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THE MICROPALAEONTOLOGY OF THE GIRALIA ANTICLINE, N.W. AUSTRALIA

by

H.S. Edgell.

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INTRODUCTION

The Giralia Structure is an eroded, doubly-plunging anticline about 60 miles in length and 10 miles in maximum width. It is situated between Exmouth Gulf and the Lyndon River near the coast in the North West Division of Western Australia (i.e. approximately 22°S Latitude, 114°E Longitude).

In this investigation micropalaeontology has been applied to help in elucidating the surface stratigraphy of the eroded Giralia Anticline. The chronology, correlation and palaeo-ecology of the exposed sediments must be considered in evaluating their oil-possibilities. To this end examination of microfossils, principally Foraminifera aids materially in recognizing unconformities, structural conditions and facies changes, in dating and correlating strata and in interpreting ancient depositional conditions.

The Foraminifera constitute the largest and best studied group of microfossils. As the geological and geographical ranges of foraminiferal species are known in detail from many parts of the world they provide a means of determining the age of sediments and the conditions under which they were deposited. Foraminifera are particularly useful in stratigraphical correlation because they occur abundantly, are more evenly distributed through the sediments than larger fossils and can be obtained and identified from small rock fragments such as drill-cores. Thus the strata outcropping at the surface may be readily recognized in subsurface samples by the characteristic foraminifera which they contain.

The conformable Upper-Cretaceous-Lower Tertiary sequence exposed in the Giralia structure is ideal for micropalaeontological examination. The surface stratigraphy and structure of the Giralia Anticline is straightforward, outcrops are prominent and individual formations extend for long distances with little facies change. The samples examined are collected from continuous, carefully measured sections and consist largely of friable material. Moreover the cosmopolitan character of Upper Cretaceous and Lower Tertiary foraminiferal faunas allows the identification and correlation of many species with those already described elsewhere.

The samples studied were collected by a field-party of the Bureau of Mineral Resources during the winter months of 1950 and 1951. Additional samples were collected by the writer in visits to the area in July 1950 and July 1952.

PREVIOUS INVESTIGATIONS

In 1935 Chapman and Crespin published the first account of microfossils from the Giralia district. Limestone samples collected by Rudd and Condit in the previous year were found to contain Discocyclina, Pellatispira, Asterocyclina and Nummulites and were referred to stage "b" of the East Indian sequence i.e. Middle or Upper Eocene.

The underlying Cardabia Series was placed in the Upper Cretaceous by Raggatt (1936) on the basis of foraminifera examined by Chapman and Crespin. The latter considered the beds below the greensand horizon to range from Cenomanian to Santonian.

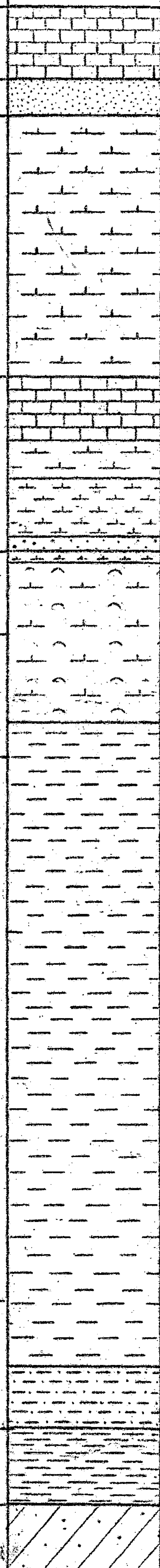
A paper by Crespin (1938) on "Upper Cretaceous Foraminifera from the North West Basin, W.A." lists foraminifera from the "cream-coloured limestones, glauconitic sand and chalks" of the Cardabia Series. The chalks are correlated with Turanian, the glauconitic sand with Santonian and the overlying cream-coloured limestones with Campanian.

