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DEPARTMENT OF MINES
SOUTH AUSTRALIA

GEOLOGICAL SURVEY

PALAEONTOLOGY SECTION

TERTIARY FORAMINFERAL ZONES IN SOUTH AUSTRALIA

by

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PALAEONTOLOGIST

D.M. 1648/66

14th August, 1967

R.B. NO. 65/25
G.S. NO. 3764
PAL. REPT. 11/67.
D.M. 1648/66

14th AUGUST, 1967

R/B 65/25

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PLAN NO 67-558/6
67-559/6

ABSTRACT

A continuous succession of fifteen planktonic foraminiferal zones is proposed for Middle Eocene to Miocene sediments in South Australia. With some slight modification the zonal scheme is closely identified with a similar succession in New Zealand. Two alternative zones are useful for the Oligocene in areas of restricted sedimentation.

INTRODUCTION

In southern Australia the establishment of

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Note: This paper is to be presented by Dr. N.H. Ludbrook at the Planktonic Conference to be held at Geneva, Switzerland between Sept. 27 and Oct. 3, 1967. It will be published in a special issue of the "Archives des Sciences de Genève" early in 1968.

J.M. Lindsay 14.8.67.

foraminiferal zones to satisfy the requirements of more precise biostratigraphy, particularly in subsurface stratigraphic studies, has been limited by several factors. Informal and somewhat general zonal schemes (Carter, 1964; Wade, 1964) have been based on discontinuous coastal sections mainly in Victoria and in the St. Vincent Basin of South Australia between which there are some differences in facies. Secondly, the foraminiferal assemblages used to define the faunal units or zones have been recorded in relatively broad terms of the more important and apparently restricted benthonic and planktonic forms. Thirdly, the present writers, working mainly on subsurface sections, are handicapped by the disadvantages of rotary or percussion drill cuttings, with only sporadic control from drill cores or surface sections.

Previous zonal schemes have proved inadequate for structural interpretations within and between rock stratigraphic units in South Australia connected with

basin studies in both petroleum exploration and hydrogeology. Using basins with differing environments, on the one hand the Gambier Embayment of the Otway Basin, and on the other the St. Vincent and Murray Basins, we propose a zonation of planktonic foraminifera which is capable of local modification for sediments of open-sea origin and those of a closed or restricted basin.

The zonal sequence permits close correlation with the succession of zones established in New Zealand by Jenkins (1965, 1966). The recognition of many of the species described in New Zealand as well as a number of those recorded from east Africa (Eames et al., 1962) has been an important stimulus in advancing Tertiary correlation not only between Australia and New Zealand, but also with Trinidad and east Africa.

The unique Tertiary geological record in New Zealand (Hornibrook, 1965) and the general similarity

of climatic conditions between Australia and New Zealand, renders stratigraphic correlation within the Australasian region an imperative initial step in interregional correlation towards the ultimate aim of relating both the New Zealand and the Australian sequences to the European Tertiary. Recent contributions to this objective have been made by Jenkins (1966) using homotaxial datum planes of planktonic foraminifera and Ludbrook (1967) with a rock correlation chart based on planktonic foraminiferal ranges and palynological data.

The lack of uniformity in foraminiferal zonation and the confusion of planktonic zonal schemes in which the same names are used for different zones has been noted (Wade, 1964; Hornibrook, 1967). Our studies have convinced us however that local modifications of zones are an inevitable consequence of the slight discrepancies in stratigraphic ranges of some planktonic species. In the interests of uniformity, we have revised some of the nomenclature used by Carter (1964)

and Wade (1964), to conform with Jenkins's zones in New Zealand.

The Tartwaup and Lacepede Formations to which reference is made are being described in a joint publication on the Otway Basin by the Geological Surveys of South Australia

FORAMINIFERAL ZONES IN THE GAMBIER EMBAYMENT OF THE OTWAY BASIN

The Gambier Embayment is an area of Cretaceous and Tertiary sedimentation at the western end of the Otway Basin in which an almost complete subsurface sequence of Paleocene to Miocene sediments occurs. Owing to lack of deformation and almost flat surface topography very little of the sequence is exposed. Paralic conditions prevailed during the Paleocene, particularly on the margins, and planktonic foraminifera are not abundant, but from the Upper Eocene to the Lower

Miocene sedimentation in an open sea environment appears to have been continuous in the southern part of the embayment, the sediments being dominated by bryozoal limestones which yield abundant planktonic foraminifera where diagenesis and recrystallization are not too advanced.

Paleocene

No local zonal name has been applied to Paleocene units. In contrast to the eastern part of the Otway Basin where Middle and Upper Paleocene planktonic faunas occur, the Bahgallah and Dartmoor Formations of the Gambier Embayment consist respectively of oolitic grit and carbonaceous silts with Cyclammina. These are stratigraphic equivalents of the Pebble Point Formation carrying Globorotalia chapmani Parr correlated with the Trinidad and Tethyan Globorotalia pusilla pusilla - G. angulata Zone, and the Dilwyn Clay containing Globorotalia pseudomenardii Bolli and abundant associat-

ed forms permitting correlation with the upper part of the G. pseudomenardii subzone of the G. velascoensis Zone (McGowran, 1965).

No Lower Eocene sediments are known to occur in the sequence.

Middle and Upper Eocene Zones

Globorotalia australiformis Zone. The Burrungule Member of the Tartwaup Formation comprising the upper part of the Knight Group is a highly carbonaceous and micaceous clay and silt containing an impoverished fauna of very small planktonic foraminifera dominated by Globorotalia australiformis Jenkins in association with Globanomalina micra (Cole), Truncorotaloides collactea (Finlay) and, rarely, a species of Guembelitria close to G. columbiana Howe, Globigerina higginsi Bolli, G. angiporoides minima Jenkins and Turborotalia spinuloinflats Bandy. This assemblage occurs in the lower Porangan of New Zealand, in the low-

er part of Jenkins's (1965) Pseudoglobocuadrina primitiva Zone.

