

The type material of the Miocene to Recent species *Globigerinoides sacculifer* (Brady) revisited

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ABSTRACT – The detailed test morphology of the type suite of specimens for the planktonic foraminifer *Globigerinoides sacculifer* (Brady) is illustrated for the first time since the species was identified in 1877. Fossil representatives of this species are a key index for oceanographic reconstruction of the Neogene and Quaternary tropics. The types of *G. sacculifer*, sourced from a loose ‘chalk’ block on a beach in New Ireland, Papua New Guinea, all bear a sac-like terminal chamber and are heavily calcified. They have undergone gametogenesis. Scanning electron microscopy identifies calcite fabrics of the test that were formed post-ontogenetically. *J. Micropalaeontol.* 25(2): 153–156, November 2006.

KEYWORDS: *Neogene, planktonic foraminifera, type material, taxonomy, Papua New Guinea*

INTRODUCTION

Globigerinoides sacculifer (Brady, 1877) is a frequent component of the near-surface dwelling assemblages of planktonic foraminifera in the modern tropical and subtropical oceans. This multi-chambered, symbiont-bearing species is commonly used for studies of low latitude surface water processes, hence it is important to define the species to avoid a broad range of morphotypes being used for calibration studies. Fossil representatives of *G. sacculifer* are used widely in oceanographic reconstructions for the Quaternary and Neogene tropics and sub-tropics. Although *G. sacculifer* has been studied intensively (e.g. Hemleben *et al.*, 1989 and references therein), its morphological definition, especially further back in the geological record, is ambiguous (see Parker, 1962 for discussion). Furthermore, genetic studies, though limited in the tropical oceans, point to the presence of cryptic, i.e. genetically distinct, but morphologically similar species (Darling *et al.*, 1999). The basis for any discussion about the taxonomy of *G. sacculifer* and its relatives is a reference to the morphology of the type specimen. A rigorous description of the type is the basis of any use of the species as a carrier of environmental signals in the geological past. This paper provides the first scanning electron micrograph illustrations of the lectotype and selected paralectotypes of *G. sacculifer*, which indicate both the state of preservation of the type material and its overall morphology.

