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MIGRATION OF FORAMINIFERA IN TERTIARY TIMES IN AUSTRALIA.

by

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Introduction

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Introduction.

The distribution of marine Tertiary rocks in Australia is restricted to the western and southern coastal areas of the continent. The rocks represented are of Paleocene, Eocene, Miocene and Pliocene ages.

Considerable material has been collected in stratigraphic sequence from many Tertiary localities in recent years and the detailed examination of the foraminiferal content of the rocks has yielded many startling discoveries. Until the last few years samples have been collected haphazardly with the result that there has been little opportunity to obtain definite information of the stratigraphic sequence and the vertical range of the foraminifera could not be properly established because of insufficient stratigraphical information. Attempts are now being made to correct this state of affairs by systematic collection of samples and already much new light has been thrown on varying foraminiferal assemblages in different parts of the Tertiary Basin.

There is evidence of considerable migration of faunas in Tertiary times throughout the world and such evidence has only recently been found in Australia. It is now known that Paleocene faunas exist in Australia but, as in many parts of the world, marine Lower Eocene deposits have not been found. Probable Middle Eocene deposits are widespread chiefly in subsurface deposits in south-eastern Australia but definite Upper Eocene beds occur in Western Australia, South Australia and Victoria. Up to the present no definite marine Oligocene has been discovered. However, limestones equivalent of "e" stage of Indo-Pacific Tertiary stratigraphic subdivision and probably representing Aquitanian of Europe are known in North-West Australia. These beds are regarded as low in the Lower Miocene or Oligo-Miocene. Miocene and Pliocene deposits are widely distributed.

Two types of foraminifera are used in stratigraphic correlation in the Tertiary - the large species and the small species. The large foraminifera are extremely valuable for regional correlation such as in the Miocene in the Indo-Pacific region. The small forms, especially the pelagic foraminifera, are now proving of considerable value as long distance age determinants because of their abundance and rapid and widespread dispersal in the seas.

In studying migration of foraminiferal species in the Tertiary of Australia, two points are outstanding:

1. The presence of widely distributed European and American species in the Paleocene and Eocene.

2. The predominance of species restricted to the Indo-Pacific region in the Miocene and Pliocene.

As regards the first point, the small species of the Paleocene of Europe and America have been found in North-West Australia. Large foraminifera of European species occur in the Upper Eocene of North-West Australia with possible migration through the Middle East and India. The assemblage of small species in the Upper Eocene of Western Australia and south-eastern Australia contain many small European, American and New Zealand species as well as certain species which are indigenous to Australian Upper Eocene. The lower Oligocene species from parts of the United States of America are extremely close to Upper Eocene and Miocene species of Australia and this similarity of species has lead to some confusion regarding the age of some of our Tertiary deposits.

As regards the second point, the assemblages in the Miocene and Pliocene of Australia are dominated by Indo-Pacific species, that is species which are found primarily throughout the Indo-Pacific region and which are characteristic of shallow, warm water and thrive under ecologic conditions such as are found associated with coral reefs. Where the waters have been more temperate and more open sea conditions prevailed, the smaller species are abundant and many of them are present which have a wide lateral distribution and long stratigraphic range.

Discussion of Foraminifera & Foraminiferal Assemblages.

In this paper it is planned to discuss briefly certain foraminiferal species from the Paleocene, Eocene, Miocene and Pliocene deposits of Australia and to show the limits of their migration in Tertiary times in Australia. It will be shown that certain pelagic species which are restricted to certain formations and stages outside Australia, have longer stratigraphic ranges in Australia.

Paleocene.