CORRELATION OF CRETACEOUS-TERTIARY SEQUENCE

Vertical Scale:- 100ft = 1 inch

GIRALIA ANTICLINE

PERIOD	EPOCH	EQUIVALENT EUROPEAN STAGE	STRATIGRAPHICAL COLUMN	FORMATION	GROUP
TERTIARY	MIOCENE	BURDIGALIAN		TREALLA LIMESTONE	(unnamed Neogene) Group
		?		LAMONT SANDSTONE	Erosional Histus
	EOCENE	BARTONIAN LUTETIAN		GIRALIA "CALCARENITE"	CARDABIA GROUP
	PALEOCENE	DANO-MONTIAN		CASHIN LIMESTONE	
				PIRIE "CALCARENITE"	
				WADERA "CALCARENITE"	
				Boongerooda "Greensand	
CRETACEOUS	UPPER CRETACEOUS	MAASTRICHTIAN		Miria Marl	
				KOROJON "CALCARENITE"	
		CAMPANIAN			
		(correlation) unknown (?)Santonian to (?)Turonian		GEARLE SILTSTONE	WINNING GROUP
		CENOMANIAN		WINDALIA SILTSTONE	
		(?) ALBIAN		MUDERONG SHALE	Angular Unconformity
PERMIAN				? KENNEDY SANDSTONE ?	



Foraminifera and radiolaria from the siltstones underlying the Cardabia Series were also listed by Miss Crespin in 1946. These microfossils were identified as Lower Cretaceous and were assigned an Upper Albian age.

In a recent review of "Australian Oil Possibilities" Reeves (1951) summarized the stratigraphic sequence and correlation of the Tertiary and Cretaceous in the North-West Basin as worked out by Miss Irene Crespin, and the writer in the Giralia district.

METHODS.

The collection and treatment of material was undertaken primarily for the purpose of making age determinations for stratigraphical correlation.

The procedures used involved collection of samples and the separation, preparation and examination of their microfossil content.

i. Collection of Samples

The samples examined were collected in sit from measured sections representing the stratigraphical sequence of the area. These sections were samples at intervals of less than 30 ft., the precise stratigraphical and geographical position of each sample being located by abney level and aerial photographs respectively. Each sample amounted to approximately 800 grams. As foraminiferal samples could only be selected where the larger foraminifera occurred emphasis was placed on the collection of friable easily disintegrated marls and chalky limestones.

ii. Separation of Microfossils

The broken up rock material was washed through a 200 mesh sieve in order to eliminate the fine rock debris. It was found that smaller foraminifera and radiolaria were lost when coarser sieves were employed. After drying the residue was carefully labelled and stored in glass tubes or small pillboxes.

In many cases the well-preserved foraminifera with air filled chambers, and also ostracod valves, were separated from the sample by flotation using carbon tetrachloride or bromoform. This method of concentrating the microfossils greatly accelerated examination of the samples.

The washed residues or foraminiferal concentrates were spread out on a small sorting tray and examined under a binocular microscope. Representatives of all the different species present in the washings were selected and mounted in roughly systematic order on the numbered squares of group slides. Each group slide then indicated the nature of the foraminiferal assemblage from a given sample.

iii. Examination and Identification

Recognition of the species of foraminifera present in each sample required the examination of their morphological characteristics. Important features of the aperture, sutures or surface markings of certain tests were often clarified by staining with a dilute solution of methylene blue or an alkaline solution of phenolphthalein. In some cases where the internal structure of the shell was important this was examined by etching away a portion of the shell wall with hydrochloric acid. Among the larger foraminifera the conventional methods of cutting equatorial and vertical thin sections of the shell were employed.

Consideration of a large number of specimens of each species served to indicate the degree of variation within that specific group and prevented the naming of extreme morphological variants as distinct species. For identification of the species examined reference was made to the "Catalogue of the Foraminifera" by Ellis and Messina and to a large body of separate literature on Cretaceous and Tertiary foraminifera.

STRATIGRAPHICAL PALAEONTOLOGY OF THE GIRALIA ANTICLINE

The Cretaceous-Tertiary succession exposed in the eroded Giralia Anticline consists of approximately 1200 ft. of concordant sub-horizontal siltstones, marls and limestones. These have been divided by the field geologists into formations as shown in the adjacent stratigraphical column.

The distribution of characteristic foraminifera or foraminiferal assemblages within the sequence allows the distinction of successive time levels. The stratigraphy can also be subdivided into narrowly restricted palaeontological units based on the vertical range and abundance of assemblages or individual species. These units provide the palaeontological counterpart of lithological or formational subdivisions and permit more detailed correlation largely irrespective of deuteric or facies changes as with lithological units.

The following ascending sequence of time and rock units with their associated characteristic foraminifera typify the Cretaceous-Tertiary deposits of the N.W. Basin.

