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RADIOLARIA IN THE LOWER CRETACEOUS ROCKS OF AUSTRALIA

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Introduction

Lower Cretaceous radiolaria-bearing rocks have been known in Australia since 1893, when Hinde described several species from the siliceous rocks at Fanny Bay, Darwin, Northern Territory; these are still the only systematic descriptions published. The broadened scope of field investigations since 1930, resulting from the search for oil, has disclosed that such rocks are widely distributed; they have been found in Western Australia, Northern Territory, Queensland, northern New South Wales and northern South Australia. The rocks are of two types: siliceous - including radiolarite - and siltstone. The Lower Cretaceous age of these sediments is determined by the presence of either zonal foraminifera or mega-fossils.

Previous Comments on Lower Cretaceous Radiolaria-bearing Rocks in Australia

Crespin (1959) has listed literature relating to the occurrence of radiolaria in Australian stratigraphy. The references used here are concerned with the Cretaceous only.

Tenison-Woods (1886) was the first to refer to a rock in which radiolaria were later discovered. He recognized "a compact, white to yellowish white, sometimes ferruginous rock" which formed cappings from 16 to 100 feet thick on many cliffs in Northern Australia. He regarded these beds as

unfossiliferous and representing decomposed volcanic ash of Miocene age.

Hinde's work (1893) went unrecognized by Woolnough (1927) who included all known occurrences of "sandy claystone" in Western Australia, Northern Territory and Queensland in his term "duricrust" and mentioned that the "sandy claystones with Belemnites at Stokes Hill, Darwin, and the chalky cliff at Fanny Bay" had harder crusts towards the surface. In 1926 Whitehouse correlated chalky beds at Point Charles, Darwin, with the Lower Cretaceous Tambo "Series" of Queensland on the evidence of the larger fossils and regarded them as the equivalent of Albian.

Noakes (1949) noted that hard, whitish to yellowish siltstone and porcellanites usually capped mesa-like outcrops in the Katherine-Darwin region, Northern Territory. Thin sections of many of the rocks revealed the presence of radiolaria. Noakes, Öpik and Crespin (1952) mentioned occurrences of radiolaria in the Cretaceous rocks of the Bonaparte Gulf Basin, north-western Australia, and Traves (1955) discussed similar rocks in the Ord-Victoria region, north-western Australia. Crespin (in Sullivan and Öpik, 1951) reported radiolaria in the "porcellanites" and "kaolinitic rock" associated with the ochre deposits at Rumbalara, southern Northern Territory.

Dun, Rands & David (1901) recorded radiolaria from rocks of Lower Cretaceous age at Maranoa, north of Mitchell, south-western Queensland, and considered the beds to be stratigraphically equivalent to the Fanny Bay occurrence.

In Western Australia, Raggatt (1936) described the occurrence of a hard siliceous rock from Winning Pool, in the Carnarvon Basin. An examination of this rock by F. Chapman revealed innumerable tests of radiolaria. Megafossils were associated with the radiolaria and an age equivalent to the Fanny Bay beds was suggested. Crespin (1946) recorded all known localities in the Carnarvon Basin from which Lower Cretaceous

radiolaria had been found and listed recognizable forms. Condon, Johnstone, Prichard and Johnstone (1956) gave the formational name "Windalia Radiolarite" to the rocks originally recorded by Raggatt (1936). They are recognized an overlying formation, the "Gearle Siltstone" in which Cretaceous radiolaria are abundant. McWhae, Playford, Lindner, Glenister and Balme (1958) also refer to occurrences of radiolaria-bearing rocks in Western Australia.

The Radiolaria-bearing Rocks

Lower Cretaceous radiolaria-bearing rocks in Australia were laid down in moderately shallow water. The fauna of the Windalia Radiolarite, and the radiolarite of the Darwin Formation, is a pelagic one with foraminifera, radiolaria, belemnites and ammonites. Following their investigations in north-western Northern Territory and north-eastern Western Australia, Noakes (1949) and Traves (1955) suggested that the radiolaria-bearing rocks were deposited in an epeiric sea which submerged the area in Lower Cretaceous times and gradually extended over much of Queensland, northern New South Wales and northern South Australia. Condon et al. (1956) suggested that the radiolaria-bearing rocks in the Carnarvon Basin, Western Australia, were deposited on a stable shelf which may have been marginal to the Timor-Celebes geosyncline. This sea most probably extended as far south from the Carnarvon Basin as Moora, in the Perth Basin, 100 miles north of Perth.