About four years ago, the writer discovered an assemblage of small foraminiferal species in the North-West Basin, Western Australia, which showed a close resemblance with an Upper Eocene assemblage described by the late W. J. Parr in 1938 from the King's Park Bore, Perth. However, systematic collection of samples in the Giralia area more recently has revealed that the samples examined earlier came from beds stratigraphically below the Upper Eocene limestones containing Discocyclina and overlying the Upper Cretaceous. The assemblage was also compared with that described from the Midway of Texas by Mrs. Plummer in 1926 and from the Paleocene of Sweden described by Brotzen in 1948. Species from both these widely separated areas were found in the Western Australian beds. The presence of Parr's Upper Eocene species indicate the long stratigraphic range of these forms in Australia for they are found in Hantkenina-bearing deposits in south-eastern Australia. An Upper Cretaceous species which persists in the Paleocene assemblage is Verneuilina parri which was described by Cushman from Gin Gin, about 60 miles north of Perth. With the incoming of the Paleocene the genera Globorotalia and Globigerina become well represented. Globorotalia is represented in Western Australia by such species as G.spinulosa, G.membranacea and G.wilcoxensis. The number of species of Globigerina are less than in the Upper Cretaceous and the commonest species are Globigerina triloculinoides Plummer and G.mexicana Cushman

A widely distributed form in the Paleocene is one related to Pulvinulina exigua Brady var.obtusa Burrows and Holland (now placed in the genus Alabamina and originally described from the Thanet beds in England which are most probably Paleocene). Dr. Glaessner in 1937 recorded this species from the Upper Cretaceous and Paleocene in the Causasus. Mrs. Plummer recorded it from the Midway of Texas which Brotzen renamed Alabamina midwayensis. Parr discovered a related form in the Upper Eocene of Perth which he called Pulvinulinella obtusa var.westraliensis, and which has also been found in the Paleocene beds at Giralia.

Eocene.

Present indications are that beds of marine lower Eocene do not occur in Australia. However, Middle and Upper Eocene deposits are fairly widespread especially in south-eastern Australia, with a considerable thickness of probable Middle Eocene.

The Eocene is represented by two main lithological types in Australia, the calcareous type and the arenaceous type. The foraminiferal assemblages are controlled by ecologic or facies conditions represented by these lithological types.

1. Calcareous rock types. Calcareous rocks of Eocene age occur in the Giralia-Cardabia area and at Cape Cuvier in North-West Australia: at Christie's Beach and in cliffs near the mouth of the Onkaparinga River, Port Noarlunga, along the Onkaparinga River at Noarlunga, in the cliffs at Maslin Beach, Blanche Point and at Aldinga and the Mt. Gambier area in South Australia; at Portland, Johenna River, Brown's Creek and Castle Cove in south-western Victoria and from Bell's Headland east to Torquay in Victoria. Calcareous rocks are also found in subsurface sections as around Perth, in bores in the Mt. Gambier area and at Portland and it is probable that the so-called "Micaceous series" in the Gippsland bores in south-eastern Victoria will be included in this group of Eocene rocks.

The calcareous rocks contain both large and small foraminifera. The microfauna in the limestones in the Giralia-Cardabia area and at Cape Cuvier in North-West Australia shows a marked difference from that found in the limestones in south-eastern Australia. The difference is that, in the North-West Basin, the assemblage is dominated by large foraminifera with which are associated numerous small species. Large genera such as Discocyclina, Asterocyclina, Actinocyclina, Alveolina and Nummulites have not yet been found in Australia outside the North-West Basin. The species recognised indicate chiefly an Upper Eocene age but it is possible that some of the limestones are equivalent to "a-b" stage of the Indo-Pacific "letter" classification which is Middle to Upper Eocene. The presence of forms similar to European species in the Middle East, India, Indonesia and North-west Australia suggests that migration of species came from a westerly direction. Few European species of the larger foraminifera occur in America, but the American species of Actinocyclina aster is apparently present in the North-West Basin. Alveolina and Nummulites are not common in North-West Australia but the species that are present are closely allied to Indo-Pacific forms.