THE TYPE MATERIAL OF *G. SACCULIFER*

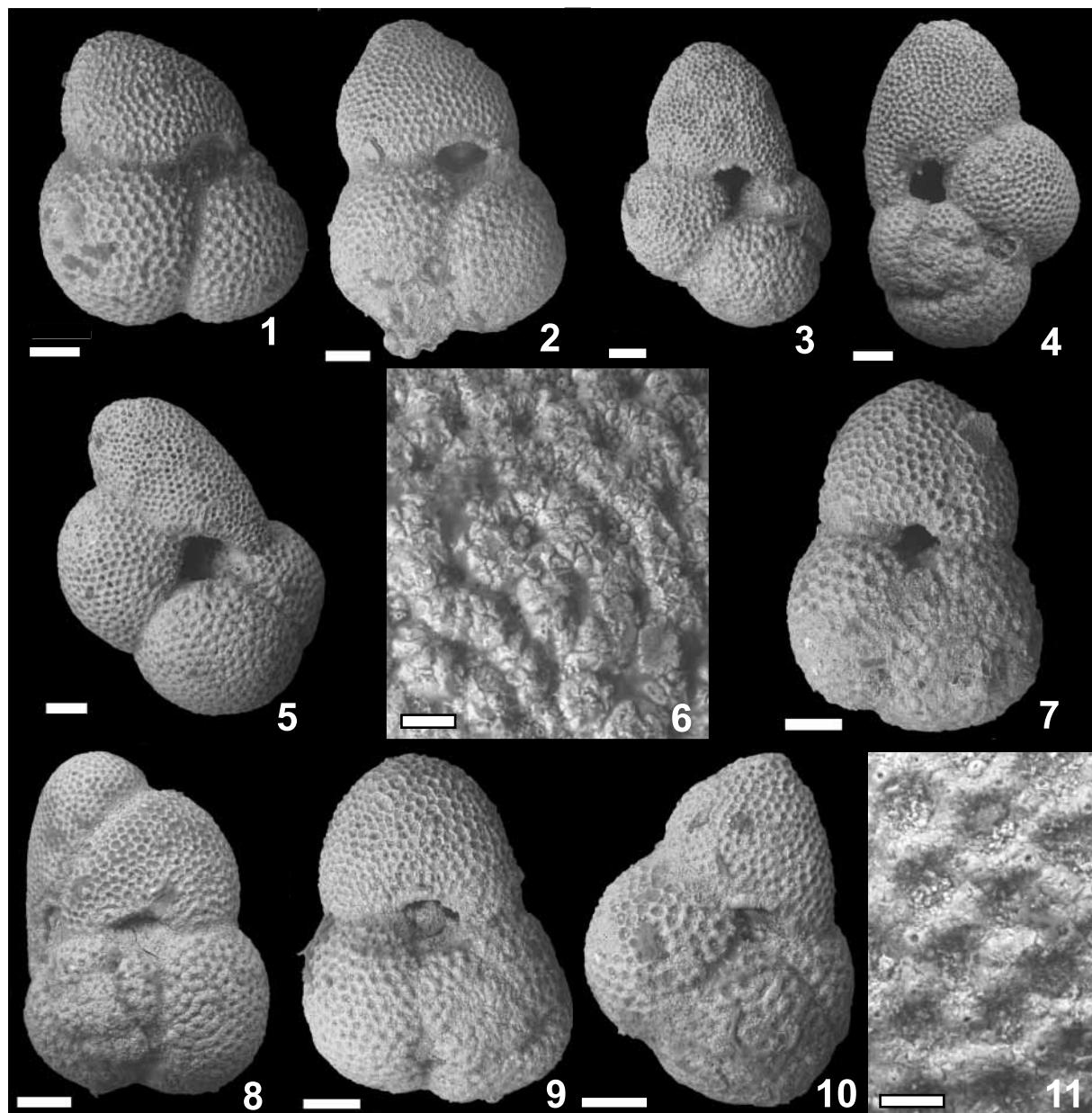
Banner & Blow (1960, p. 21; see also Brady, 1884, p. 604) indicated that Carpenter (1862, pl. 12, fig. 11) was the first to figure *G. sacculifer*, but under the name *Globigerina helicina* d’Orbigny. Carpenter’s material has not been re-examined to confirm this. Despite Brady’s initial identification in 1877, *G. sacculifer* was figured under that name for the first time seven years later, though from material collected in the North Pacific (Brady, 1884), and not from the original type material from New Ireland. Although *G. sacculifer* has been illustrated on numerous occasions, including line drawings (e.g. Banner & Blow, 1960;

Bé, 1980), the original type material has not been illustrated by scanning electron microscopy. To aid the identification of fossil representatives of this species, and as a spur to further work on its morphological variation, the lectotype, NHM P44033 (Pl. 1, figs 1, 11), selected by Banner & Blow (1960, p. 22), is illustrated, together with selected paralectotypes (Pl. 1, figs 2–10).

Brady’s (1884, p. 604) formal description of *G. sacculifer* is Test oblong, compressed, Rotaliform; segments few, usually five to seven in number, of which four generally compose the final convolution; earlier chambers small and sub-globular; the ultimate segment, and sometimes also the penultimate, elongated radially and more or less pointed at the peripheral extremity. Aperture variable; consisting of a single large opening at the inferior umbilical margin of the terminal segment, and one or sometimes several rounded orifices in the sutural depressions of the superior face. Pelagic specimens spinous externally. Longer diameter 1/25th inch (1 mm) more or less.

