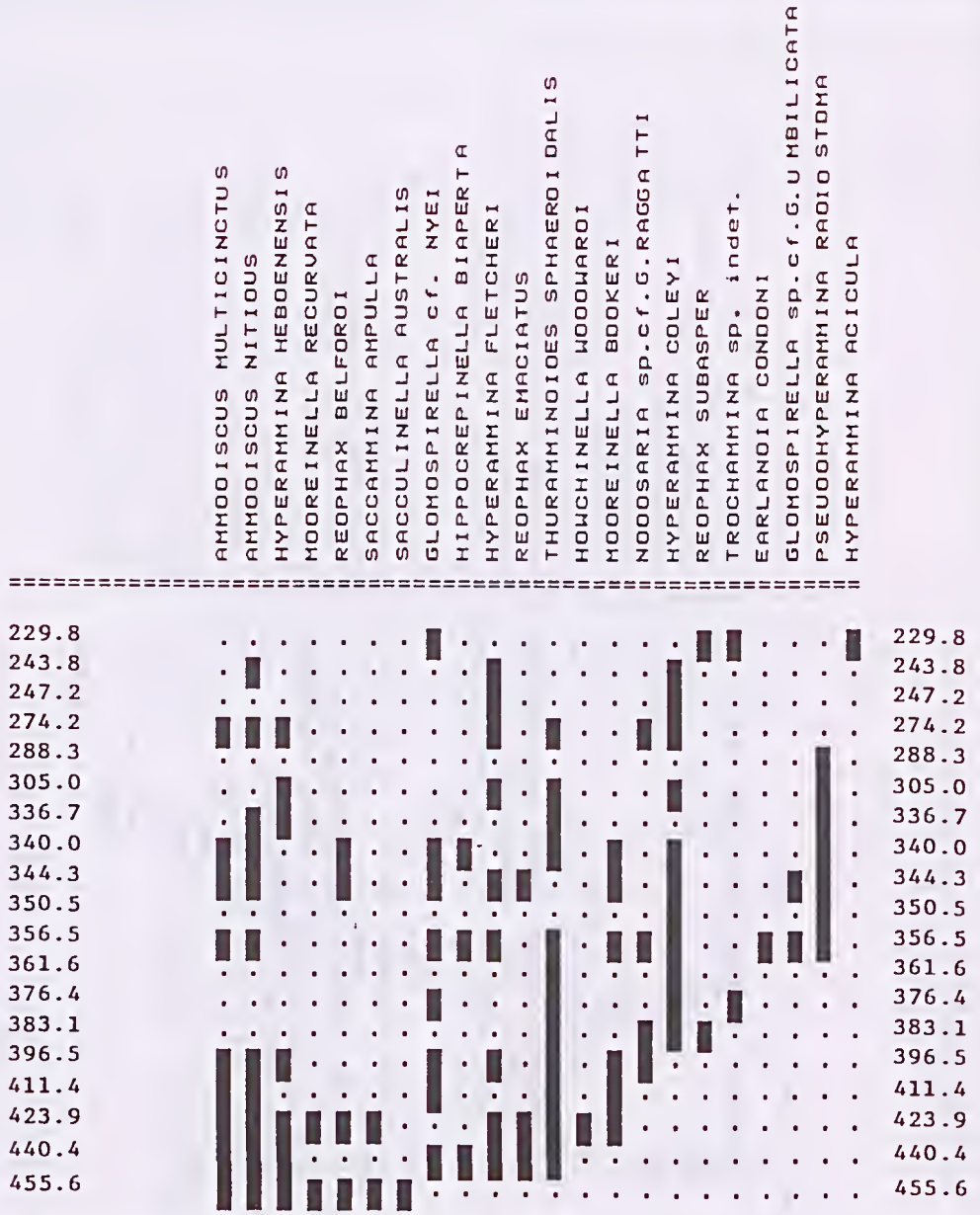


Fig. 11. Foraminifera distribution in GSQ Springsure 7. Range-chart of presence/absence by lowest appearance.

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 lunucamminids 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.