Based on the evidence available at the moment, it appears that these genera of large foraminifera do not occur in south-eastern Australia. Consequently a proper correlation of the Eocene beds of the North-West Basin with those of south-eastern Australia, was impossible to make. However, quite recently, two moderately large forms, namely Victoriella plecta and Crespinella sp.nov., which occur rather abundantly in Upper Eocene deposits in south-eastern Australia, have been found in the North-West Basin in association with the above mentioned large foraminifera. They now form the link for correlation of these widely separated areas. It is also known that both Victoriella plecta and Crespinella sp.nov.

occur in south-eastern Australia, in Eocene beds together with the widely distributed American Upper Eocene species Hantkenina alabamensis Cushman. The new and most interesting fact established through recent work, therefore, is the proof that in the Eocene beds of the North-West Basin, although their fauna is dominated by Indonesian forms, a transition has taken place from the Indonesian province to the typical south-eastern Australia province. A similar transition is established for the south-eastern Australia province between the Australian forms, such as Victoriella pleata and Crespinella sp. nov. and North American forms represented by Hantkenina alabamensis.

Victoriella pleata was described by Chapman in 1921 from a bore near Bird Rock, Torquay. Its importance as a zonal species for the Upper Eocene in Australia cannot be underrated because of its adaptability to varying ecologic conditions. It apparently thrived in warm, clear waters in which limestones were deposited as well as in more temperate and more turbid waters in which calcarenites were laid down. As regards Crespinella sp.nov., it has only been found in limestones. Both forms are most probably indigenous to the Australian Eocene. However, the adaptability of Victoriella pleata permitted it to migrate as far as Gippsland in south-eastern Victoria but Crespinella sp.nov., so far, has not been found east of the Aldinga area, South Australia.

Small foraminifera occur abundantly in the Upper Eocene calcarenites in the bores at Perth and in surface outcrops in south-western Victoria. They are common in the limestones in South Australia and in the North-West Basin. Many species are referable to Eocene and a few to Lower Oligocene species of America and Europe, and Upper Eocene species from New Zealand are also widely distributed. The most characteristic assemblage of species, however, is that described by Parr from the King's Park Bore, Perth (Parr, 1938). This assemblage is widespread in South Australia where it is found in bores in the Adelaide Basin, at localities at Port Noarlunga, and in the cliffs at Maslin Beach, Blanche Point and Aldinga Bay. In Victoria it is present in the calcarenites at Johanna River, Brown's Creek, and Castle Cove in the Otway area and in the Bird-Rock-Point-Addis section to the east. Species described by Parr from the King's Park Bore, Perth, and found in widely separated areas include Cibicides umbonifer, C.pseudoconvexus, Bolivinopsis crespinae, Bulliminella westralensis, Quembelina venezuelana var. rugosa, Globorotalia chapmani, Anomalina perthensis, Angulogerina subangularis and Alabamina obtusa var. westraliensis. Amongst the interesting pelagic species described from New Zealand and America and found in the Australian Upper Eocene are Globigerina triloculinoides Plummer, G.pseudobulloides Plummer, Globigerina mexicana Cole, Globigerinoides index Finlay, "Globigerinella" aspera Cole and Hantkenina alabamensis Cushman. All these forms are known to exist in the Eocene of America and the Middle East (Gramsdale, 1951). It is impossible at present to suggest any one direction of migration. G.triloculinoides and G.pseudobulloides were described by Mrs. Plummer from the Midway (Paleocene) of Texas and seem to range stratigraphically higher in Australia than elsewhere.

The migration of Hantkenina alabamensis is of considerable importance because it occurs in Upper Eocene deposits in so many parts of the world with little change in shape. Bronnimann (1950) thinks that the variety compressa instituted by Parr for the Victorian form at Johanna River, Brown's Creek and Hamilton Creek, is only a slight variant of the type species, but suspects that another American species H.primitiva is also present. The discovery of the species at Maslin Beach, Blanche Point, South Australia, by the late W. J. Parr shortly before his death, and the more recent discovery at Bird Rock, Torquay, Victoria, have done much to confirm an Upper Eocene age for the beds in these localities which previously had been regarded as either Oligocene or Miocene.