1. Upper Cretaceous

A. Winning Group (Cenomanian-Campanian)

This major unit comprises 600 ft. of siltstones with some basal sandstone beds representing the Cretaceous transgression. The Winning Group appears to cover the long time interval from Cenomanian to Campanian, based on age determinations of its lower and upper layers. However, inadequate exposures and impoverished foraminiferal assemblages prevent the recognition of intermediate European stages, which may be represented by one or more hiatus.

i. Muderong Shale. (Cenomanian or Upper Albian)

The base of the Cretaceous sequence is not exposed in the Giralia Anticline. However to the south near Muderong Bore, Middalya Station subhorizontal beds of Cretaceous age unconformably overlie the Permian Kennedy Sandstone. Twenty feet of unfossiliferous, ferruginous sandstone forming the basal transgressive beds of the Cretaceous are overlain by fifty-five feet of sandy shale. This shale formation is known as the Muderong Shale and contains numerous foraminifera as well as some radiolaria.

The foraminiferal assemblage consists of arenaceous types adjusted to the particular sandy environment. The abundant, arenaceous forms such as:-

Haplophragmoides eggeri, H. excavata
Ammobaculites coprolithiformis and Ammodiscus cretaceous
do not give any precise age determination although they indicate a general Cretaceous age. However the rare calcareous foraminifera such as:-

Eggerellina oroides
Pleurostomella subnodosa
and Globigerina washitensis

suggest a correlation of the Muderong Shale with the Cenomanian or Upper Albian (i.e. the base of the Upper Cretaceous or the top of the Lower Cretaceous).

ii. Windalia (Radiolarian) Siltstone (Cenomanian)

The lowest beds outcropping in the eroded core of the Giralia Anticline belong to the Windalia Siltstone Formation, which conformably overlies the previously mentioned Muderong Shale.

This formation of hard, white siltstone attains a thickness of 60 ft. Radiolaria comprise a few per cent of the siltstone and the disintegration of their tests by ground waters may have contributed to the extra silicification of the rock. However, although the relative abundance of radiolaria distinguishes the siltstone palaeontologically it is not sufficient to justify the term "radiolarite" as pointed out by A.B. Edwards C.S.I.R.O. Report 1952. Some foraminifera were separated from softer samples of this siltstone. These were predominantly arenaceous and included:-

<u>Haplophragmoides excavata</u>
<u>H.</u> <u>eggeri</u>
<u>Ammomarginulina</u> cf. <u>cragini</u>
<u>Pelosina lagenoides</u>
<u>Ammobaculites</u> cf <u>fisheri</u>

None of these forms indicates more than a general Cretaceous age while the accompanying rich radiolarian faunule appears to be endemic to Australia. The following radiolaria were identified from one sample (M37)

<u>Cenosphaera</u> sp. 1
<u>Cenosphaera</u> sp. 2
<u>Lithocyclia exilis</u>
<u>Dictyomitra australis</u>
<u>Dictyomitra</u> cf <u>multicostata</u>
<u>Lithocarpe fusiformis</u>
<u>Rhopalodictya</u> sp.
<u>Spongodiscus</u> cf <u>expansus</u>
<u>Spongasteriscus</u> sp.
<u>Porodiscus</u> sp.

It can be seen that there is no detailed microfossil evidence for a precise age for the Windalia Siltstone. Previously an Upper Albian age had been assigned, not only to this formation but to the whole Winning Group, based on the identification by F.W. Whitehouse of the belemnite <u>Dimetobelus diptychus</u> McCoy. Since these belemnites occur only as internal casts and since the species mentioned is restricted to Australia, this evidence seems inadequate for such an exact definition of the age of the formation. Also the identification of Acanthoceratid ammonites from the Windalia Siltstone gives a definite indication of its Cenomanian (i.e. basal Upper Cretaceous) age.

iii. <u>Gearle Siltstone</u>

This formation conformably overlies the harder white Windalia Siltstone and occurs over a wide area in the central eroded core of the Anticline, near Cadabia Pool. It is the thickest lithological unit in the entire sequence, with a total of 535 ft. as estimated from discontinuous outcrops east of Remarkable Hill. Despite this considerable thickness and uniformity outcrops are very poor because of the soft, bentonitic properties of the dark grey siltstones and claystones comprising the formation.