In view of the absence of P. primitiva (Finlay) from the assemblage and the overall difference in faunal composition from that of the younger P. primitiva Zone, we consider it preferable to distinguish the G. australiformis Zone from the P. primitiva Zone. It is a total range zone in South Australia.

Pseudoglobocuadrina primitiva Zone. This zone is represented in the lower part of the Lacepede Formation in which Pseudoglobocuadrina primitiva occurs in some abundance associated with Truncorotaloides collactea in dark green-grey sandy clay. Although the environment is unfavourable for abundant planktonic foraminifera, the association is essentially that of the upper part of Jenkins's P. primitiva Zone. The lower boundary of the zone is marked by the last appearance of Globorotalia australiformis and the upper by the initial appearance of Globigerapsis index index. A variety of Globigerina

linaperta with a large final chamber (pl. 2 figs. 14, 15) occurs in the Zone.

Globigerapsis index index Zone. The zone defined by Jenkins is also represented in the Lacepede Formation. It is stratigraphically lower than the zone established by Carter (1958) as "Faunal Unit 2", later (1964) as Globigerinoides index Zone, and by Wade (1964, 1966), as index Zone.

The lower boundary of the zone is marked by the initial appearance of the zone fossil and the upper by the extinction of Pseudoglobоquadrina primitiva rather than the initial appearance of Chiloguembelina cubensis, the lower range of which in South Australia is somewhat uncertain. The zone is essentially an assemblage of G. index index with Truncorotaloides collectea, rare Pseudoglobоquadrina primitiva, Globigerina angiporoides minima, G. linaperta, and Globanomalina micra.

The recognition of the Globigerapsis index

index Zone in the sense of Jenkins would place the species in the perspective of its typical occurrence in the Bortonian of New Zealand and also in the Middle Eocene of east Africa. Extinction levels of the species show considerable interregional variation.

The boundary of the G. index index / T. aculeata Zones approximates to the Bortonian - Kaiatan boundary in New Zealand at which the boundary of the Middle and Upper Eocene is tentatively placed.

Turborotalia aculeata Zone. Globorotalia inconspicua Howe has not so far been identified in southern Australia. The species Turborotalia aculeata (Jenkins), described as a subspecies of G. inconspicua, is common, widely distributed, and of considerable utility in correlating sediments of differing facies. The top of the range of T. aculeata in New Zealand is the same as that of G. inconspicua, but in Australia T. aculeata has a longer upward range into Jenkins's G.

linaperta Zone.

The lower boundary of the T. aculeata Zone is placed at the top of the range of Pseudoglobоquadrina primitiva, and the upper boundary at the extinction of T. aculeata. The Turborotalia aculeata Zone is divisable into two subzones. In the lower, T. aculeata is associated with Globigerapsis index index, Globigerina linaperta, Turborotalia increbescens, Globanomalina micra, Truncorotaloides collactea, and, rarely, Globigerina pseudoeocaena Subbotina. Truncorotaloides collactea and G. pseudoeocaena do not occur in the upper subzone and Turborotalia opima nana and Globigerina gortanii praeturritilina are not present in the lower.

Globigerina linaperta Zone. The Zone is characterized by the association of the tolerant species G. linaperta, which occurs in limestones as well as in the glauconitic marls preferred by Globigerapsis index index, with Globigerina angiporoides angiporoides Hornibrook and Chiloguembelina cubensis. Globigerapsis

index index disappears within the zone and Guembelitria stavensis first appears at the top of the zone.

The lower boundary of the G. linaperta Zone is marked by the extinction of Turborotalia aculeata and the upper boundary by the extinction of G. linaperta. Globigerina euapertura appears immediately above this level.

The Eocene-Oligocene boundary is tentatively placed at the top of the G. linaperta Zone.

The G. linaperta Zone is represented in the lowest part of the Gambier Limestone, sedimentation then continuing without interruption to at least the Miocene Globorotalia menardii praemenardii Zone.

Oligocene Zones

Globigerina angiporoides angiporoides Zones. The Globigerina brevis Zone of Jenkins has not been recognized in southern Australia, and within the siliceous

sponge spicule member of the Gambier Limestone G. linaperta becomes extinct, marking the lower boundary of the zone of G. angiporoides angiporoides Hornibrook. The zone fossil is associated with G. ampliapertura Bolli, G. angustiumbilicata Bolli, G. euapertura Jenkins, G. labiacrassata Jenkins, G. officinalis Subbotina, G. praebulloides Blow, Turborotalia increbescens (Bandy), Globanomalina micra (Cole), Chiloguembelina cubensis (Palmer), and Guembelitria stavensis Bandy. The upper boundary is marked by the extinction of G. angiporoides angiporoides.

Globigerina labiacrassata Zone. This zone, placed between the G. angiporoides angiporoides and the G. euapertura Zones, represents the upper part of the range of G. labiacrassata in which it is associated with Globigerina euapertura, Chiloguembelina cubensis, and Guembelitria stavensis. Globigerina ampliapertura, G. angustiumbilicata, G. officinalis, G. praebulloides and G. praebulloides occlusa, Turboratalia increbescens, T.

opima contimuosa, T. opima nana, and T. munda are also usually present. The lower boundary of the zone is marked by the final appearance of G. angiporoides angiporoides andthe upper by the extinction of Chiloguembelina cubensis.