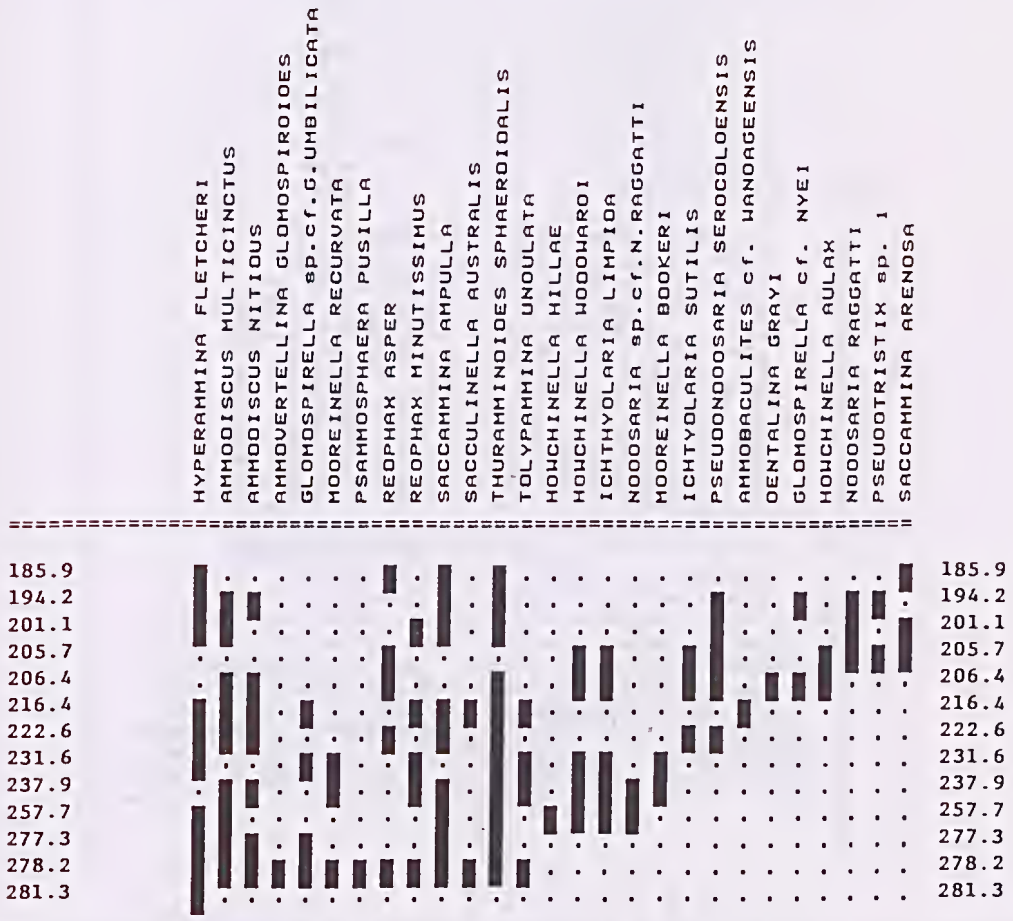


Fig. 12. Foraminifera distribution in GSQ Springsure 6. Range-chart of presence/absence by lowest appearance.