Characteristically, radiolaria occur in abundance throughout the stratigraphic column in siliceous rocks as jasperoid, chert, porcellanite and siliceous shale (Campbell, 1952). In Australia, radiolaria of Lower Cretaceous age are present also in siltstones.

Siltstone. This rock is typified by the "Gearle Siltstone", which is described from a section in C-Y Creek, Carnarvon Basin, Western Australia, at lat. 22°54'S, long. 114°09'E. (Condon et al, 1956). This section is estimated to be 535 feet thick, and consists of dark grey, brownish and greyish bentonitic siltstone with foraminifera, radiolaria, and belemnites. It conformably overlies the Windalia Radiolarite. Well-preserved radiolaria are abundant in certain bands throughout the section. This rock is known only in the Carnarvon Basin.

Siliceous rock type. A fine-grained siliceous rock is widely distributed in outcrop, especially in the northern half of the continent, where it occurs characteristically as cappings on flat-topped mesa-like prominences, which, at times, afford the only topographical relief over considerable distances. The siliceous rock includes chert, porcellanite, radiolarite (micaceous in places), and sandy siltstone. The colour varies considerably, from white to deep yellowish, pink or purple. Some parts of the weathered portions have a very low specific gravity and the rock in general has a characteristic conchoidal fracture. Radiolaria are present in varying abundance in the different lithologies: they are mostly well-preserved and can often be identified even specifically in thin rock sections.

A typical radiolaria-bearing siliceous rock is found at Windalia Hill (trig. point A46, lat. 23°16'S, long. 114°48'E), Winning Station, Carnarvon Basin, Western Australia, where it has been given the formational name "Windalia Radiolarite" (Condon et al., 1956). The section is 100 feet thick and the radiolarite contains a pelagic fauna of foraminifera, radiolaria, belemnites, ammonites and pelecypoda.

Chemical analyses of Hinde's (1893) "white, yellowish white, earthy rock" from Fanny Bay, and two samples of Windalia

Radiolarite from Windalia Hill (Table 1), show that as the silica content falls, that of alumina rises; this is probably related to variation in the amount of clay minerals present.

Table 1

	A	B	C
SiO_2	84.2%	94.44%	87.90%
Fe_2O_3	Trace	0.94	0.90
Al_2O_3	10.7	1.79	7.01
Na_2O	n.d.	0.06	0.14
K_2O	n.d.	0.29	0.24
CaO	-	n.d.	Trace
MgO	-	-	-
Cl	-	Trace	Trace
Loss on ignition	5.0	1.99	3.72

A. Fanny Bay, N.T., Analysis, Geol. Surv. Gt. Britain, 1893.

B.) Windalia Hill, W.A., Analysis, S. Baker,
C.) Bur. Min. Resources, Canberra, 1959.

The silica content and the relative abundance of radiolaria tests in samples of radiolarite from Western Australia, Northern Territory and Queensland are shown in Table II.

Table II

Silica and Radiolaria in Radiolarite

Locality	SiO_2 per cent (weight)*	Radiolaria per cent (volume)
Fanny Bay, Darwin, N.T. Hinde, 1893	84.20	
Windalia Hill, Carnarvon Basin, W.A., type Windalia Radiolarite (GCC.20) (a)	94.44	80
(b)	87.90	80
Between West Point and Delissa Mission, N.T. (LCN.118)	86.04	More than 50% less than 80%
Glenormiston 4-mile Sheet, Queensland. (G.134)	94.54	More than 50% less than 80%
Glenormiston 4-mile Sheet, Queensland. (G.526)	72.68	50% or less
Boulia 4-mile Sheet Queensland	74.28	More than 50%
Rumbalara, N.T. (23A)	83.46	Less than 30%

* Analysis by S. Baker, Bur. Min. Resour., Canberra, 1959.