Globigerina euapertura Zone. The base of the Globigerina euapertura Zone in southern Australia is marked by the extinction of Chiloguembelina cubensis and the top by the initial appearance of Globoquadrina dehiscens dehiscens. Globigerina yeguaensis yeguaensis Weinzierl and Applin occurs rarely near the bottom of the zone. Guembelitria stavensis becomes extinct in the lower part of the zone while Globigerina angulisuturalis Bolli occurs in a narrow interval near the top of the zone. Globorotaloides testarugosa Jenkins has a restricted range within the G. euapertura Zone and the upper part of the G. labiacrassata Zone. Turborotalia opima opima occurs very rarely near the top of the zone.

The Oligocene-Miocene boundary is tentatively placed at the top of the G. euapertura zone. On the evidence presented by Banner and Blow (1965) the upper part of the G. euapertura Zone would come within the Miocene.

Miocene Zones

The successive appearance zones of Globoquadrina dehiscens dehiscens, Globigerina woodi woodi, Globigerinoides trilobus trilobus, Globigerinoides bisphericus, Praeorbulina glomerosa curva, Orbulina suturalis, and Orbulina universa described by Jenkins from the Gippsland Basin (1960) and from New Zealand (1965, 1966) are recognized in the Gambier Limestone, with the exception of the uppermost part of the sequence where it has been removed by erosion.

ZONATION IN THE ST. VINCENT AND MURRAY BASINS

Since sedimentation occurred in more restricted environments in the Murray and St. Vincent Basins, diagnostic Oligocene Globigerinacea of the Gambier Embayment are rare or absent. Under these circumstances the heterohelicids Chiloguembelina cubensis and Guembelitria stavensis provide useful alternative planktonic zonation within an interval equivalent to the G. angiporoides angiporoides Zone, the G. labiacrassata Zone, and the lower part of the G. euapertura Zone.

Two local and informal zones have been proposed for this interval in the St. Vincent Basin (Lindsay, 1967), and are also recognized in the Murray Basin, the older a zone of C. cubensis and the younger a zone of G. stavensis, comprising in effect successive extinction zones.

The C. cubensis Zone is recognized in the Port Willunga Beds of the St. Vincent Basin, and in the lower

part of the Ettrick Formation of the Murray Basin. The base of the zone is defined by the final appearance of Globigerina linaperta, an event widely accepted as being associated with the close of the Eocene. The top of the C. cubensis Zone is marked by the final appearance of the zonal species. This extinction level is considered by Jenkins (1966) an Oligocene event. It occurs in southern Australia early in the Janjukian Stage. Species associated with C. cubensis include Guembelitria stavensis, Cassigerinella chipolensis, Globigerina euapertura, and very rare and doubtful G. angiporoides angiporoides. Towards the top of the zone, G. bulloides, G. labiacrassata, and Globorotaloides testarugosa are present. Globerina yeguaensis yeguaensis occurs near the top of the zone in the Ettrick Formation of the Murray Basin.

The Guembelitria stavensis Zone is characterized by that part of the range of the zone species which follows the final appearance of C. cubensis. Cassigeri-

nella chipolensis, Globigerina bulloides, and G. euapertura are associated with Guembelitria stavensis, the extinction of which marks the top of the zone.

The Zones of Turborotalia aculeata and Globigerina linaperta are recognized in both the St. Vincent and Murray Basins.

The evolutionary lineage of Globigerinoides trilobus trilobus - Orbulina universa occurs in the limestones of the Murray Basin (Ludbrook, 1961), culminating in the Orbulina universa Zone of the Pata Limestone. Members of the lineage as high as Praeorbulina glomerosa circularis (Blow) have been recorded from subsurface Port Willunga Beds in the St. Vincent Basin (Lindsay and Shepherd, 1966). The absence of the upper zones in the Port Willunga Beds and the Gambier Limestone is due to erosion.

THE STRATIGRAPHIC POSITION OF EOCENE ZONES PREVIOUSLY USED IN SOUTHERN AUSTRALIA

The Zone of Hantkenina alabamensis compressa was proposed by Glaessner (1951) in the sense of a total range zone, and with slight nomenclatural modification, or as "Faunal Unit 1", it was used by subsequent workers (Carter 1958a, b; 1964; Ludbrook, 1963; Wade, 1964). Although the species is locally common in the Adelaide Sub-basin of the St. Vincent Basin, its occurrence elsewhere is extremely rare, and its utility as a zone fossil consequently restricted. In the St. Vincent Basin and Gambier Embayment it occurs near the base of the upper subzone of the T. aculeata Zone. A species of Hantkenina also occurs in the Eucla Basin in the west of South Australia at a lower stratigraphic level, associated with Pseudoglobquadrina primitiva.

The Zones of Globigerapsis index and Globigerina linaperta (Faunal Units 2 and 3) of Carter and of Wade, appear to come within the upper part of our T.

aculeata Zone. Carter's Faunal Unit 3 or G. linaperta Zone was defined as a biostratigraphic unit represented in the upper part of the Castle Cove Limestone and in the "Lower Glen Aire Clays". The "Lower Glen Aire Clays" contain an Eocene microfauna similar to that in the T. aculeata Zone of the Port Willunga Beds, with T. aculeata, G. linaperta, typical G. angiporoides angiporoides, and Globanomalina micra. The underlying Castle Cove Limestone contains T. aculeata in association with Globigerapsis index and Turborotalia gemma (Jenkins). The overlap of the latter two species occurs in New Zealand only at the base of the Globigerina brevis Zone. Both T. aculeata and T. gemma appear to have longer ranges in southern Australia, that of T. aculeata extending above the range of Hantkenina alabamensis compressa. T. gemma though common in the G. index Zone of Carter, has not yet been definitely recognized in South Australia.

Difficulty has been experienced in clearly differentiating the G. linaperta and G. angiporoides angiporoides Zones owing to the intergradation of the two species at the top of the range of G. linaperta sensu stricto. This has resulted in some doubt of the correlation of Carter's Faunal Unit 3 or of the upper boundary of the Aldingan with the lower part of the Whaingaroan being indicated by Jenkins (1966) and Ludbrook (1967). It may also explain the statement by McTavish (1966, p. 16) that G. linaperta "persisted into the Oligocene in Australia."