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

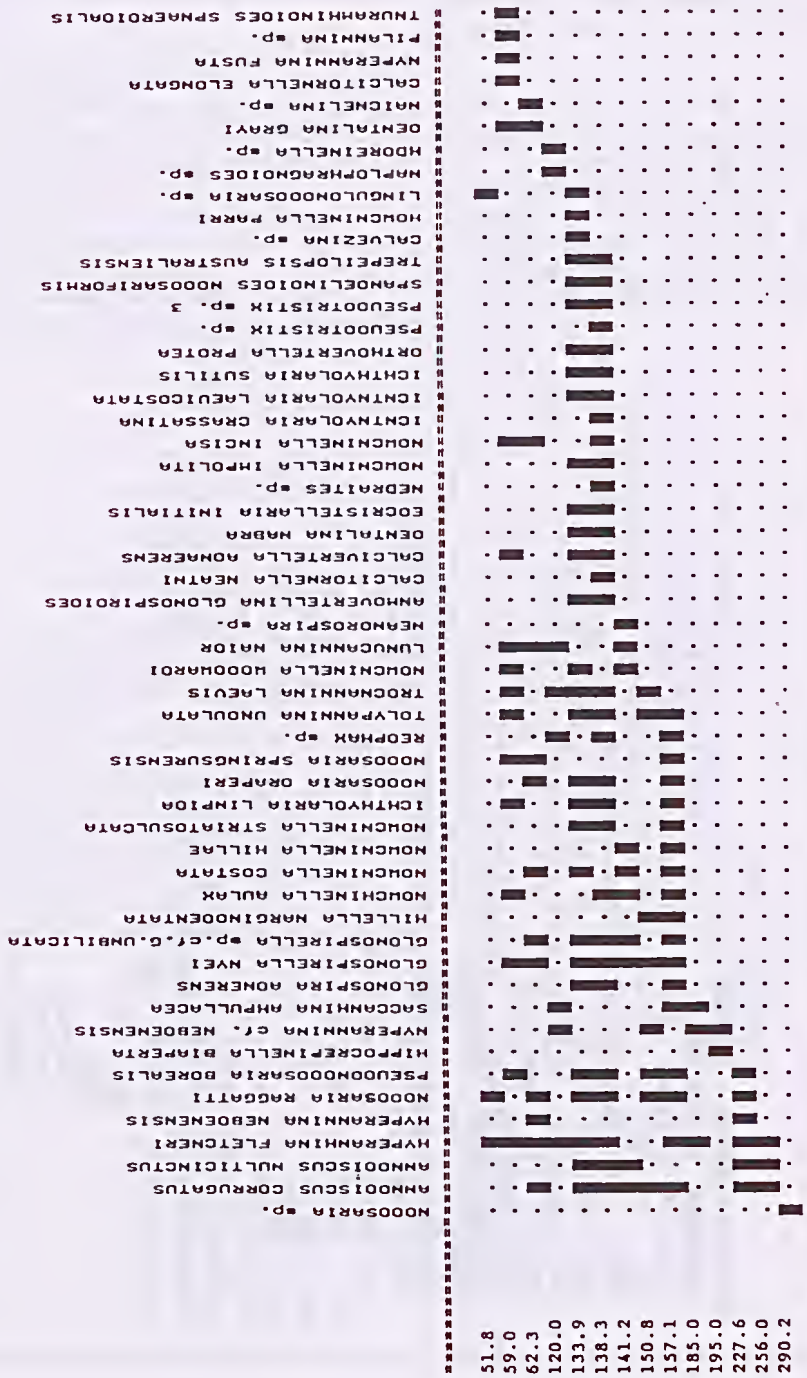


Fig. 13. Foraminifera distribution in GSQ Springsure 3. Range-chart of presence/absence by lowest appearance.

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.