The percentages of radiolaria shown in the above table are based on several thin sections of an individual rock specimen. Hinde (1893) noted in the Fanny Bay rock that "in some portions the tests were so crowded as to be in contact with one another, whilst in others they are sparsely scattered here and there".

Many deposits of radiolarian chert and radiolarite are considered to be connected with geosynclines and with volcanic activity (Campbell, 1952). But there is no evidence that volcanic activity is associated with the Lower Cretaceous radiolaria-bearing rocks of Australia, or, indeed, with any part of the Lower Cretaceous sequence. Craig (1950) considered the rock at Windalia Hill to be an argillaceous tuff; but petrological examination has proved that minerals usually found in deposits associated with vulcanism are absent. The Australian rocks appear to be essentially of sedimentary origin. Condon et al. (1956) stated that the Windalia Radiolarite is laminated, and quoted the results of a petrological examination:

"Whole radiolarian test (0.1 mm.) - about 2.5 percent, quartz (0.05-0.005 mm.) - about 2 percent, ? diatoms, ? chalcedony, a very fine grained (less than 0.002 mm.) ground-mass of rods, rings and stars of ?opal. Probably the rods etc. of ? opal are fragments of radiolaria as they have the same colour and refractive index as the radiolarian test".

Hill and Jukes-Browne (1895) considered that the radiolarian skeleton varied in its stability during fossilization. Those in more purely siliceous rocks were little altered, whilst those in material partly siliceous and partly calcareous were more readily altered.

The problem of the abundant silica in the Lower Cretaceous siltstone and radiolarite of Australia has not yet

been satisfactorily solved. Taliaferra (1943) in discussing the Franciscan Formation of California suggests that one of the essential factors for the rapid multiplication of radiolaria was created by the great amount of silica introduced into the sea water. However, the radiolarian rocks of the Franciscan Formation are closely associated with vulcanism which is not known to be associated with the rocks in Australia.

The siliceous rock type is associated with opal and ochre deposits in Australia. Radiolaria and arenaceous foraminifera were discovered in the white to cream and pale pink siliceous claystone of the opal deposits at Coober Pedy, north-eastern South Australia; a few foraminifera but no radiolaria were recognized in a similar rock from Andamooka in the same area (Croll, 1950). Porcellanite and chalky siltstone are associated with the opal deposits at Mt. Cannaway near Quilpie, south-western Queensland, but no radiolaria have been identified (Cribb, 1948).

The "kaolinitic rock" of the ochre deposits included in the Rumbalara Shale, southern Northern Territory, contains radiolaria and many megafossils (Sullivan and Öpik, 1951).

The Radiolarian Assemblages

The only systematic contribution on the radiolaria from the Lower Cretaceous rocks of Australia is by Hinde (1893), who listed and figured ten genera and eleven new species from thin sections of the siliceous rock from Fanny Bay, Northern Territory. They are as follows:

Amphibrachium truncatum Hinde
Amphibrachium crassum Hinde
Amphibrachium fragile Hinde
Amphibrachium sp.
Astrophacus sp. a
Astrophacus sp. b
Astrophacus sp.

Cenellipsis sp.

Dictyomitra australis Hinde

Dictyomitra triangularis Hinde

Lithocampe fusiformis Hinde

Lithocyclia exilis Hinde

Spongodiscus expansus Hinde

Spongodiscus sp.

Spongolena symmetrica Hinde

Stichocapsa pinguis Hinde

Stichocapsa chrysalis Hinde

Chapman (in Raggatt, 1936) was the first to note the abundance of radiolaria in the rock now known as the Windalia Radiolarite from Windalia Hill, Carnarvon Basin, and identified Dictyomitra australis, Lithocyclia exilis and Stichocapsa sp.

Crespin (1946) commented on the abundance of discoidal Spumellarians in the yellowish chert and sandy siltstone of the Windalia Radiolarite and on the excellently preserved forms in the siltstones now referred to as the "Gearle Siltstone". She listed 23 forms.

Edgell (in Condon et al., 1956) listed eleven species from the type Windalia Radiolarite, and Belford (1959) identified three of Hinde's species (1893) amongst the many forms from the Gearle Siltstone.