Correlation of the Zones now proposed with those previously used and with those of East Africa or Trinidad are tabulated in Figure 3 below.

CORRELATION OF THE SOUTH AUSTRALIAN ZONES WITH THOSE OF TRINIDAD AND EAST AFRICA

The Globorotalia australiformis Zone contains

Globigerina higginsi (Bolli) and Geumbelitria sp. close to, if not identical with, G. columbiana Howe. G. higginsi has a limited range in the Porangan - Bortonian (Pseudogloboquadrina primitiva to Globigerapsis index index Zones) of New Zealand, and in Trinidad from the Globorotalia palmerae to the Globigerapsis kugleri Zone. Geumbelitria columbiana was described from the Claiborne, and has a range in Trinidad from the Hantkenina aragonensis to the Porticulasphaera mexicana Zone. The Globorotalia australiformis Zone appears therefore to approximate to the Hantkenina aragonensis Zone. Globigerina pseudoeocaena occurs over a narrow interval of one metre in the Lacepede Formation in the lower part of the Turborotalia aculeata Zone. It ranges in East Africa and in Trinidad from Middle Eocene to the Cribrohantkenina danvillensis Zone. It has not been recorded from New Zealand. The upper part of the Turborotalia aculeata Zone contains Globigerina gortanii praeturritilina, which ranges in East Africa from the Globigerapsis semiinvoluta Zone to the lower part of the Globigerina gortanii

gortanii Zone. The absence of *G. gortanii praeturritilina* from the lower part of the *T. aculeata* Zone, if it is significant, permits correlation of the lower part of the *Turborotalia aculeata* Zone with the uppermost *Truncorotaloides rohri* and lower *Globigerapsis semiinvoluta* Zones.

The correlation of the upper part of the *Turborotalia aculeata* Zone with the *Globigerapsis semiinvoluta* to *Cribrohantkenina danvillensis* Zone is further supported by the occurrence together in the upper part of the Tartwaup Formation and also in the Brown's Creek Clays of the eastern part of the Otway Basin in Victoria of *Hantkenina alabamensis compressa* in association with *Turborotalia centralis* (Cushman and Bermudez) and *Globigerapsis index index*. The rare occurrence of *Turborotalia centralis* in this association appears to be near the top of its range as indicated by Eames *et al.* (1962, Fig. 20), although it seems obvious by comparing the ranges of the more important

constituents of the assemblage that Globigerapsis has a longer upward range in Australia and New Zealand than it has in east Africa. Equivalents of the upper part of the Cribrohantkenina danvillensis Zone to lowermost G. gortanii gortanii Zone are present in the upper part of both the Tartwaup Formation and Brown's Creek Clays, where G. gortanii praeturritilina occurs in association with Globigerapsis index index, Globigerina linaperta and Turborotalia increbescens. We have not been able to distinguish Globigerapsis tropicalis Blow and Banner from G. index index in any part of the range of the species.

The Globigerina linaperta Zone is equivalent to the G. gortanii gortanii (G. turritilina turritilina) Zone of Eames et al. (Ludbrook, 1967). It is equivalent also to the lowermost part of Jenkins's G. brevis Zone.

The long range of Cassigerinella in South Australia is noteworthy. Forms comparable with C. chipolensis (Cushman and Ponton) first appear in the Eocene associated with Globigerapsis index index in the

T. aculeata Zone of stratotype Port Willunga Beds (Lindsay, 1967). *C. chipolensis* then ranges from the *Chiloguembelina cubensis* zone to the *O. universa* Zone.

FIGURE 3. Correlation of foraminiferal zones

		PLANKTONIC FORAMINIFERAL ZONE	AUSTRALIAN STAGE	CARTER 1964 ZONE 1958 UNIT	TRINIDAD VENEZUELA EAST AFRICA EQUIVALENTS
MIOCENE		Orbulina universa	Bairnsdalian	Orbulina universa 11	Globigerinatella insueta
		Orbulina suturalis	Balcombian	Globigerinoides transitoria 10	Globigerinoides bisphericus
		Praeorbulina glomerosa curva			
		Globigerinoides bisphericus	Batesfordian	Austrotrillina howchini 9	
		G. trilobus trilobus	Longfordian	Globigerinoides ruber 8 G. trilobus trilobus 7	G. insueta G. trilobus
		G. woodi woodi		Globoquadrina dehiscens 6	?. Catapsydrax dissimilis
		G. dehiscens dehiscens			
OLIGOCENE		Globigerina euapertura	Janjukian	Victoriella conoidea 5 4	G. opima opima G. ampliapertura
		G. labiacrassata G. angiporoides angiporoides			Globigerina sellii sellii
EOCENE	U	Globigerina linaperta	Aldingan	G. linaperta 3	G. gortanii gortanii Crib. danvillensis
		Turborotalia aculeata		G. index 2 H. alabamensis compressa 1	Globigerapsis semiinvoluta Truncorotaloides rohri
	M	Globigerapsis index index	"Johannian"		? Globigerapsis kugleri
		Pseudoglobo-quadrina primitiva			
		Globorotalia australiformis			Hantkenina aragonensis
	L				
PALEOCENE	U	G. pseudo-menardii equiv.	Wangerripian		Globorotalia pseudomenardii
	M	G. pusilla pusilla equiv.			G. pusilla pusilla
	L				

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EXPLANATION OF PLATES

PLATE 1

(All figures X 110)

1. Guembelitria sp. cf. G. columbiana Howe

   Hypotype Ff442, side view showing aperture. Gambier Embayment, Burrungule Member of Tartwaup Formation, Globorotalia australiformis Zone, Middle Eocene. Bore CG6, 25.9 - 26.2 m.