The types of *G. sacculifer* are all ‘opaque white’ when viewed by light microscopy, lack spines – though the spine bases are visible on the lectotype (Pl. 1, fig. 11), and are heavily calcified when compared to plankton tow specimens of the same species. The latter are spine bearing and translucent. This indicates that all of the type specimens have undergone gametogenesis (see Bé, 1980), which has formed a veneer of secondary calcite on the outer test surface that has obscured structures such as pore pits (Pl. 1, figs 6, 11). The type material is very similar in preservation to Neogene material recovered from Ocean Drilling Program sites (see Williams *et al.*, 2005), though this does not necessarily confirm Banner & Blow’s (1960) observation that Brady’s material is fossil (Neogene?), and not recent.

The slide in the Natural History Museum collection NHM P.43317 marked ‘Geol. Mag. Dec. 1877’, which contains 11 of the paralectotypes of *G. sacculifer*, is labelled on the front as being from ‘New Ireland’ (Papua New Guinea), but on the back of the slide, in Brady’s hand, is written ‘New Britain’. Banner & Blow (1960, p. 22) noted that New Britain and New Ireland,



Explanation of Plate 1.

Photomicrograph (back-scattered) images of *Globigerinoides sacculifer* (Brady, 1877) made using scanning electron microscopy with a low vacuum chamber, at the Natural History Museum in London. Use of the low vacuum chamber means that no coating was applied to the specimens. A few of the illustrated specimens show traces of gum on the test surface used to fix the specimens into the slides. Rather than risk dissolution or damage of the test surface, this material was not cleaned before mounting the specimens on stubs for scanning electron microscopy. Most views of the whole test are umbilical or oblique to umbilical, except figures 4 and 8, which are spiral side and oblique to spiral side views, respectively. All figures are of specimens from the 'chalk' block collected during the Challenger Expedition from the coast of New Ireland, Papua New Guinea. Digital copies of these figures are available from the authors at request. **figs 1, 11.** Lectotype (designated Banner & Blow, 1960, p. 22), NHM P.44033 (this specimen was taken out of slide NHM P.43317). A detailed description of the lectotype is given by Banner & Blow (1960, p. 22). The presence of gametogenic calcite coating the surface of the test is evident from closure of the pore pits (fig. 11). This is also suggested by the blocky calcite forming the interporal ridges, though the latter might also suggest a later diagenetic calcite. The primary aperture appears to be filled with sediment or diagenetic calcite. **figs 2–10.** Paralectotypes from slide NHM P.43318 (renumbered as following): 2, NHM PM PF 67310; 3, NHM PM PF 67311; 4, NHM PM PF 67312; 5, NHM PM PF 67313; 6, 8, NHM PM PF 67315; 7, NHM PM PF 67314; 9, NHM PM PF 67316; 10, NHM PM PF 67317. Gametogenic calcite forms thick crusts on the surface of the tests of all of these specimens (see particularly fig. 6), though the coarse blocky nature of some of this calcite veneer might be diagenetic. All scale bars are 100 µm, except 6 and 11, which are 20 µm.

which lie in the same archipelago, appear to have been confused in Brady's notes, but not in his publications. A second slide, NHM P.43318, also sourced from New Ireland, and labelled

'syntypes', contains 22 paralectotypes of similar preservation to those of slide P.43317. Banner & Blow (1960) thought the 'chalk' fragment, from which these foraminifera were sourced, was Late

G. sacculifer type material

Miocene or Pliocene in age, rather than from the recent seabed. The stratigraphically earliest *G. sacculifer* (and its possible synonyms, for which see below) probably occur in the Early Miocene (e.g. Banner & Blow, 1960; Jenkins *et al.*, 1986). Kennett & Srinivasan (1983) gave the range for *G. sacculifer* as 'Early Miocene Zone N6 to Recent'. The species remains extant in tropical and warm subtropical conditions.