Samples from the lower part of this formation contain foraminifera which suggest a Cenomanian age. The occurrence of associated radiolaria also indicates a continuance of depositional conditions not unlike those of the underlying Windalia Siltstone. However, samples from the upper part of the formation have yielded distinctive foraminifera indicating a Campanian age. Whether the Gearle Siltstone represents such a long time interval can only be solved by detailed sampling which is difficult because of the poor outcrops.

Foraminifera from 189 ft. below the top of the Gearle Formation are predominantly arenaceous and comprise:-

Ammobaculites cf *fisheri* (M.S.)
Ammomarginulina cragini
Ammodiscus cretaceus
Gaudryinella irregularis
Haplophragmoides sp.
Marssonella oxycona
Pelosina sp.
Spiroplectammina gryzbowskii
Textularia cf *washitensis*
Trochamminoides cf *coronus*

Among the calcareous forms the following species are represented:-

Anomalina rubiginosa
Globigerina cretacea
Globigerinella aspera
Globotruncana arca
Frondicularia sp.
Lagena sulcata
Planularia cf *liebusi*
Planulina taylorensis
Saracenaria triangularis
Vaginulina cf. *recta*. (The presence of a dwarfed specimen of *Globotruncana arca* in this sample already indicates a Senonian age.) Samples from the upper 10 feet of the formation contain a rich calcareous foraminiferal assemblage similar to that of the overlying Inoceramus marl.

The occurrence of such forms as *Globotruncana arca Globotruncana stuarti* and *Globorotalites micheliniana* correlates the upper part of the Gearle Siltstone with the Campanian stage.

B. Cardabia Group (Upper Cretaceous-Paleocene-Eocene)

The group is composed of Upper Cretaceous and Lower Tertiary marls and limestones. The stratigraphical unit has a thickness of approximately 427 feet on the West flank of the Giralia structure, and is conformable with the underlying Winning Group with which it is continuous in time. The time continuity is indicated by the similarity of the Campanian foraminiferal assemblages from the top of the Gearle Siltstone and the base of the Korojon "Calcarenite".

i. Korojon "Calcarenite" (Campanian-Maestrichtian)

This 'Inoceramus' marl attains a thickness of approximately 150 feet in the Giralia Anticline and is conformable with the underlying Gearle Siltstone. Lithologically the formation consists of friable, cream chalky limestones and marls, alternating with harder bands of 'Inoceramus coquinite'. Shells of Inoceramus up to 2 to 3 feet in width are common in the coquinite layers but are almost invariably broken up both by contemporaneous wave action and by subsequent compaction of the sediments.

Micropalaeontologically this lithological unit is well characterized by a large assemblage of Upper Senonian species. The abundance and cosmopolitan character of the foraminiferal assemblages within the Korojon "Calcarenite" allow it to be subdivided into well-defined foraminiferal zones, and correlated fairly precisely with European stages of the Senonian. This exact long range correlation is based on planktonic species of foraminifera which evolved rapidly in time and were more rapidly distributed in space by surface currents.

The lower fifty or sixty feet of the Inoceramus marl is characterized by the abundant occurrence of

Planulina taylorensis and the restricted occurrence
of Frondicularia biformis
Globotruncana lapparenti bulloides
and Cibicides ribbingae

These species particularly that of Globotruncana indicate a Campanian age.

Above the layers of 'Inoceramus' shell, which form 'coquinite' beds at about the middle of the formation, the foraminiferal assemblage points to a Maestrichtian correlation. The presence of typical Maestrichtian species of world wide distribution places this correlation beyond reasonable doubt. Some of the most valuable guide foraminifera are:-

Bolivinoides draco draco
Flabellina reticulata
Globotruncana stuarti
Pseudotextularia varians

With a decrease in the amount of Inoceramus shell the light brown, friable marl of the Korojon Formation passes upwards into the overlying Miria Marl with scarcely any change in lithology.

ii. Miria Marl (Maestrichtian)

The highest stratigraphical unit of the Cretaceous sequence in the N.W. Basin is the Miria Marl, which is distinguished by the abundant occurrence of ammonites. The formation has a maximum thickness of 8 ft. at the north end of the Giralia Anticline and does not differ appreciably in lithology or foraminiferal content from the underlying upper part of the Korojon "Calcarenite". The marl is slightly glauconitic but glauconitic marls also occur in the underlying formation.