2. Guembelitria stavensis Bandy

   Hypotype Ff419, side view showing aperture. St. Vincent Basin, type section of Port Willunga Beds, top of Chiloguembelina cubensis Zone, Oligocene.

3. Chiloguembelina cubensis (Palmer)

   Hypotype Ff420, oblique view showing aperture. Locality as for fig. 2.

4-6 Globorotalia australiformis Jenkins

Hypotype Ff443, locality as for fig. 1.

4. Spiral view 5. Side view 6. Umbilical view.

7-8 Turborotalia aculeata (Jenkins)

Hypotype Ff444, S.W. corner of Murray Basin, Lacepede Formation, Pseudoglobоquadrina primitiva Zone, Middle Eocene. Engineering and Water Supply Department. Construction Camp bore, 3 km. N. of Kingston, 61.0 - 61.3 m.

7. Spiral view 8. Umbilical view.

9-10 Turborotalia spinuloinflata Bandy

Hypotype Ff445, Gambier Embayment, bore CG6, 42.7 - 43.0 m.

9. Spiral view 10. Umbilical view.

11-12 Turborotalia centralis (Cushman and Bermudez)

Hypotype Ff446, Gambier Embayment, base of Lacepede Formation, upper subzone of Turborotalia aculeata Zone, Upper Eocene. O.D.N.L. Mt. Salt

Structure Hole No. 4, 14 km. S.W. of Mt. Gambier, 189 m.

11. Spiral view 12. Side view.

13-15 Turborotalia increbescens (Bandy)

Hypotype Ff447, S.W. corner of Murray Basin, Lacepede Formation, lower subzone of Turborotalia aculeata Zone, Upper Eocene. Construction Camp bore as for figs. 7-8, 58.6 - 58.9 m.

13. Spiral view 14. Umbilical view 15. Apertural view.

16-18 Turborotalia opima opima Bolli

Hypotype Ff448, Gambier Embayment, Gambier Limestone, Globigerina euapertura Zone, ?Oligocene. Beach Petroleum Geltwood Beach No. 1 Well, 11 km. S.W. of Millicent, 128 - 131 m.

16. Spiral view 17. Side view 18. Umbilical view.

19-20 Globigerina euapertura Jenkins

Hypotype Ff449, S.W. corner of Murray Basin, Gambier Limestone, Globigerina angiporoides angi-

poroides Zone, Oligocene. Engineering and Water Supply Department. Kingston bore 3, 56 - 58 m.

19. Umbilical view 20. Side view

21. Globigerina labiacrassata Jenkins

Hypotype Ff435, apertural view. Gambier Embayment, Gambier Limestone, Globigerina labiacrassata Zone, Oligocene. O.D.N.L. Mt. Salt Structure Hole No. 3, 171 - 174 m.

PLATE 2

(All figures X 110)

1-2 Truncorotaloides collactea (Finlay)

Hypotype Ff450, as for pl. 1, figs. 13-15.

1. Spiral view 2. Umbilical view.

3. Globigerina angiporoides angiporoides Hornibrook

Hypotype Ff438, umbilical view. St. Vincent Basin, type section of Port Willunga Beds, high in upper subzone of Turborotalia aculeata Zone, Upper Eocene.

4-5 Globigerina angulisuturalis Bolli

Hypotype Ff451, Gambier Embayment, Gambier Limestone, Globigerina euapertura Zone, ?Oligocene. E. and W.S. Department Millicent bore 2, 105 - 107 m.

4. Spiral view 5. Umbilical view

6-8 Globigerina pseudoeocaena Subbotina

Hypotype Ff452, Construction Camp bore as for pl. 1, figs. 13-15; 59.2 - 59.5 m.

6. Spiral view 7. Umbilical view 8. Oblique view.

9-10 Globigerina gortanii praeturritilina Blow and Banner

Hypotype Ff453, Construction Camp bore, Kingston, 54.0 - 55.5 m. Lacepede Formation, upper subzone of Turborotalia aculeata Zone, Upper Eocene.

9. Side view 10. Umbilical view

11-12 Globigerina higginsi (Bolli)

Hypotype Ff454, bore CG6 as for pl. 1, fig. 1,

32.0 - 32.3 m.

11. Side view 12. Apertural view.

13. Globigerina linaperta Finlay

Hypotype Ff455, as for pl. 2, figs. 9-10. Side view, showing well-developed apertural lip.

14-15 Globigerina linaperta var.

Hypotype Ff 456, Construction Camp bore, Kingston, 61.0 - 61.3 m. Lacepede Formation, Pseudoglobo-quadrina primitiva Zone, Middle Eocene.

14. Spiral view 15. Side view.

16-18 Pseudogloboquadrina primitiva (Finlay)

Hypotype Ff457, Construction Camp bore, Kingston, 63.7 - 64.1 m. Lacepede Formation, Pseudoglobo-quadrina primitiva Zone, Middle Eocene.

16. Spiral view 17. Side view 18. Umbilical view.

19. Globigerina yeguaensis yeguaensis Weinzierl and Applin

Hypotype Ff458, umbilical view showing "umbilical

teeth". Southern Murray Basin, Ettrick Formation, base of Globigerina euapertura Zone, Oligocene. Emu Flat bore, Keith, 63 - 58 m.