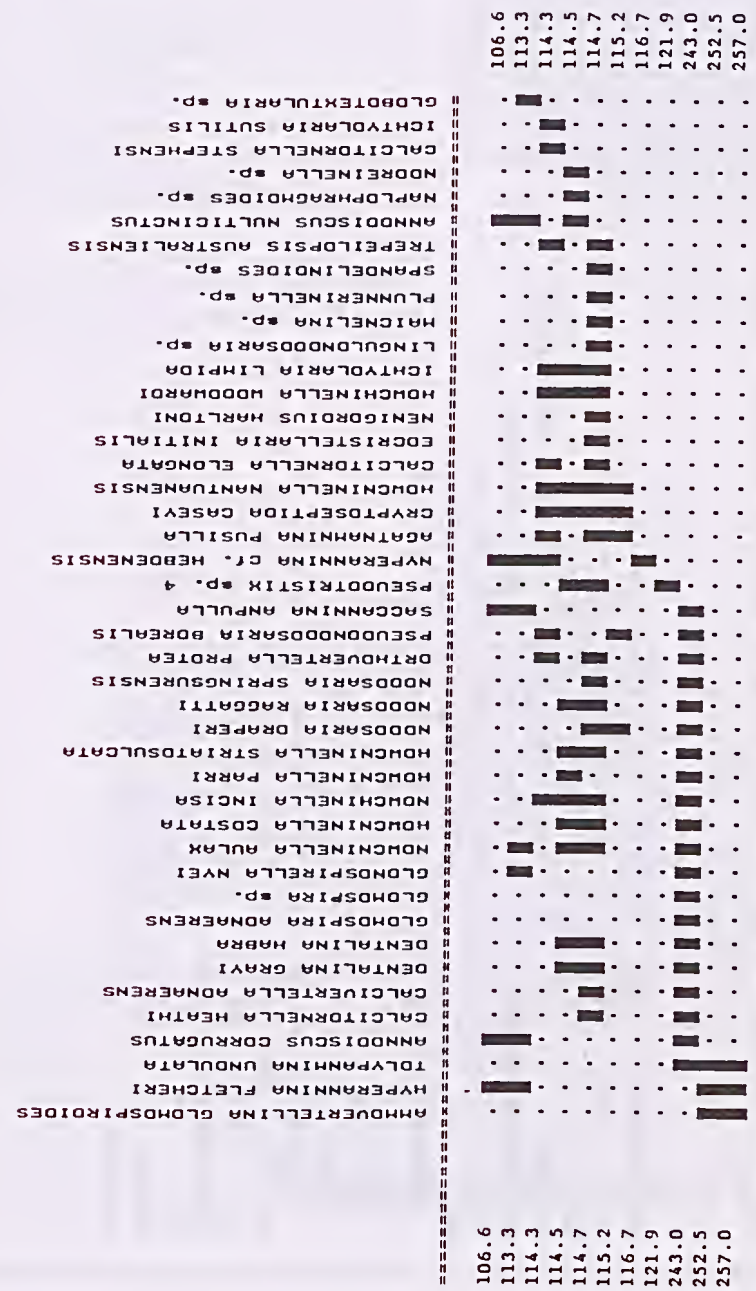


Fig. 14. Foraminifera distribution in GSQ Springsure 2. Range-chart of presence/absence by lowest appearance.

Howchinella mantuanensis Zone

Synonymy. Assemblage Zone C3 (Palmieri 1983).

The index taxon represent the last stage of the evolutionary lineage of the howehinellid 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 glaueonitie sandy siltstone of the Black Alley Shale. The latter represents the last stage of a shallow restrieted marine environment with the area subjeeted to uplift and eonsequent ereation 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 seetion.

CONCLUSION

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

Fig. 15. Foraminifera distribution in GSQ Springsure 10. Range-chart of presenee/absenee by lowest appearanee.

amount of diachroncity 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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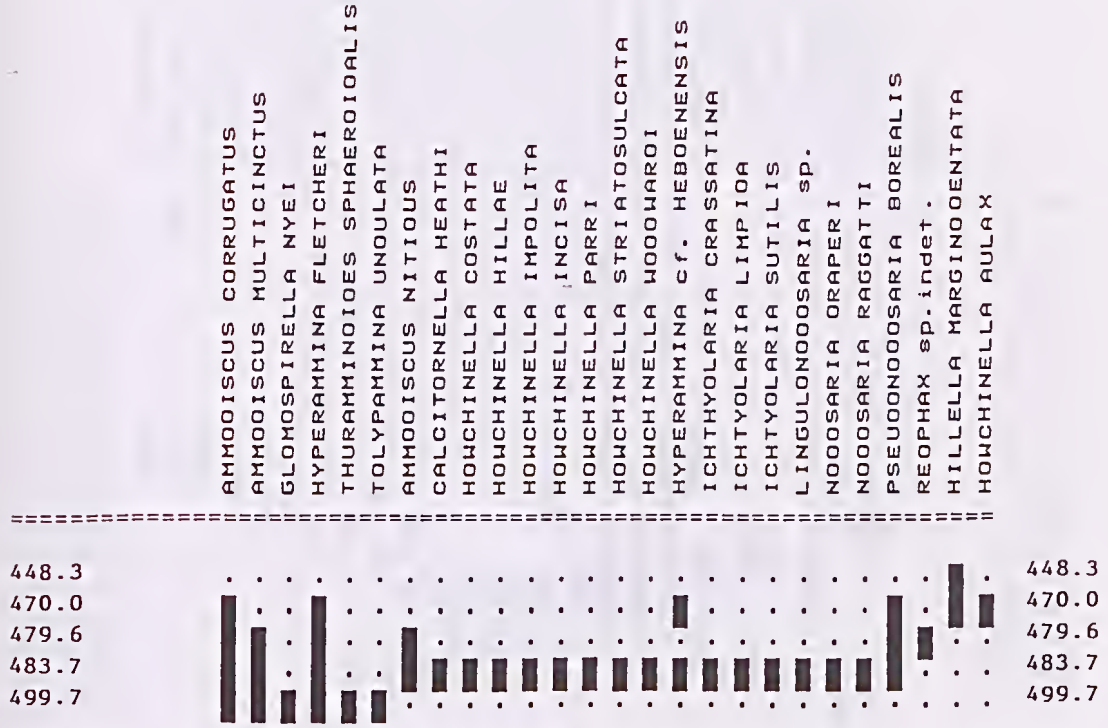

Fig. 16. Foraminifera distribution in GSQ Springsure 18. Range-chart of presence/absence by lowest appearance.