GENERAL MORPHOLOGY OF *G. SACCULIFER*

G. sacculifer has a medium to large, low trochospiral test comprising 2½ whorls (see Pl. 1). Tests typically reach a diameter of 500–800 µm, but maximum diameters can exceed 1100 µm (Schmidt *et al.*, 2004). The spherical chambers enlarge rapidly in the initial part of the test, although the final 3½ to 4 that comprise the last whorl increase in size more slowly (Pl. 1, figs 4, 8). Chambers are coarsely pitted with large, deep pores. Brady (1884, pl. 80, figs 15–16) and Saito *et al.* (1981) showed that specimens collected *in vivo* have long spines with moderately high spine-bases in the interpore areas. The spines are reabsorbed during gametogenesis and dissolution, and thus are absent from fossil forms, and from the type material (herein Pl. 1). The primary aperture is an interiomarginal, umbilical and broad arch with a rim. Sub-triangular to elliptical secondary apertures occur on the spiral side (Pl. 1, fig. 8). The position of the secondary apertures is variable in *G. sacculifer*, in contrast to *Globigerinoides ruber*, where these are confined to the contact point of the three chambers. Banner & Blow (1960) indicated that chamber overlap and aperture shape change slightly through geological time, but variation remains within the morphological concept of the species. All chambers show regular growth and morphology, except in those specimens bearing a distinctive final sac-like chamber. This varies considerably in size and shape, even in material from the same locus (Pl. 1, figs 1–5, 7–10), from small to large and spherical, elongate or lobate, and this also appears to have varied throughout the history of the species (Banner & Blow, 1960). In Miocene forms, the sac-like chamber is very simple and not as large as in modern forms.

DISCUSSION

When present, the terminal sac-like chamber is very characteristic, but its absence has led to taxonomic complexity, compounded by preservation differences in fossil assemblages. Forms with and without the sac-like chamber have been considered to be different species, subspecies, varieties and forms ('forma'). Bé (1980, p. 285) identified differences in the frequency of development of the sac-like chamber in *G. sacculifer* according to feeding frequency. In those specimens fed brine shrimp nauplii on a daily basis, more than 76% of specimens developed the sac-like chamber, whereas fed once a week, only 29% produced this structure. His laboratory studies showed that forms with the sac-like chamber, and those without, belong to a single species, and that formation of the 'sac' is a terminal ontogenetic feature. Bé (1980, p. 287) considered *G. trilobus* (Reuss, 1850), *G. quadrilobatus* (d'Orbigny, 1846) and *G. sacculifer* (Brady, 1877) to be a single species. However, as *G. sacculifer* and *G. trilobus* 'morphospecies' possess different stratigraphic ranges, their distinction can be useful for biostratigraphy (Pearson *et al.*, 1997, p. 296). Hecht (1974, p. 1226) observed that 'with the exception of the final chamber, *G.*

sacculifer and *G. trilobus* are morphologically similar', but he noted a preponderance of *G. sacculifer* types at lower latitudes.

A select review of past publications with high quality illustrations, supports the view that *G. sacculifer* has a very complex taxonomy. The species and its related morphologies, have been referred to as *Globigerina sacculifera* var. *recumbens* Rhumbler, 1901 and var. *galeata* Rhumbler, 1911; *Globigerina tricamerata* Tolmachoff, 1934; *Globigerina triloba sacculifera* (Brady) (by Bolli, 1957); *Globigerinoides suleki* Bermúdez, 1961; *Globigerinoides quadrilobus sacculifera* (by Parker, 1962); *Globigerinoides trilobus forma typica* Boltovskoy, 1968 and *G. trilobus forma sacculifera* (by Boltovskoy, 1968); *Globigerinoides triloba triloba* (Reuss) and *G. triloba immatura* LeRoy (by Bermúdez & Bolli, 1969); *Globigerinoides sacculifer* (by Saito *et al.*, 1981; Kennett & Srinivasan, 1983) and *Globigerinoides trilobus sacculifer* (by Bolli & Saunders, 1985). All of the 34 specimens in the type suite of *G. sacculifer* bear the sac-like terminal chamber.

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