The rock being friable is easily disintegrated and yields an abundant and varied microfauna. The more important index species of foraminifera in this microfauna are:-

Globotruncana arca
Globotruncana stuarti
Globotruncana conica
Bolivinoides draco draco
Lituola taylorensis
Pseudotextularia acervulinoides
Pseudotextularia varians.

At least five of these species are characteristic for the Maestrichtian stage in Europe. According to Brotzen S.G.U. Arsbok, 38, 1945 one of these species Pseudotextularia varians Rzehak is a guide fossil for the Upper Maestrichtian. However, because of the short duration of the Maestrichtian stage and the great distance of the N.W. Basin outcrops from the type locality it is not attempted to correlate with parts of this stage; and it is thought that any attempt to do so is ill-considered even on the basis of ammonites.

2. Tertiary

Cardabia Group (cont'd)

i. Boongerooda Greensand (Paleocene)

The Cretaceous-Tertiary boundary in the Giralia structure is clearly marked by the presence of a persistent bed of 'Greensand' up to 10 ft. in thickness conformably overlying the friable, light-brown ammonite marl. This 'Greensand' is actually a soft friable, dark green 'calcarenite' at least 50% of which consists of glauconite grains.

A large foraminiferal assemblage quite distinct from those of the underlying beds, has been separated from samples of this 'greensand'. Many species are index fossils for the lowest epoch of the Tertiary, namely the Paleocene. It is evident that this microfaunal change is not due to different depositional conditions (i.e. facies change) because the benthonic and planktonic components of the fauna are both quite different from those of the underlying layers. In addition, this Paleocene assemblage of microfossils extends upwards into different lithological types such as chalks and limestones without any marked change.

The first occurrence of Globorotalia represented by the species G. spinulosa, G. wilcoxensis and G. membranacea, and the presence of the distinctive Globigerinid species G. triloculinoides, G. mexicana and G. pseudobulloides, is ample proof of the Paleocene, Lower Tertiary age of the formation. Many of the forms recorded from the Boongerooda Greensand are conspecific with those recorded from the Lower Paleocene (Seelandian) in Denmark and Sweden, from the Midway formation in America, and from the Dano-Montian deposits of North Africa. Random examples of such cosmopolitan species are Angulogerina wilcoxensis Bulimina midwayensis, Citharina plummoides and Kerreria fallax.

The following characteristic Lower Tertiary foraminifera are present in the Boongerooda Greensand'.

Anomalinoides danica
Clavulinoides aspera
Citharina plummoides
Bulimina aspera-aculeata
Bulimina midwayensis
Dentalina vertebralis
Gavelinella lellingensis
Globigerina pseudobulloides
Globigerina mexicana
Globigerina triloculinoides
Globorotalia cocoaensis
Globorotalia membranacea
Globorotalia spinulosa
Globorotalia wilcoxensis
Guttulina hantkeni
Parrella velascoensis
Siphonodosara plummerae
and Vaginulina legumen

This Lower Paleocene "greensand" formation has a perfectly conformable relationship with the underlying Maestrichtian ammonite marl. Evidence of continuous deposition from Cretaceous into Tertiary time, is provided by the increasing amount of glauconite from the Miria Marl into the Greensand itself. The continued presence of typically Cretaceous forms in this Paleocene formation also suggests continuous deposition.

This conformity and continuity from fossiliferous Maestrichtian correlatives directly into fossiliferous Paleocene beds raises the question of the position of the Danian. The Danian Stage is usually recognized as uppermost Cretaceous. However in this area both macrofossil and microfossil evidence coroborate the views of Morozowa 1936 and Jeletsky 1951 who include the Danian in the Tertiary as the lowest stage of the Paleocene.

ii. Wadera 'Calcarenite' (Paleocene)

The loose, dark green, glauconitic sand of the Boongerooda Greensand is conformably overlain by a formation composed of alternating friable and hard layers of glauconitic chalky limestone. The thickness of this so-called Wadera

"Calcarenite" varies from 75 ft. along the west flank of the anticline to about 35 ft. in places along the east flank of the structure and the west flank of the adjacent Marilla Anticline.