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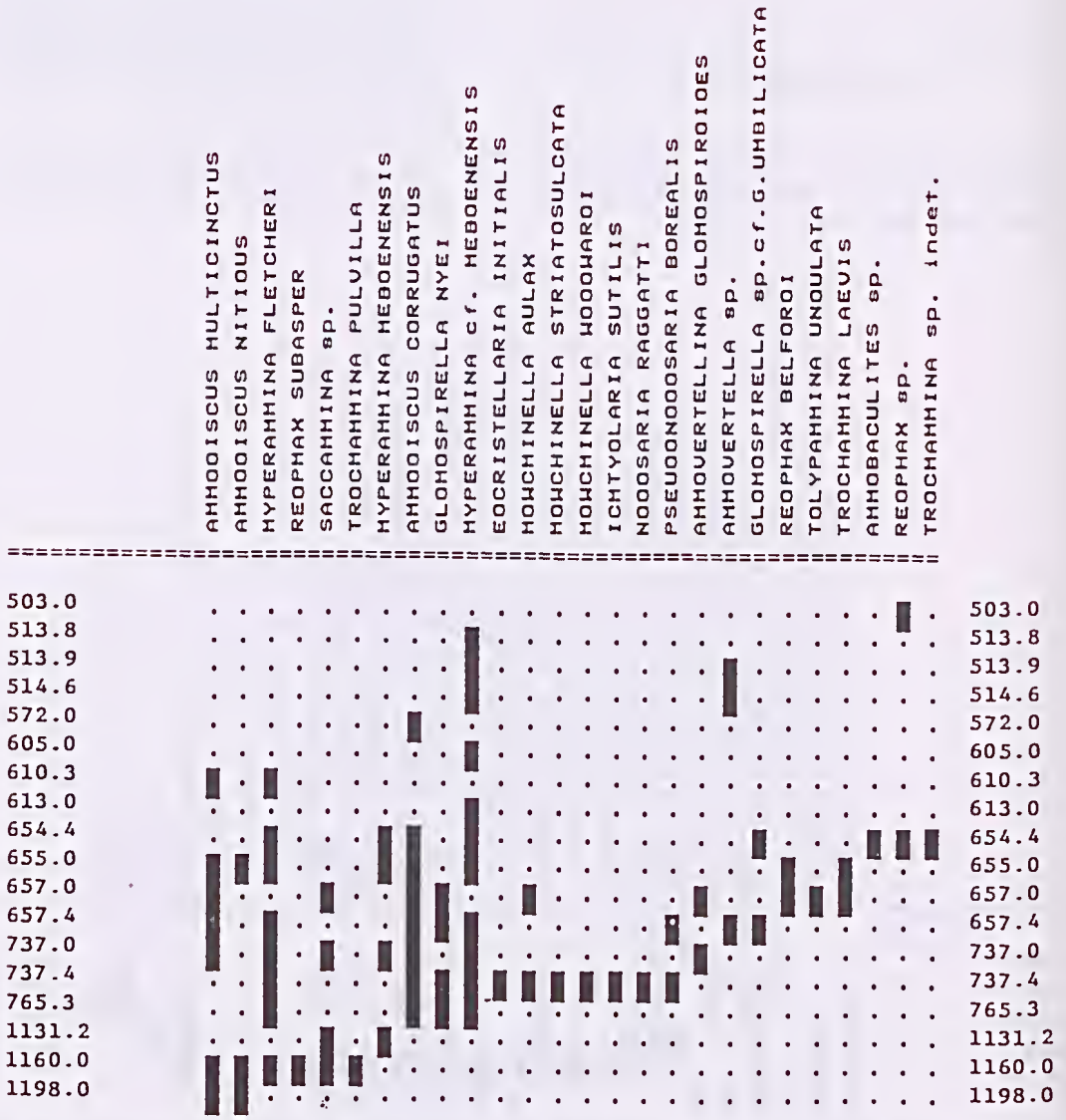

Fig. 17. Foraminifera distribution in GSQ Springsure 19. Range-chart of presence/absence by lowest appearance.

