WELL-PRESERVED LATE PALEOCENE RADIOLARIA FROM TANGIHUA COMPLEX, CAMP BAY, EASTERN NORTHLAND

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SUMMARY

A sparse but very well-preserved radiolarian fauna has been obtained from interpillow limestone in the allochthonous Tangihua Complex at Camp Bay, northwest of Whangaroa Harbour. A Late Paleocene age (58-62 Ma) is probable; primarily because of the presence of *Buryella* cf. *tetradica* Foreman, a variant of *B. tetradica* known only from the Paleocene, and the absence of Early Paleocene or latest Paleocene-Eocene index species. This is the first unequivocal record of Tertiary fossils from Tangihua sediments. The assemblage suggests upper-mid bathyal, warm-temperate conditions of deposition.

The good state of preservation and the presence of established index species show that radiolarians have potential for improving age control and clarifying the depositional conditions of sediments associated with Tangihua igneous massifs.

INTRODUCTION

The Tangihua Complex of Northland is exposed in a number of massifs (Fig. 1) which consist of cumulate and noncumulate gabbros, sheeted dikes, and pillow lavas with minor mudstone, limestone and chert. These massifs were first recognized as obducted ocean crust (ophiolites) by Brothers (1974). They comprise the uppermost part of the Northland Allochthon which was emplaced on autochthonous sequences in the Late Oligocene or Early Miocene (Ballance and Spörli 1979; Hayward *et al.* 1989).

The complex is thought to range in age from Early Cretaceous to probable Paleogene (Early Tertiary). However, most age determinations have been based on incomplete and poorly preserved macrofossils or long-ranging agglutinated foraminifera (Farnell 1973; Hornibrook and Hay 1978; Brothers and Delaloye 1982; Hayward 1983; Brook *et al.* 1988; Brook and Hayward 1989). Consequently, most ages are poorly constrained. Age relationships between the massifs in Northland are obscure because most are still undated. Similarly, age relationships between the different types of sediment are unknown.

For these reasons, study of radiolarians from Tangihua sediments is long overdue. Radiolarians have been frequently reported (e.g. Farnell 1973; Hornibrook and Hay 1978; Hayward 1983) but never before described, yet they
have the potential to provide well-constrained ages. Their siliceous tests have high preservation potential and permit their easy extraction from fine-grained, indurated sediments by acid-leaching (see Sanfilippo and Riedel 1985; Jones and Murchey 1986).

The radiolarian fauna discussed here was obtained from micritic limestone within pillow lavas in middle Camp Bay (Figs. 1 and 2; Grid Reference: P04/753918, NZMS 260 Sheet P04, Whangaroa, first edition). The locality was sampled in the course of a detailed structural study of Tangihua Complex at Camp Bay (Hanson 1991). C. Hollis examined the fauna as an adjunct to his doctoral study of Late Cretaceous to Late Paleocene Radiolaria from Marlborough and DSDP* Site 208 (NW Lord Howe Rise, Leg 21).

Camp Bay is about 1km north of Taupo Bay, northwest of Whangaroa Harbour. The fossil locality can be reached through Tupou Farm with permission from the landowners. A private road leading to the farmhouse branches to the northeast from Taupo Bay Road about 3km west of Taupo Bay. From the farmhouse a 2km walking track through farmland leads to Camp Bay.

* DSDP = Deep Sea Drilling Project.

Fig. 1. Localities and general geology of the area between Camp and Taupo Bays. Inset shows location of Camp Bay and occurrences of Tangihua Complex in northern Northland. Detail of study area is shown in Fig. 2.
Fig. 2. Schematic geological map of mid Camp Bay showing fossil locality (sample 17, P04/f99). A - D identify subunits mentioned in the text.
OUTLINE OF GEOLOGY

The geology of autochthonous and allochthonous sequences of the broader area including Camp Bay has recently been described by Brook and Hayward (1989). Lithostratigraphic names follow their usage.

At Camp Bay (Fig. 2) the Tangihua Complex structurally overlies the Tupou Complex which consists of indurated sandstones and mudstones of probable Cretaceous age (Brook and Hayward 1989). Tangihua rocks are overlain by the Miocene Wairakau Volcanics. The following descriptions of relevant lithologies are summarised from Hanson (1991).

The Tangihua rocks consist of two distinct structural, metamorphic and lithological units (Figs. 1 and 2), both of which have N-type MORB (mid ocean ridge basalt) geochemical signatures:

1) A 1.1km thick dominantly mylonitic igneous complex of diabase basalt, microgabbro and diorite. These rocks are all metamorphosed to greenschist facies, except for the youngest dikes which have prehnite-pumpellyite assemblages. K-Ar dates from the mylonitic igneous complex give metamorphic closure ages of 20 to 27ma (Hanson, 1991).