The Wadera "Calcarenite" formation is not well distinguished from the similar friable, glauconitic, bryozoal, chalky limestones of the overlying formation. The foraminiferal assemblage is so similar to that of the "Greensand" that it is difficult torecognise distinctions of even sub-zonal importance. The abundant occurrence of Vaginulinopsis longiformis the rare presence of Coleites reticulosus and the existence of large specimens of Falmula sp. appear to be distinguishing palaeontological characters.

iii. Pirie "Calcarenite" (Paleocene)

Foraminiferal species from this formation of friable glauconitic bryozoal limestone are identical with those from the two other Paleocene formations which conformably underlie it. Certainly the forms Cibicides ekblomi, Discorbis midwayensis and Angulogerina subangularis are more common in relation to the total fauna. A distinctive species which makes its first appearance in this formation is Bolivinoides cf. velascoensis. The composition of the foraminiferal assemblage still points to a Paleocene age for this formation.

Except for the species outlined above there are no qualitative grounds for the recognition of distinct, easily correlated, foraminiferal zones within the Pirie "Calcarenite".

On the other hand a quantitative assessment of the frequency per thousand of certain foraminiferal species from successive samples shown that this could yield very detailed subdivision and correlation of this and other formations. Since the above method is rather time-absorbing it appears that palaeontological zoning of the Paleocene formations is more favourably based on the occurrence of restricted echinoid and terebratulid assemblages or species. Obviously such macrofossil subdivisions can only be employed in surface sections and must be replaced by microfossil criteria in subsurface work. The alternating hard and soft bryozoal chalky limestones of the Pirie Formation range in total thickness from 30 ft. at the south-west end of the structure, in the Korojon Pool area, to 100 ft. in the north-west at C.Y. Creek.

iv. Cashin Limestone ("Calcarenite") (Paleocene)

The hard limestones comprising the Cashin Formation form the protective capping to many of the striking conical buttes, such as Remarkable Hill and Section Hill, which occur along the west flank of the anticline. The Pirie "Calcarenite" passes upwards into these conformably overlying hard limestones by the increasing prominence of hard limestone bands towards the contact. Lithologically the Cashin Limestone capping Section Hill has been described by Condon and party (1950) as a hard, light buff fine "calcarenite" and that forming the top of Remarkable Hill, as a hard, dense, yellowish-brown fine crystalline limestone. The formation is not more than 45 ft. in thickness in the C.Y. Creek area and is thought to form the uppermost part of the Paleocene sequence in the Giralia area. Thin sections of the limestone show that it is composed largely of bryozoa similar to those of the underlying calcarenite. Only a few provisional identifications have been made of foraminiferal species from thin sections of the formation. These include:-

Anomalina perthensis
Cibicides pseudoconvexus
Cibicides umbonifer
Globigerina triloculinoides

These species although characteristically Lower Tertiary could indicate Eocene or Paleocene. However the Cashin Limestone is assigned to Paleocene because of lithological continuity with undoubted Paleocene deposits below and because the definitely Eocene formation overlying it is different both in fauna and rock type.

v. Giralia "Calcarenite" (Middle and Upper Eocene)

There is no angular unconformity between this thick formation of ferruginous, foraminiferal and bryozoan limestones and the underlying hard, bryozoan limestones of the Cashin Formation. The contact between the two is poorly exposed but wherever observed, such as in the section 4 mls. S.S.W. of Jubilee Bore, Giralia, there appears to be transitional lithology.

Thus the absence of Lower Eocene is not definitely established simply because index fossils for the Ypresian stage have not been found; more especially as the Ypresian is poorly characterized palaeontologically, except where it is developed in nummulitic facies. The hard limestones of the Cashin Formation and/or the overlying hard Jubilee Limestone, without larger foraminifera, could well represent the transition from Paleocene to Middle Eocene and the lithology certainly suggests this. Because of the absence of 'larger' foraminifera, and the hardness of these limestones the question cannot easily be solved by palaeontology. The Giralia Calcarenite is best exposed and developed on the west flank of the anticline at the north end in the vicinity of Centipede Hill, and Jubilee Bore. Here it attains a thickness of 200 ft. and consists of alternating layers of friable and hard glauconitic calcarenite with limonite grains. Limonite grains and nodules give the formation a characteristic ferruginous appearance. These are thought to be due to secondary replacement of glauconite rather than derivation of the sediments from a limonitic source. The larger foraminifera are also often replaced by ironstone.