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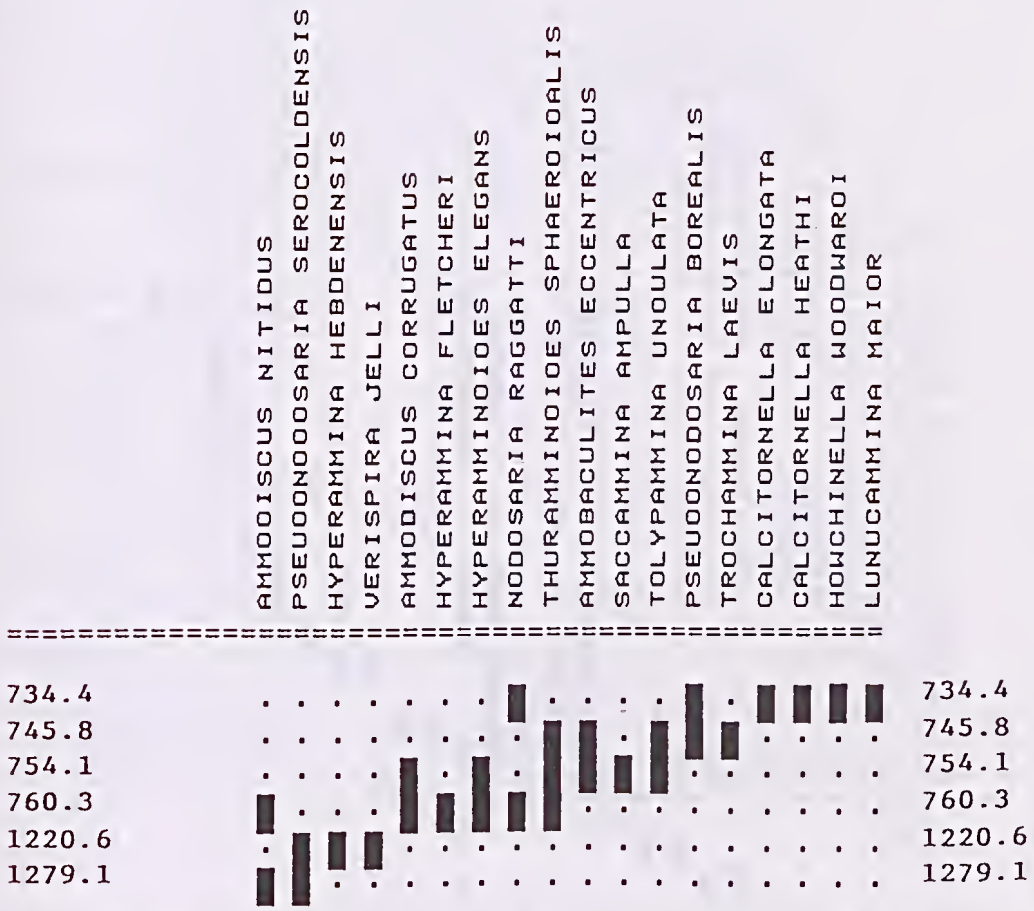

Fig. 18. Foraminifera distribution in GSQ Eddystone 5. Range-chart of presence/absence by lowest appearance.