PLATE 1

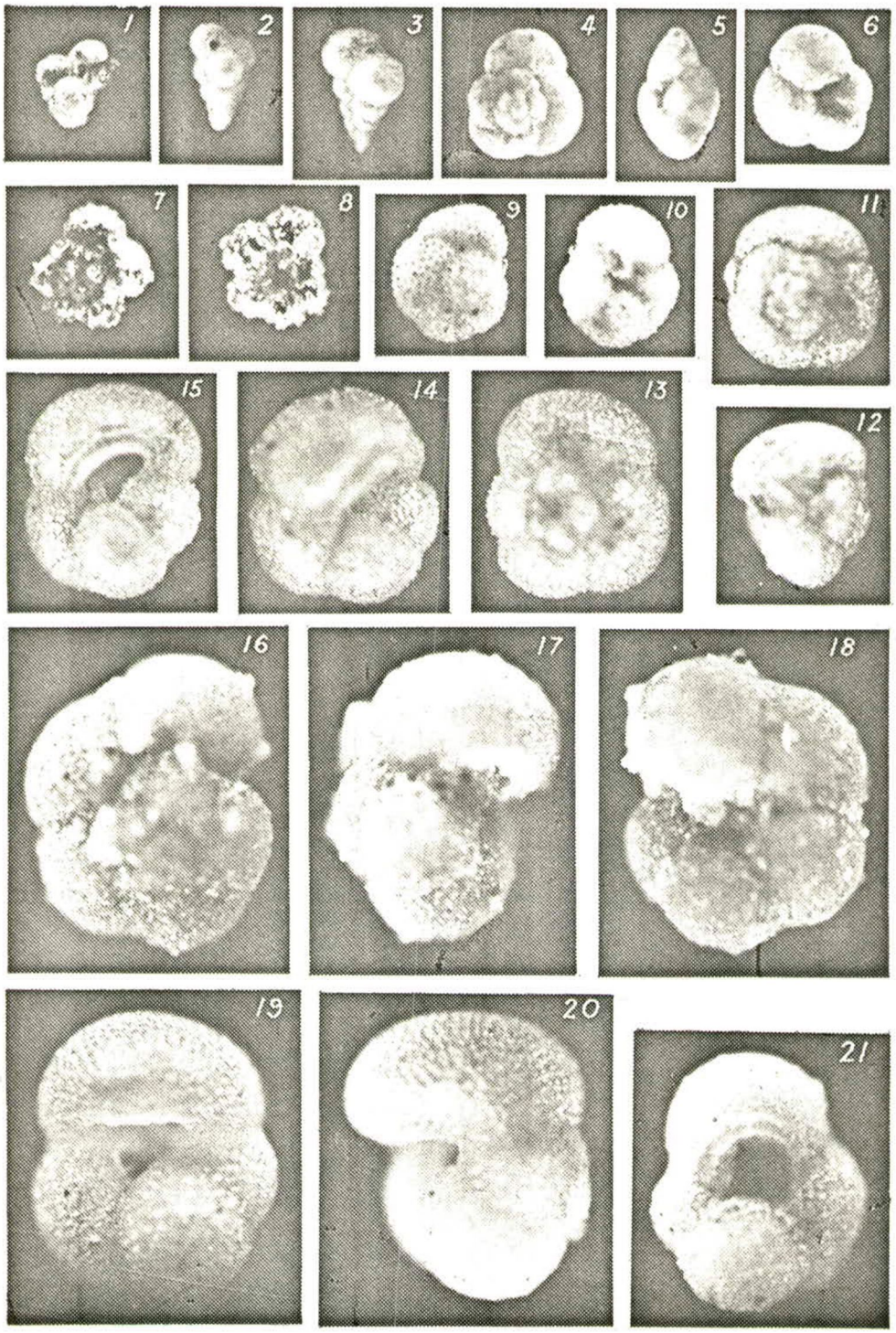

PLATE 2

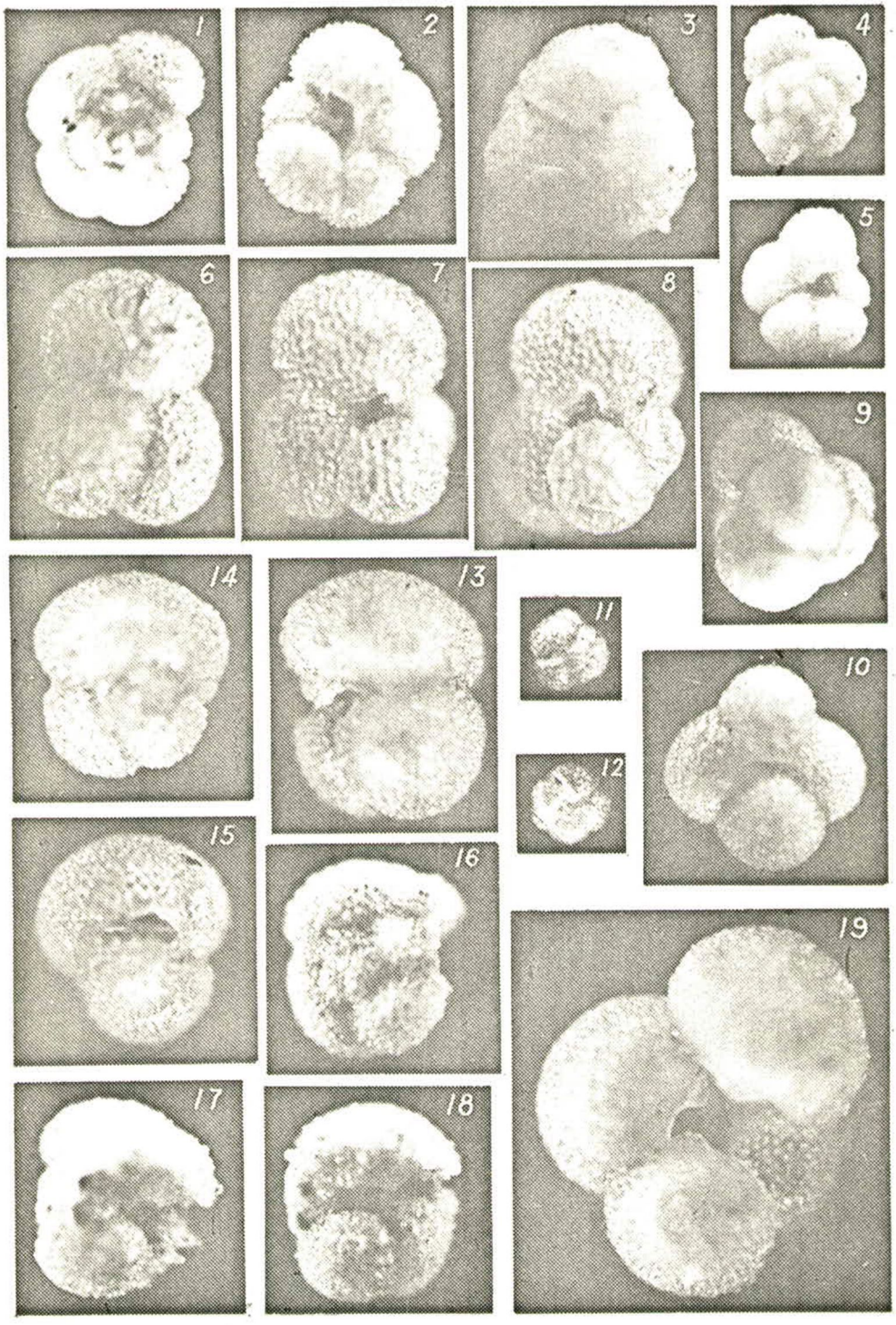

Figure 1.
Locality Map

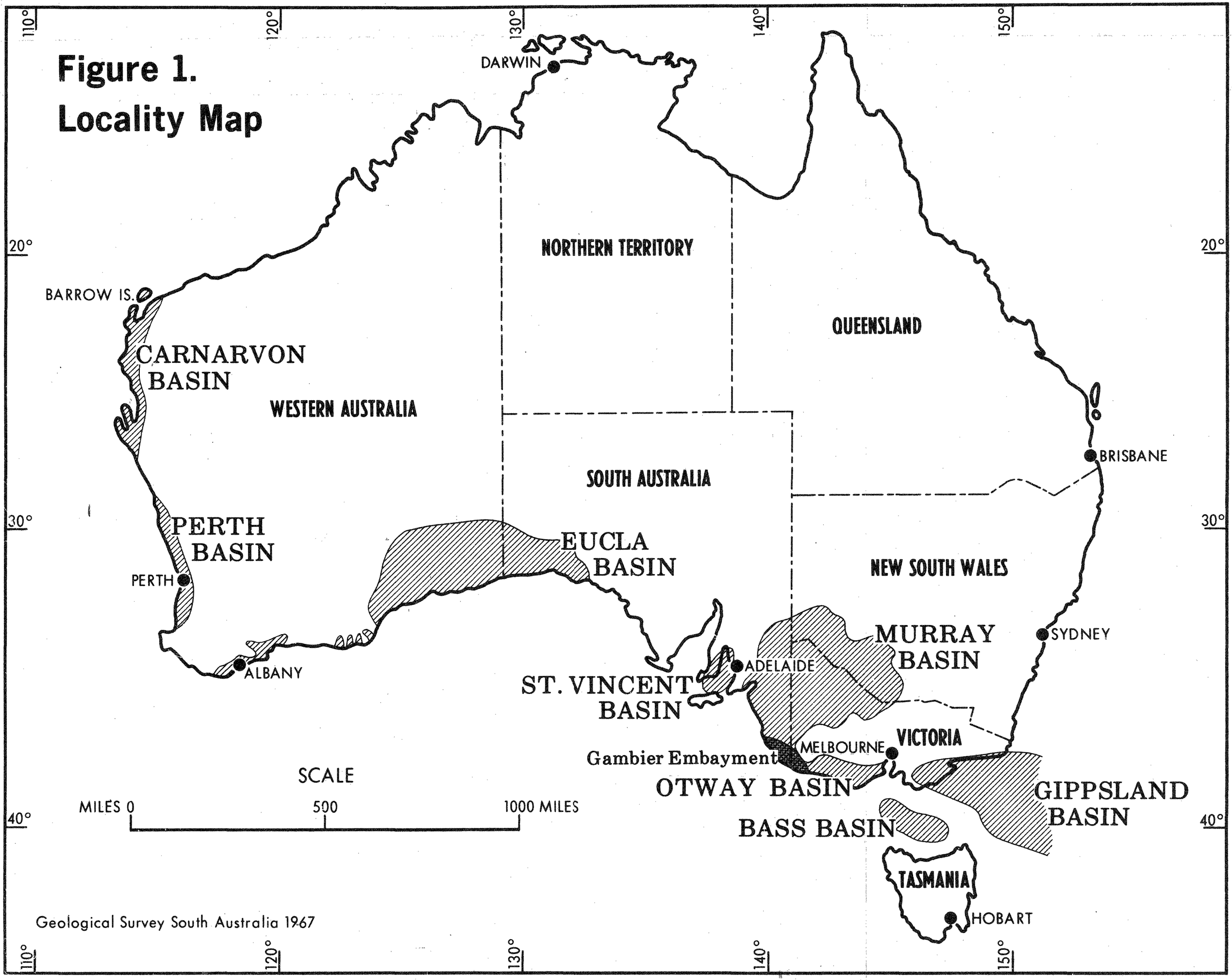

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Figure 2.

RANGE and CORRELATION CHART of PLANKTONIC FORAMINIFERA in SOUTH AUSTRALIAN TERTIARY.