Radiolaria have been recorded by the writer in unpublished departmental reports from many localities in Northern Australia and south-western Queensland, from which the siliceous rock type has been collected.

Age of the Radiolaria-bearing Rocks

Many fossil radiolaria are now known only as long-ranging genera, but when they have been systematically studied, the species distinguished will certainly have a considerably more precise stratigraphical connotation. They are of

particular importance in the Lower Cretaceous rocks of Australia, in many of which other fossils are absent. Dr. W. R. Riedel, in a personal communication to the writer a few years ago, said he regarded the assemblage of forms in the Windalia Radiolarite and Gearle Siltstone as unique, and if this is so, it is safe to assume that they will ultimately be of stratigraphical value.

The stratigraphical sequence, lithology, and fossil content of the Cretaceous radiolaria-bearing rocks of the northern part of the Carnarvon Basin (Condon et al., 1956) is shown below. The age determination has been revised because of recent work on the faunas (Belford, 1959; Brunnschweiler, 1959).

Formation	Lithology	Common Fossils	Age
Korojon Calcarenite	Friable white and cream fossiliferous calcarenite	Inoceramus, Ostrea, brachiopoda, foraminifera	Upper Cretaceous (Campanian to Maestrichtian)
----------Disconformity----------			
Gearle Siltstone	Soft, tough to friable, brownish-grey bentonitic claystone and siltstone with gypsum	Foraminifera, radiolaria, belemnites	Upper part Up. Cretaceous (Cenomanian to Lr. Turonian) Lower part Lr. Cretaceous (Up. Albian)
Windalia Radiolarite	Vari-coloured permeable radiolarite and chert with numerous radiolaria	Radiolaria, foraminifera, brachiopods, ammonites, belemnites	Lr. Cretaceous (Lr. Albian to Up. Aptian)
Muderong Shale	Grey, fossiliferous bentonitic shale and siltstone with gypsum	Foraminifera, radiolaria	Lr. Cretaceous (Aptian)

The age of the rocks has been based on the associated foraminifera and megafossils. The Windalia Radiolarite contains many arenaceous foraminifera and a few calcareous forms, some of which have been described by the writer (Crespin,

1953) from the beds known to underlie the radiolarite in the Great Artesian Basin and to be associated with a megafossil fauna of Aptian age (Whitehouse, 1954). It is only in the Carnarvon Basin of Western Australia that this rock type is immediately overlain by beds of Cretaceous age. The foraminifera of the Windalia Radiolarite are known to range through the Aptian and Albian and some into the Cenomanian. Belford (1959), in his study of the foraminifera from this formation and the succeeding Gearle Siltstone, suggests that the Windalia is at least lower Albian in age and may even be Aptian, whilst the Gearle with its abundant radiolaria, is Upper Albian. The underlying formation, the Muderong Shale, which contained few radiolaria, is referred to the Aptian. Brunnschweiler (1959) regards the ammonites from the Windalia Radiolarite as Upper Aptian to Lower Albian.

The writer (in Noakes, 1949) suggested an Albian age for the radiolarites of the Darwin Formation, Northern Territory. Whitehouse (1926) made no reference to the radiolaria-bearing rocks of Hinde (1893) from Fanny Bay, when he referred the beds containing a megafossil fauna at Point Charles, a short distance away, to the Albian.

Radiolaria occur abundantly in some of the Mesozoic rocks of Indonesia. Hinde (1900) recorded two of this Fanny Bay species, Dictyomitra australis and Amphibrachium crassum, from beds in Central Borneo. Tan (1931) referred to those beds as "Prae-Cenomanian" because of the presence of the Lower Cretaceous foraminiferal species Orbitolina concava in the overlying beds. The radiolarian cherts and jaspers of the Moluccas are Triassic and Jurassic and most are probably associated with volcanic activity.(van Bemmelen, 1949). Tan (1927) described species from Rotti near Timor, in beds which he placed as Pliocene. Riedel (1953) with the discovery of two restricted Cretaceous genera, now regards the deposits as Mesozoic.

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