2) Underlying the mylonitic igneous complex is a thin, highly disrupted unit consisting of haematitic, basaltic pillow lavas and layered flows (both with zeolite metamorphic assemblages) with minor limestone and chert.

At the fossil locality (Fig. 2) Unit 2 is 42m thick and consists of four distinct subunits (from bottom to top):

A) Largely undeformed, upright, rounded pillows containing pockets of red limestone.

B) Layered lava flows. Each flow is no more than 15 cm thick. A thin interval of layered lava also underlies this Subunit A (see Fig.2).

C) Red chert interlayered with highly zeolitised basalt. This unit is less than 15m across and is often obscured by sand.

D) Breccia composed of fragments of lava and chert.

The juxtaposition of Unit 1 on Unit 2 indicates an inversion of metamorphic zones.

MATERIAL AND METHODS

Four samples of dark red, micritic limestone were collected from within the pillow lavas of Subunit A. Calcite veining was evident in all samples but less pervasive in the one productive sample (Sample 17) in which veins were more dispersed. Samples were disaggregated by the following method which is a modification of standard procedures for extracting radiolarians from limestone (e.g. Sanfilippo and Riedel 1985):

1) Break about 100g of rock into 1-2cm pieces and place in 500ml beaker.
2) Rinse thoroughly and leave to stand overnight in 4:1 solution of 15% H₂O₂ and 5% (NaPO₃)₆. This removes surficial organic material and clays.

3) Rinse and slowly cover with 15% HCl, monitoring reaction until it ceases. All samples broke down under this treatment.

4) Sieve residue through a 63μ stainless-steel screen and transfer to a 200ml pyrex beaker.

5) To remove remaining organic material and disperse clays, cover residue with H₂O₂ / (NaPO₃)₆ solution (as in Step 2) and slowly heat on hot-plate, monitoring reaction to avoid excessive boiling; simmer for 1-2 hours. Leave to cool. Add a few drops of concentrated HCl to check that all carbonate has been removed.

6) Sieve residue again and transfer to 200ml teflon beaker.

7) Cover with 1-2% HF for not more than 2 minutes. This final cleaning step is very effective for removing fine siliceous aggregates but will etch radiolarian tests if prolonged.

8) Sieve again over a bucket containing a saturated NaCO₃ solution (to neutralise HF), rinse thoroughly, dry and scan for radiolarians under stereo microscope.

All chemical treatment was carried out under a fume-hood. Only Sample 17 was productive. All radiolarians were picked and mounted in a microfossil cavity slide. Representative specimens were mounted with double-sided tape on a SEM (scanning electron microscope) stub and examined and photographed with a Phillips 505 scanning electron microscope. All SEM photomicrographs in Fig. 3 are contact prints from Ilford large format film (FP4).

Some unprocessed material, the cavity slide and SEM stub are stored in the Department of Geology, University of Auckland (paleontology curation number RA1051; NZ fossil record number P04/f99).

FAUNAL CHARACTER

The radiolarian fauna in Sample 17 is relatively sparse (c. 10 radiolarians per gram of original sediment), of low diversity, but extremely well-preserved. The fauna is listed in Table 1 and representative taxa are illustrated in Fig. 3. Excellent preservation is shown particularly well by the actinommmids figured (Fig. 3.1-3.3), in which intact internal shells can be seen, and by the fine detail of the concentric meshwork in the figured litheliid (Fig. 3.4). Such details are rarely preserved in Paleogene faunas from on-land exposures. It is not clear why preservation is so good in this setting given the tectonic disturbance the units have undergone. It seems likely that this sample at least was protected from both mechanical disturbance and the effects of solution by its location within the pillow lavas. It appears significant that the sample has fewer calcite veins than
the others examined.

At present, paleoenvironmental interpretation of the fauna is uncertain. It contains no clear depth indicators and only a few taxa have been allocated to known species. Low total abundance and diversity as well as the absence of diatoms indicate low fertility. The relatively low abundance of actinommids and high abundance of litheliids and *Buryella* are also features of the Paleocene faunas at Site 208 and may indicate similar upper to mid bathyal depths and warm-temperate conditions. This is compatible with the bathyal to abyssal setting for Tangihua sediments inferred from foraminifers (e.g. Brook and Hayward, 1989).

Comparisons made here and below with radiolarian faunas from Marlborough and DSDP Site 208 (Burns et al. 1973) are based on Hollis' doctoral study (Hollis 1991) and an earlier report on the radiolarians from Site 208 by Dumitrica (1973).