EPOCH		AUSTRALIAN STAGE	NEW ZEALAND STAGE	FORMATION: GAMBIER EMBAYMENT	FORMATION: MURRAY BASIN	FORMATION: ST. VINCENT BASIN	PLANKTONIC FORAMINIFERAL ZONE
MIOCENE	MIDDLE		WAIAUAN	LIMESTONE		BEDS	
		BAIRNSDALIAN	LILLBURNIAN		PATA LST.		*Orbulina universa*
		BALCOMBIAN	CLIFDENIAN		MORGAN LIMESTONE		*Orbulina suturalis*
		BATESFORDIAN	ALTONIAN				*Praeorbulina glomerosa curva*
	LOWER	LONGFORDIAN	AWAMOAN				*Globigerinoides bisphericus*
			HUTCHINSONIAN		MANNUM	WILLUNGA	*Globigerinoides trilobus trilobus*
			OTAIAN				*Globigerina woodi woodi*
			WAITAKIAN	GAMBIER			
OLIGOCENE		JANJUKIAN	DUNTROONIAN		ETTRICK FM.		*Globoquadrina dehiscens dehiscens*
							Globigerina euapertura
							G. stavensis
							Globigerina labiacrassata
			WHAINGAROAN				*Globigerina angiporoides angiporoides*
EOCENE	UPPER	ALDINGAN	RUNANGAN		BUCCLEUCH GROUP	PORT	*Globigerina linaperta*
			KAIATAN	LACEPEDE		BLANCHE PT. TORTACHILLA	*Turborotalia aculeata*
	MIDDLE	JOHANNIAN	BORTONIAN				*Globigerapsis index index*
			PORANGAN	BURRUNGULE			*Pseudogloboquadrina primitiva*
			HERETAUNGAN				*Globorotalia australiformis*
	L		MANGAORAPAN				
PALEOCENE	M U	WANGERRIPIAN	WAIPAWAN	DARTMOOR			Planktonics locally absent
			TEURIAN	BAHGALLAH			
DANIAN							

1 *Globigerina ampliapertura* Bolli
2 *Globigerina angiporoides angiporoides* Hornibrook
3 *Globigerina angiporoides minima* Jenkins
4 *Globigerina angulisuturalis* Bolli
5 *Globigerina angustiumbilicata* Bolli
6 *Globigerina bradyi* Wiesner
7 *Globigerina brevis* Jenkins
8 *Globigerina bulloides* d'Orbigny
9 *Globigerina ciperoensis* Bolli
10 *Globigerina darvillensis* Howe
11 *Globigerina euapertura* Jenkins
12 *Globigerina foliata* Bolli
13 *Globigerina* sp. cf. *G. gortanii* (Borsetti)
14 *Globigerina gortanii praeturritilina* Blow and Banner
15 *Globigerina higginsi* Bolli
16 *Globigerina juvenilis* Bolli
17 *Globigerina labiacrassata* Jenkins
18 *Globigerina linaperta* Finlay
19 *Globigerina linaperta* var.
20 *Globigerina officinalis* Subbotina
21 *Globigerina ouachitaensis* Howe and Wallace
22 *Globigerina praebulloides* Blow
23 *Globigerina praebulloides occlusa* Blow and Banner
24 *Globigerina pseudoeocaena* Subbotina
25 *Globigerina sentilis* Bandy
26 *Globigerina tripartita tripartita* Koch
27 *Globigerina woodi connecta* Jenkins
28 *Globigerina woodi woodi* Jenkins
29 *Globigerina yeguaensis yeguaensis* W. and A.
30 *Globigerinoides bisphericus* Todd
31 *Globigerinoides quadrilobatus* d'Orbigny
32 *Globigerinoides ruber* d'Orbigny
33 *Globigerinoides trilobus immaturus* Le Roy
34 *Globigerinoides trilobus trilobus* (Reuss)
35 *Globigerinoides transitorius* Blow
36 *Praeorbulina glomerosa circularis* (Blow)
37 *Praeorbulina glomerosa curva* (Blow)
38 *Praeorbulina glomerosa glomerosa* (Blow)
39 *Orbulina suturalis* Bronnimann
40 *Orbulina universa* d'Orbigny
41 *Globoquadrina dehiscens advena* Bermudez
42 *Globoquadrina dehiscens dehiscens* Chapman, Parr and Collins
43 *Globoquadrina larmeui* Akers
44 *Globoquadrina venezuelana* (Hedberg)
45 *Globorotalia australiformis* Jenkins
46 *Globorotalia menardii praemenardii* Cushman and Stainforth
47 *Globorotalia scitula praescitula* Brady
48 *Globorotalia suteri* Bolli
49 *Globorotaloides testarugosa* (Jenkins)
50 *Hantkenina alabamensis compressa* Parr
51 *Pseudogloboquadrina primitiva* (Finlay)
52 *Truncorotaloides collactea* (Finlay)
53 *Turborotalia barisanensis* (Le Roy)
54 *Turborotalia extans* (Jenkins)
55 *Turborotalia aculeata* Jenkins
56 *Turborotalia increbescens* (Bandy)
57 *Turborotalia munda* (Jenkins)
58 *Turborotalia opima continuosa* (Blow)
59 *Turborotalia opima nana* (Bolli)
60 *Turborotalia opima opima* (Bolli)
61 *Turborotalia stukensis* (Le Roy)
62 *Turborotalia spinuloinflata* (Bandy)
63 *Catapsydrax dissimilis* (Cushman and Bermudez)
64 *Globigerapsis index index* (Finlay)
65 *Globanomalina micra* (Cole)
66 *Cassigerinella chipolensis* (Cushman and Ponton)
67 *Chiloguembelina cubensis* (Palmer)
68 *Guembelitria stavensis* Bandy
69 *Guembelitria* sp. *cf. G. columbiana* Howe
70

NOTE: Ranges of Zone Fossils in thick lines

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