Another small but distinctive Upper Eocene assemblage occurs at Bird Rock and includes Massilina torquayensis (Chapman), Dimorphina laniukensis Crespin, Quinqueloculina ornithopetra Crespin, Q.singletoni Crespin, Lamarckina glencoensis Chapman and Crespin and Victoriella plecte (Chapman). There is no evidence as yet of migration of any of these species beyond south-eastern Australia other than Victoriella plecte which has already been discussed.

2. Arenaceous rock types. Lignitic sandstones and siltstones occur in the base of some of the bores in the Perth area, Western Australia; in bores at Moorlands and in the Mt. Gambier areas in south-eastern South Australia; in the Nelson Bore and Dartmoor bores in south-western Victoria, in bores in the Mallee and in Gippsland. Outcrops occur in the Anglesea and Dartmoor areas, all these occurrences are now regarded as Middle Eocene in age.

In all occurrences, except in the Moorlands Brown Coal deposits, the foraminiferal assemblage is dominated by the genus Cyclammina. One well-known species Cyclammina incisa is widely distributed as it is found in New Zealand and America. The beds containing Cyclammina are approximately 4,300 feet thick in the Nelson Bore on the Glenelg River in south-eastern Victoria.

The lignitic sandstone in the Moorlands Bores contain Foannularia, a genus described by Storrs Cole and Bermudez in 1944 from the Middle Eocene of Cuba. This genus is also present in the calcarenites at Johanna River and at Fisherman's steps, south-western Victoria and at Port Noarlunga, South Australia.

Miocene.

According to present knowledge, no marine deposits of definite Oligocene age occur in Australia but Miocene rocks are widely distributed. The Miocene foraminiferal assemblages are dominated by species which occur in assemblages throughout the Indo-Pacific region and which are found in deposits which have been laid down in warm, shallow clear waters associated with coral reefs. The writer has discussed this problem in different publications (Crespin, 194 , 1950). Stratigraphic work on measured sections in the Cape Range, North-West Australia during the last three years, has helped to clarify some of the problems that had confronted the writer and it is now possible to trace the easterly migration of certain species of the large and small foraminifera from the western Indo-Pacific region to the south-eastern corner of Australia. It seems advisable that when studying the Miocene stratigraphy of Australia that one should be conversant with the Miocene stratigraphy of the Indo-Pacific region in general. With the study of the larger foraminifera it is possible to apply the "letter" classification.

A migration of Indo-Pacific species from Indonesia south-eastward, is suggested by the distribution in Australia of the following foraminifera:

1. Eulepidina

2. Nephrolepidina, Trybliolepidina, Cycloclypeus, Miogypsina and Flosculinella

3. Austrotrillina howchini

4. Many small foraminifera.

1. The well-known Indo-Pacific "Te" stage foraminifer Eulepidina, in Australia has only been found so far in the North-West Basin, Western Australia. Limestones containing Eulepidina badiirraensis Crespin, which with E.dilatata var.

tidoenganensis, is one of the largest Lepidocyclinae in the Indo-Pacific region, are to be placed in the Lower Miocene or Upper Oligocene (Oligo-Miocene or Aquitanian). Associated with Eulepidina badiirraensis is Cycloclypeus eidae Tan, an Indo-Pacific species which has not been found in Australia outside the North-West Basin. The absence of Eulepidina and Cycloclypeus eidae elsewhere in Australia, indicates that either the Oligo-Miocene seas did not extend, in Australia, beyond the North-West Basin or that these typical Indonesian forms have reached the limit of the distribution in a south-eastern direction in the North-West Basin.