### TABLE 1 Faunal List for Sample 17

<table>
<thead>
<tr>
<th>Number</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>Actinommmidae indet.</td>
</tr>
<tr>
<td>4</td>
<td><em>Amphisphaera radiosa</em></td>
</tr>
<tr>
<td>2</td>
<td><em>Amphisphaera spinulosa</em> *</td>
</tr>
<tr>
<td>57</td>
<td>Litheliidae indet.</td>
</tr>
<tr>
<td>14</td>
<td>Spongodiscidae indet.</td>
</tr>
<tr>
<td>3</td>
<td>Sponguridae indet.</td>
</tr>
<tr>
<td>2</td>
<td>Eucryrtidiidae indet.</td>
</tr>
<tr>
<td>31</td>
<td><em>Buryella</em> cf. tetradica</td>
</tr>
<tr>
<td>4</td>
<td><em>Clathrocycloma</em> sp. A</td>
</tr>
<tr>
<td></td>
<td><strong>Total radiolarians</strong></td>
</tr>
</tbody>
</table>

**AGE**

As well as overall faunal similarities, all four species identified in the sample from Camp Bay also occur in the Early to Late Paleocene at Site 208. Both *Amphisphaera spinulosa* and *A. radiosa* range into the Eocene (Sanfilippo and Riedel 1973; Petrushevskaya 1974). The other two species are known only from Site 208 and Marlborough. *Clathrocycloma* sp. A ranges from earliest to Late Paleocene and may be a local variant of one of several similar species known from the Eocene (e.g. those ascribed to *Clathrocyclas* in Clark and Campbell 1942). *Buryella* cf. *tetradica* provides the best age control for the sample. It co-occurs with *B. tetradica* at Site 208 and in Marlborough and, as is noted
below, may be simply a variant of *B. tetradica*. Both taxa first appear in the latest Early Paleocene at Site 208 (upper part of Nannofossil Zone NP4). Although *B. tetradica* ranges into the Early Eocene, in the upper part of its range (latest Paleocene-Early Eocene) it is accompanied by other species of *Buryella* and the genus *Bekoma* (Foreman 1973; Sanfilippo *et al.* 1985; Nishimura 1987). The absence of these latter taxa indicates that the sample is older than latest Paleocene. *Bekoma* first appears in the basal Waipawan (latest Paleocene-Early Eocene) at Mead Stream in Marlborough (Strong *et al.* in prep.). The fauna also lacks early species of *Buryella* (i.e. *Buryella* sp. A and B of Dumitrica, 1973) and the many Cretaceous-Tertiary species which characterise the Early Paleocene in Marlborough and at Site 208.

For these reasons, the sample is considered to be of Late Paleocene (upper Teurian) age. This age must be treated as provisional until more material is examined. Given the low diversity of the fauna it is possible that some absences are due to environmental factors rather than to age. If absences of taxa are excluded from consideration, the possible age range of the fauna is late Early Paleocene to Early Eocene (based on the range of *B. tetradica*).

**CONCLUDING REMARKS**

The discovery of this fauna is significant for several reasons:

1) It confirms that the age of the Tangihua Complex extends into the early Paleogene. Foraminifera of definite early Paleogene age (Eocene, possibly Paleocene) have also been reported from sediments within correlative Matakaoa Volcanics in East Cape (Strong 1980).

2) It shows that even with largely chance sampling workable radiolarian faunas can be obtained from Tangihua sediments. The extremely good preservation of this fauna indicates that, with more selective sampling, improved age control is possible for the pelagic limestones. It is significant that radiolarians have been reported from several otherwise sparsely fossiliferous samples that have formed the basis of some age determinations (e.g. Farnell 1973, Hornibrook and Hay 1978; Hayward 1983). These samples were most likely disaggregated using standard methods for retrieving calcareous fossils which are not suitable for extracting radiolarians. The HCl-leaching method outlined above is likely to produce rich radiolarian faunas in such samples and may substantially improve age control.

3) This age determination only applies to the pillow lavas (Subunit A). Radiolarians are also expected in the chert of Subunits C and D at Camp Bay (see Fig. 2) and can be extracted using standard HF-etching methods (see Sanfilippo and Riedel 1985). Comparisons between faunas from the limestones, cherts and mudstones at this locality and elsewhere are necessary to clarify age
and paleoenvironmental relationships between different sediment types.

4) The fauna highlights the value radiolarians offer for providing well-constrained ages for the allochthonous ophiolites of Northland and East Cape. Preliminary studies of radiolarians from these rocks have recently been reported (Aita and Spörli in press, in prep.).

