Discussion : age and correlation

Windalia sp. D
Plate 5, Figs. 16, 18

Remarks. – *Windalia* sp. D is characterized by having a greatly inflated spindle-shaped test.
Range. – Late Aptian to Early Albian.
Occurrence. – Western Australia.

Note. – Due to moderate and poor sample preservation and because samples exist over a narrow time range (latest Aptian to Early Albian), it is unclear whether *Windalia* sp. A, sp. B, sp. C and sp. D are distinct species or whether they are heteromorphs of *Windalia pyrgodes*. These forms are left under open nomenclature until a larger database can be assembled fully documenting their relationships.

Genus ***Xitus*** PESSAGNO

Xitus PESSAGNO 1977b, p. 55.

Type species. – *Xitus plenus* PESSAGNO 1977b.

Xitus vermiculatus (RENZ)
Plate 4, Figs. 12, 13

Eucyrtidium vermiculatum RENZ 1974, p. 792, pl. 8, figs. 17–19; pl. 11, fig. 22 (refigured pl. 8, fig. 17).
Xitus spineus PESSAGNO 1977b, p. 56, pl. 10, figs. 3, 12, 16, 20.
Xitus vermiculatus (RENZ), Schaaf 1981, p. 441, pl. 19, figs. 6a–b.
Xitus sp. cf. *X. spicularius* (ALIEV), Schaaf 1981, p. 441, pl. 4, fig. 12.
Novixitus tuberculatus WU & LI 1982, p. 69, pl. 2, fig. 6.
Parvicingula (?) sp. THUROW 1988, p. 403, pl. 6, fig. 10.
Pseudodictyomitra sp. A TUMANDA 1989, pl. 8, fig. 10.
cf. *Xitus* sp. indet. SCHAAF 1981, pl. 21, figs. 10a–b.
aff. *Dictyomitra* sp. FOREMAN 1975, p. 615, pl. 1H, fig. 5; pl. 2H, fig. 2.

Range. – Berriasian (?) to middle Cretaceous.
Occurrence. – California, Japan, Tibet, Pacific and Indian Oceans, Western Australia.

6. Discussion: Age and correlation

At present, ammonites offer the most reliable age determination of the type section. The most common forms identified from the Windalia Radiolarite at Winning Station are *Tropaeum* and *Australiceras*, which are widely distributed only in Aptian-Albian strata (Whitehouse 1927; Day 1969, 1974). Day (1969, 1974) further showed that if Australian species of these genera are the same age as their northern European and Madagascan analogues, which have been accurately dated by their association with hoplitids, then only Late Aptian-Early Abbian time is represented by their ranges. Other age-diagnostic ammonite genera (*Aconoceras, Toxoceratoides* and *Sanmartinoceras*) and the belemnite genus *Peratobelus* recorded from the type section are consistent with a Late Aptian-Early Albian age. Although little published data is publicly available, the preceeding Muderong Shale and succeeding Gearle Siltstone have been dated with palynomorphs,

foraminifera and nannoplankton by petroleum industry consultants (see Hocking et al. 1987), and together bound the Windalia Radiolarite to the latest Aptian to Early Albian.

Coeval radiolarian-rich sediments have been recorded from outcrops across Australia, but only few studies have dealt seriously with the constituent radiolaria. The Windalia fossil assemblages are similar to those illustrated from the Doncaster Member of the Wallumbilla Formation, Surat Basin, Queensland (Haig & Barnbaum 1978). This formation is also regarded as Upper Aptian-Early Albian based on associated ammonites (similar to those recovered from the Windalia Radiolarite) and more broadly with foraminifera and palynomorphs. The Aptian-Albian Darwin Formation in the Northern Territory (Pietsch 1983) was visited by the author in 1990 and 1992. At outcrop, this formation is lithologically identical to the type Windalia Radiolarite. Radiolaria from the Darwin sediments have only been briefly described by Hinde (1893) and Lloyd (1966) but are comparable to those of the Windalia Radiolarite. Detailed comparison with these assemblages is difficult due to poor illustrations and broad taxonomic descriptions. The middle Cretaceous (Aptian-Cenomanian?) radiolarian assemblages recovered from the eastern Indian Ocean during Deep Sea Drilling Project (DSDP) Leg 27 (Renz 1974) are more diverse than those illustrated here but have many taxa in common; the most notable of which include *W. epiplatys* (RENZ), *W. pyrgodes, A. stocki*, species of *Spongopyle, Artocapsa ultima* TAN, *Crucella messinae* PESSAGNO, *Gongylothorax cephalocrypta* (TAN), and *T. antiqua*. Unfortunately, *A. exilis, A. pleiadesensis, P. excelsa* and *S. renillaeformis*, which compose the dominant taxa in the Windalia Radiolarite, could not be accurately compared with the DSDP Leg 27 fauna illustrated by Renz (1974).