2. Nephrolepidina is present with Eulepidina in the North-West Basin, but it appears in abundance only in the overlying "Tf$_1$" limestones where also the first Tryblio1epidina make their first appearance. Tryblio1epidina has not been so far in any locality between the North-West Basin and south-eastern Australia. It is very common at Hamilton in Western Victoria. From there on to the south-eastern portion of Victoria, it occurs in many localities in surface and subsurface sections. Nephrolepidina however, appears to be restricted to the North-West Basin. The foraminiferal fauna in Victoria is dominated by Tryblio1epidina. The Indo-Pacific species L.(N.) farreroi, L.(N.) angulosa, L.(N.) borneensis and L.(T.) martini are found in the North-West Basin but in Victoria they are replaced by L.(T.) gippslandica, L.(T.) howchini and L.(T.) batesfordensis. L.(T.) gippslandica, however, has been found in the Cape Range limestones. As far as can be ascertained the subgenus Eulepidina dominated the Oligocene and the lower part of the Miocene both in Europe and the Indo-Pacific. The subgenus Nephrolepidina dominated the Miocene assemblages in Europe but the subgenus Tryblio1epidina is apparently restricted to Indo-Pacific Miocene assemblages and became the exclusive subgenus when Indo-Pacific bathymetric and climatic conditions reached south-eastern Australia.

As regards Cycloclypeus in "f" stage rocks, the Indo-Pacific species C.indopacificus Tan which is found in the North-West Basin is replaced in Victoria and in South Australia by C.victoriensis Crespin. And it is of some importance that the "Tf$_1$" stage genera Flosculinella and Miogypsina do not appear in any assemblage beyond the North-West Basin. Miogypsina occurs in New Zealand but I am inclined to think that this important Indo-Pacific genus migrated to New Zealand via New Guinea.

In the Lepidocyclina horizon in Victoria, it is found that although the species have many of the specific characters of the Indo-Pacific form, in the long migration from the North-West Basin, Western Australia, to south-eastern Australia, some of these distinctive characters were lost and it is noticeable that when one compares the Lepidocyclinae of New Zealand with those of Australia the influence of Indo-Pacific ecological conditions did not extend very markedly beyond south-eastern Australia.

3. Probably the most interesting species of the Miocene assemblages is Austrotrillina howchini described by Schlumberger in 1893 from Clifton Bank, Hamilton, Victoria and which has become an important zonal species throughout the Indo-Pacific region. Although it is recognised in "e" stage limestones in Java and Borneo, it has not yet been found until "Tf$_1$" stage in Australia. Further work in Victoria may show that it ranges a little higher in the south-eastern part of the continent. The most easterly occurrence of A.howchini in Australia is in Skinner's section along the Mitchell River above Bairnsdale in south-eastern Gippsland where it is scarce. It has not been found in the numerous bores in Gippsland which passed through the Lepidocyclina horizon. It occurs in some abundance in some of the Mallee bores in western Victoria which are included in the "old Murray Gulf" area, the eastern limit of which marks the most easterly extension in Australia of typical Indo-Pacific assemblages. (Crespin, in Glaessner, 1947)

4. In 2e" and "f" stage rocks in Australia small foraminifera are very common. In the North-West Basin there is an inter-mingling of species described by Le Roy and others from localities in Indonesia and other parts of the western Indo-Pacific region with those described by Chapman, Howchin Parr and Heron-Allen and Earland from south-eastern Australia. Species described from Indonesia and the western Indo-Pacific region are exceedingly rare in south-eastern Australian assemblages but such forms as Gypsina howchini, Planorbulinella plana, Calcarina verriculata, Cibicides victoriensis Crespinella umbonifera and Lenoxtomum hentyanum which are common in the Lepidocyclina horizon at either Batesford, Hamilton or Gippsland, are well represented in the North-West Basin assemblages. It is a feature, however, that Crespinella umbonifera, Calcarina verriculata as well as Austrotrillina howchini decrease in abundance as the eastern margin of the Miocene sea is reached in Australia. A. howchini and C.verriculata are very scarce in the Gippsland deposits and so far Crespinella umbonifera has not been found east of Batesford.

There is a cream coloured limestone containing the assemblage of Austrotrillina howchini, Marginopora vertebralis and numerous small miliolidae at the top of "f" stage in the North-West Basin. This assemblage occurs in hard limestone of similar lithological character to that in the North-West Basin, at localities on the Nullarbor Plains, in a moderately friable cream limestone in sub-surface deposits in the Adelaide Basin and in similar limestones which become rather sandy, in bores in the Mallee, western Victoria. This association is not found east of the area last mentioned which, as already stated, most probably forms the eastern limit of typical Indo-Pacific Miocene conditions in south-eastern Australia.