The foraminiferal assemblage of this formation is characterized by 'larger' foraminifera typical of the "a-b" stages of the East Indies letter classification. Among the large genera Discocyclina and Asterocyclina predominate while Aktinocyclina, Nummulites and Alveolina are also present. The species of Alveolina and Nummulites represented are both most closely comparable with East Indian species such as A.timorense and N.Kemmerlingi. As well as these Indo-Pacific forms several large forams occur which were previously only known from the newly appointed Upper Eocene of South-East Australia. These include a new species of Victoriella closely related to V.plecte and a new species of Rotalia. As pointed out by Miss Crespin (Records 1952/61) these now form a link for the correlation of these widely separated areas.

Several species of 'smaller' foraminifera known from the Victorian Eocene also occur. These are Notorotalia sp. aff. clathrata and Siphogaudryina victoriana. The species Stomatorbina torrei described by Doreen from the Upper Eocene of New Zealand, is also represented.

The following species of foraminifera have been identified from the Giralia Formation:-

A. 'Larger' Foraminifera
   Alveolina cf. timorense
   Asterocyclina Stellaris
   Asterocyclina stella
   Assilina orientalis
   Discocyclina dispansa
   Discocyclina fritschi
   Discocyclina cf turnerensis
   Nummulites irregularis
   Nummulites cf Kemmerlingi
   Operculina cf vaughani

B. 'Smaller' Foraminifera

Anomalina cf perthensis
Angulogerina sp II
Cibicides umbonifer
Crespinella sp I
Glabratella sp I
Globigerina eocenica
Globigerina mexicana
Globigerina triloculinoides
Globorotalia spinulosa
Linderma cf brugesi
Notorotalia sp. aff clathrata
Parrella mexicana
Stomatorbina torrei
Victoriella plecte
Siphogaudryina cf victoriana

Three horizons distinguished by the association of apparently restricted larger foraminifera can be recognized within the Giralia "Calcarenite". These are (1)

Alveolina cf timorense
and Assilma orientalis
at the top of the formation.

(2) A level at the middle of the formation with large discocyclines and Nummulites. The species are

Discocyclina discus
Linderina brugesi
Nummulites cf irregularis

(3) The first occurrence of 'larger' foraminifera at the base of the formation. These are a small species of Discocyclina namely:-

Discocyclina sp. aff turnerensis
and Asterocyclina stella also a small species.

C. Miocene

i. Lamont Sandstone

In places, particularly along the eastern flank of the Giralia Anticline, an irregular formation of hard to friable quartz sandstone overlies the Eocene, Giralia "Calcarenite". Because of the obvious erosional disconformity between the two and because of small amount of sand in the overlying Trealla Limestone this sandstone formation is placed in the Miocene. A thin section of this sandstone yielded the following foraminifera which also points to a Miocene age:-

Triloculina cf tricarnata
Discorbis sp.

ii. Trealla Limestone. (Lower Miocene)

Although no angular unconformity exists between this hard, white, crystalline limestone and the underlying ferruginous Giralia Calcarenite a large time break separates them. The contact between these formations is irregular and suggests a time break but micropalaeontological evidence shows conclusively that the entire Oligocene is represented by an erosional hiatis.

The following species of 'larger' foraminifera occurring in the Trealla Limestone are typical of the "f" stage of the East Indian sequence. This stage is known to be equivalent to the Burdigalian or Lower Miocene. The species recorded are:-

Austrotrillina howchini _Flosculinella bontangensis_ _Marginopora vertebralis_ _Valvulina_ cf _davidiana_	} restricted forms.

The Trealla Limestone is the highest stratigraphical unit in the Giralia area and is widely distributed as a thin veneer (not more than 50 ft) concordantly capping the Older Tertiary strata.

CONCLUSION.

The application of micropalaeontology to the Upper Cretaceous-Lower Tertiary sequence of the Giralia Anticline has shown the existence there of uninterrupted deposition from the Mesozoic into the Cainozoic era. It has also been possible to recognize an exact boundary between the rocks of these two eras, as well as between the rocks of the Tertiary epochs. These boundaries will be of some practical value in mapping.

In addition, precise correlation has been made with European time stages based on the occurrence of restricted assemblages and species of foraminifera. This correlation has extended the knowledge of Cretaceous-Tertiary palaeogeography, and of the migration of foraminiferal species. The value of planktonic, "smaller" foraminifera in long-range correlation has been demonstrated, and age determinations now show close agreement with those based on macrofossils.

Lastly the sequence has been closely subdivided into foraminiferal zones and subzones, which will enable accurate local correlation with similar deposits in borings or surface outcrops.

(H.S. Edgell)
Geologist.

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