**TAXONOMIC NOTES**

Brief taxonomic notes are necessary for the four species recorded because there are considerable nomenclatural differences between records of stratigraphic significance mentioned above. Only these synonyms are listed and are accompanied by brief comments to clarify the concept of the species as applied here. In general, nomenclatural changes follow Petrushevskaya (1974). More thorough systematic treatment of these species is given in Hollis (1991).

Class ACTINOPODA  
Subclass RADIOLARIA  
Superorder POLYCYSTINA  
Order SPUMELLARIA  
Family ACTINOMMIDAE

**Amphisphaera spinulosa (Ehrenberg) - Fig. 3.1**

*Stylatractus spinulosus* (Ehrenberg) group, Petrushevskaya and Kozlova 1972, p.519, pl.11, figs.2-4.  
*Stylosphaera goruna* Sanfilippo and Riedel 1973, p.521, pl.1, figs.20-22; pl.25, figs.7,8; Nishimura 1987, p.729, pl.1, fig.3.  
*Druppatractus* cf. *coronatus* (Squinabol), Dumitrica 1973, p.787, pi.6, figs.4,6; pi.12, fig.11 (non Squinabol 1904).  
*Amphisphaera spinulosa* (Ehrenberg) group, Petrushevskaya 1974, p.570, pi.16, fig.8; Hollis 1991, p.69, pl.3, figs.11-15.

**Remarks:** Although "*Stylosphaera goruna*" is the name most commonly used for this taxon, Sanfilippo and Riedel (1973) did not discuss how their material differed from *A. spinulosa* which was shown to have priority by Petrushevskaya (1974).

**Amphisphaera radiosa (Ehrenberg) - Fig. 3.2**

*Stylatractus radiosus* (Ehrenberg), Petrushevskaya and Kozlova 1972, p.520.  
*Druppatractus* sp., Dumitrica 1973, p.787, pl.12, fig.3.
Amphisphaera radiosa (Ehrenberg), Petrushevskaya 1974, p.570, pl.2, figs.18-20; Hollis 1991, p.71, pl.3, figs.16-19. 
Stylosphaera coronata coronata Ehrenberg, Nishimura 1987, p.729, pl.1, figs.1, 2 (non Ehrenberg 1873).

Remarks: This species is distinguished from "Stylosphaera" coronata coronata by the length and shape of its shorter polar spine. The spine is rarely more than a third the length of the main axis of the outer shell and is simply conical rather than cylindrical proximally and tapering abruptly distally. As such the specimens figured by Nishimura (1987) are more properly referred to A. radiosa.

Order NASSELLARIA
Family EUCYRTIDIIDAE

Clathrocycloma sp. A - Fig. 3.6

Clathrocyclas? spp., Dumitrica 1973, p.788, pl.2, fig.3; pl.9, fig.3 (?pl.10, fig.5).


Remarks: This species is distinguished from other members of the genus by its cylindrical thorax with large sub-rectangular pores distally (main diameter usually axial). The third specimen Dumitrica (1973) figured is only doubtfully placed in synonymy as the thorax flares at the base.

Buryella cf. tetradica Foreman - Figs. 3.7-3.10

Buryella sp. C Dumitrica 1973, p.789, pl.11, figs. 5, 6.

Buryella tetradica Foreman 1973, p.433, pl.8, figs.4, 5; pl.9, figs.13, 14;
Nishimura 1987, p.721, pl.2, fig.8; Hollis 1991, p.139

Remarks: The forms Dumitrica (1973) separated into two species differ from B. tetradica by lacking distinct longitudinal alignment of pores on the third segment. The form he ascribed to B. cf. tetradica frequently has disturbed longitudinal pore alignment (as in Fig. 3.7) while Buryella sp. C was described as having quincuncially or irregularly arranged pores (as in Fig. 3.8-3.10). Both appear to intergrade with B. tetradica in material examined from Site 208 and Marlborough and here they are only provisionally separated from it. Some
specimens resemble *Buryella* sp. A of Dumitrica (1973) but lack its distinctly lobate outline. All these forms differ from *B. clinata* by having a broader test and a slightly weaker apical spine.

It is possible that *B. tetradica* s.s. occurs in Sample 17. Several specimens, including some of those figured here, appear to have pores longitudinally aligned when viewed under stereomicroscope. The SEM may have revealed irregularities not always apparent with optical microscopy. To our knowledge the only other SEM photograph of *B. tetradica* is that of Nishimura (1986).

ACKNOWLEDGEMENTS

We are grateful to Assoc. Profs. K.B. Sporli and J.A. Grant-Mackie who critically reviewed the manuscript, to Dr Yoshiaki Aita for his helpful comments, and to Louise Cotterall who draughted the figures.

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