The wide dispersal of smaller species which are apparently indigenous to Australian Miocene assemblages is further demonstrated by the occurrence of some of them in the Miocene of New Zealand. Such forms as Planorbulinella plana, Cibicides victoriensis, Pavonina triformis and Tubulogenerina moorabooiensis are found in New Zealand.

Pliocene.

As with the Miocene, Indo-Pacific climates strongly influenced the Pliocene assemblages in North-West Australia and in the Adelaide Basin but the Pliocene deposits in Victoria suggest more temperate but still shallow water conditions. Warm, shallow water forms such as Marginopora vertebralis, Sorites marginalis and Peneroplis planatus are not found in Pliocene assemblages east of the Adelaide Basin and this marked change in the assemblage of species indicates that the warm Indo-Pacific waters did not reach beyond that area. Some Victorian Pliocene (Kalimnan) species such as the restricted species Flintina intermedia, and longer ranging species such as Massilina lapidigera, and Gravelinoides multigenerata are found in the assemblages in the Adelaide Basin and to the west, but for the most part the species in the Victorian deposits are much smaller in size than those in the Adelaide Basin and North-West Basin calcareous sandstones.

This regression of warm-water faunas in the Pliocene is marked by a further regression to the west in Pleistocene and Recent assemblages.

Conclusions.

The conclusions regarding migration of foraminifera in Australia are:-

1. There is definite evidence of world-wide dispersal of small species of foraminifera in the Paleocene and Eocene

assemblages with a limited migration of larger foraminifera. Species of Discocyclina and Asterocyclina appear to be world-wide in their distribution but species of Pellatispira and Alveolina are more closely related to Indo-Pacific forms.

2. The world-wide distribution of small pelagic species in the Upper Eocene is indicated by the recent discoveries of the American species Hantkenina alabamensis at several localities in south-western Victoria and its known occurrence in the Middle East; of other species such as Globigerina triloculinoides, G.dissimilis, G.pseudobulloides, Globigerinoides index, and Globorotalia wilcoxensis in the Paleocene and Upper Eocene of Australia.

3. The apparent restriction of certain species such as Victorialla pleata and Crespinella sp. nov. to Australian Upper Eocene deposits.

4. The effect of Indo-Pacific climatic and bathymetric conditions on Miocene and Pliocene foraminiferal assemblages throughout Australia. The eastern boundaries of such influences can be traces throughout the Miocene deposits in Australia and a regression of these conditions is noticeable in the Pliocene and even in Pleistocene and Recent times.

5. The restriction of the occurrence of Eulepidina the important "e" stage genus and Cycloclypeus eidae, a species restricted to "e" stage, to the North-West Basin indicates the limit of the transgression of "e" stage larger foraminifera in Australia.

6. The restriction of Nephrolepidina to the North-West Basin and the wide-spread distribution of Trybliolepidina in the North-West Basin and in south-eastern Australia, and the slight differences in specific characters in Lepidocyclina and Cycloclypeus in the North-West Basin and south-eastern Australia.

7. The appearance of Austrotrillina howchini in "f_1" stage in North-West Australia rather than in "e" stage as in the Indo-Pacific region to the west and the possibility of the species ranging into "f_2" stage in south-eastern Australia. A.howchini is common in the North-West Basin and in the Adelaide Basin and in the Mallee and Wimmera of western Victoria but scarce in south-eastern Victoria.

8. The south-eastern boundary of typical Indo-Pacific conditions in the Miocene in Australia is along the eastern margin of the old Murray Gulf which runs in a more or less northerly direction through the Wimmera and Mallee areas. This fact has been proved by borings.

9. The south-eastern boundary of typical Indo-Pacific warm shallow water conditions in the Pliocene is in the Adelaide Basin and in the deposits southward to Aldinga. There is a marked regression in the Miocene of the warm shallow water conditions of the Miocene, westward from the Mallee and Wimmera areas to the Adelaide Basin and the area to the south.

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