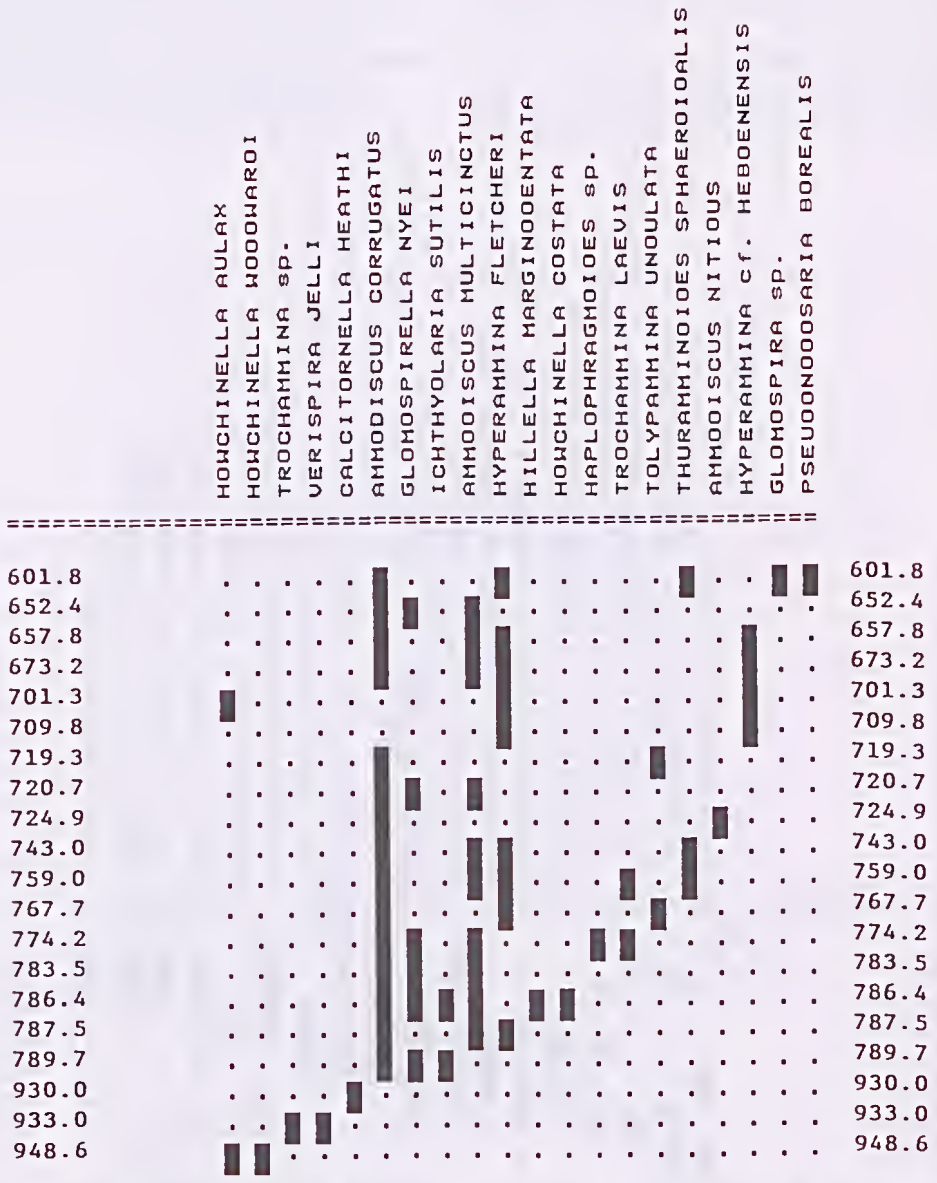

Fig. 19. Foraminifera distribution in GSQ Eddystone 1. Range-chart of presence/absence by lowest appearance.