It is not possible, nor the intention of this paper, to construct a radiolarian biozonation based on the limited material recovered from a single section. The large number of specifically unidentifiable taxa and the uncertain stratigraphic ranges of many new and old radiolarian species (especially when applied to the southern hemisphere) make chronostratigraphic correlation and calibration difficult. However, several biostratigraphic trends in radiolarian composition are present at Windalia Hill and in other southern hemisphere sites currently being investigated, and hold promise for future refinement of the Cretaceous radiolarian biozonation. *Windalia pyrgodes* is common in the Windalia Radiolarite and has been recorded from the Doncaster Member, from middle Cretaceous sediments recovered from the eastern Indian Ocean (DSDP Leg 27, Renz 1974) and more recently from the Weddell Sea (ODP Leg 113, Ling & Lazarus 1990). *Windalia epiplatys* has previously been recorded only from DSDP Leg 27. The genus *Windalia* has also been illustrated by Baumgartner (1992), and appears to extend from the Valanginian through to the Albian. Another radiolaria, *Arachnosphaera exilis*, has been recorded, so far, only from the onshore Australian "radiolarites".

No single radiolarian biozonation can be applied to the Cretaceous faunas from the Windalia Radiolarite. Although comparisons are possible, the paucity and absence of many zonal species hinders any direct correlation with the Lower Cretaceous zonations of Pessagno (1977a), Schaaf (1981), Nakaseko & Nishimura (1982) and Sanfilippo & Riedel (1985; which incorporates assemblage data from DSDP Legs 26 (Riedel & Sanfilippo 1974) and 27 (Renz 1974)) and Teraoka & Kurimoto (1986). The semiprobabilistic technique used to construct the apparently refined Cretaceous zonation presented by Schaaf (1985) has been criticized by Guex (1992, p. 190; see also Baumgartner 1992) and

shows discrepancies within the data set used and with the zonation of Sanfilippo & Riedel (1985); only the ranges of specific taxa documented by Schaaf (1985) are considered here. Biozonal data extracted from these studies, and others (particularly Taketani 1982, Baumgartner 1984, Yao 1984, Aita 1987; Thurow 1988 and Blome 1992), does, however, help in assigning an age to the Windalia Radiolarite based on radiolaria. Well-documented, biostratigraphically diagnostic taxa include *A. diaphorogona, A. ultima, G. cephalocrypta, H. barbui barbui, Pseudodictyomitra lodogaensis* PESSAGNO, *S. renillaeformis, T. antiqua* and *Xitus vermiculatus* (RENZ) whose concurrent ranges suggest an age of Late Aptian to Early Albian, equivalent to the lower part of the *A. umbilicata* Zone of Sanfilippo & Riedel (1985). Many of the above species, and including *Archaeospongoprunum carrierensis* PESSAGNO, *Archaeodictyomitra sliteri* PESSAGNO, *A. vulgaris* PESSAGNO, *C. messinae, Napora dumitricai* and *N. durhami*, are all common in the *Kozorium zinguli* Zone (Zone 7) of Pessagno (1977a) and suggest only Early Albian time is represented. However, Pessagno (1977a, p. 18) expressed uncertainty with his positioning of the Aptian-Albian boundary in the California Coast Ranges sequence. It is probable that many of these species have ranges extending into the Late Aptian, as seems to be the case at Windalia Hill.

Specific identification of the radiolaria from the Windalia Radiolarite conforms with the original descriptions. Although variations do exist (see remarks for each taxon in the systematic section), placement of such taxa is considered acceptable either due to assumed intraspecific variation or that the original descriptions are sufficiently broad to allow incorporation. Many other forms are either only tentatively compared or left under open nomenclature because of large discrepancies in the ages of similar known species. The Late (latest) Aptian-Early Albian age for the Windalia Radiolarite also indicates that the published ranges of many radiolaria need revision, including *Archaeocenosphaera boria* PESSAGNO, *Mesosaturnalis hueyi* group (PESSAGNO), *Orbiculiforma depressa* WU, *O. mclaughlini* PESSAGNO, *Praeconocaryomma lipmanae* PESSAGNO, *P. prisca* PESSAGNO. These points highlight the current lack of detailed knowledge of many radiolaria in the early to middle Cretaceous, and, in particular, the difficulties in applying biozonations based on low-latitude radiolarian assemblages to the medium and high-latitude Austral region.

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