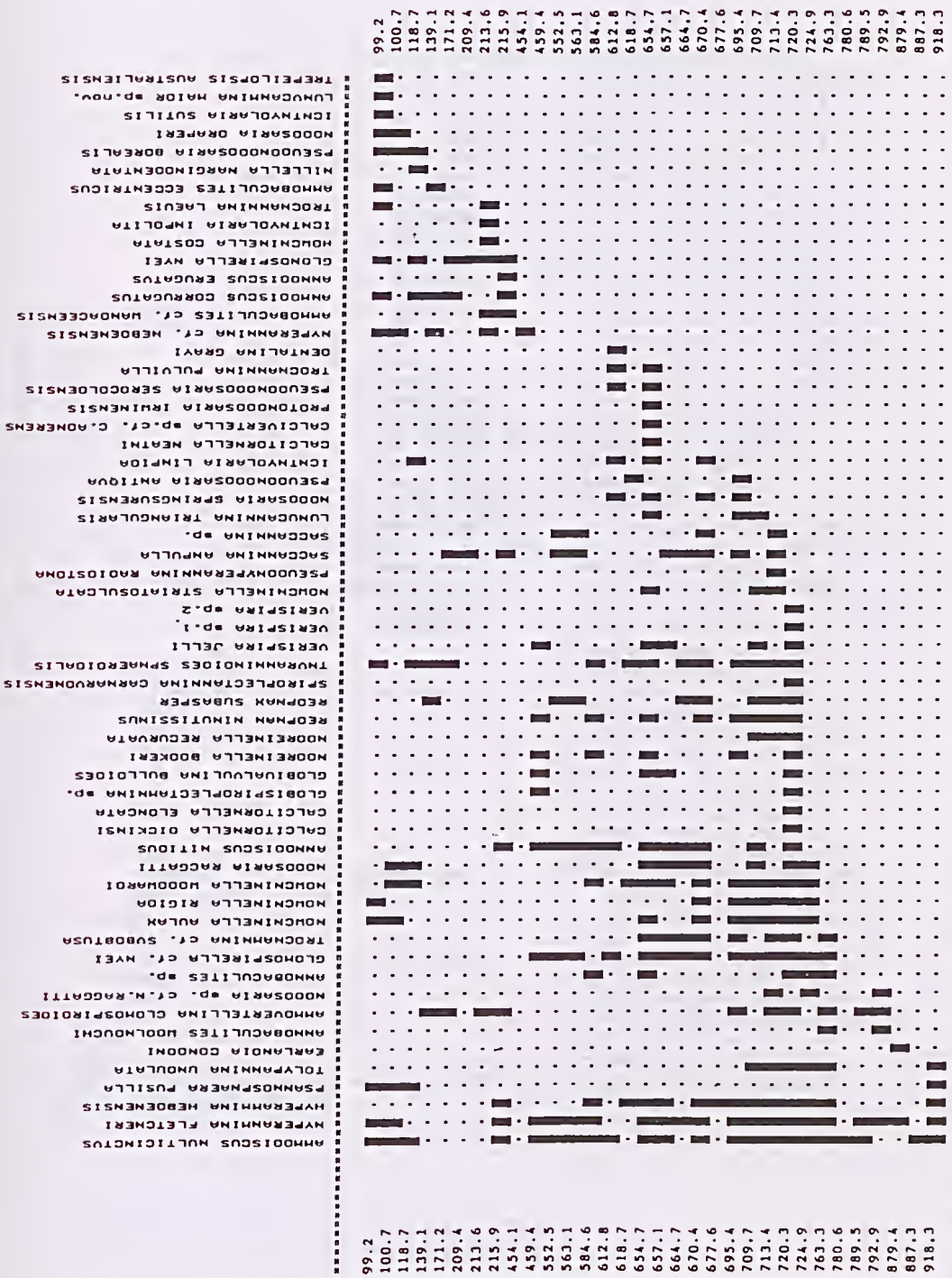

Fig. 20. Foraminifera distribution in GSQ Eddystone 4. Range-chart of presence/absence by lowest appearance.

Fig. 21. Foraminifera distribution in GSQ Taroom 10. Range-chart of presence/absence by lowest appearance.

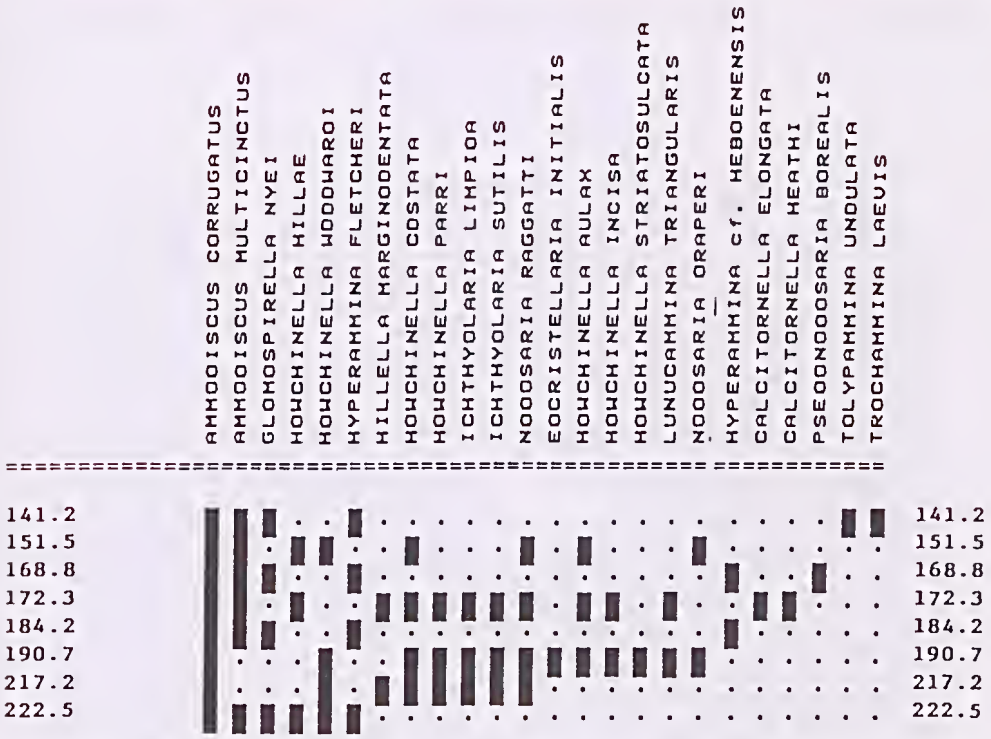

Fig. 22. Foraminifera distribution in GSQ Taroom 11. Range-chart of presence/absence by lowest appearance.