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Indigenous agglutinated foraminifera from the Eocene La Meseta Formation, Seymour Island, West Antarctica

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Abstract: Here are reported the first certainly indigenous agglutinated foraminifera known for the Eocene La Meseta Formation on Seymour Island, West Antarctica. The specimens were identified as *Textularia* sp. and occur in the upper portion of the unit, just below the contact with the overlying post-Eocene deposits. Despite being rare, the specimens are interpreted as autochthonous or parautochthonous due to their overall good preservation, fragility, and lack of sedimentary filling. The La Meseta Formation seems to have passed through a major diagenetic dissolution of calcareous microfossils, but the present findings suggest that indigenous agglutinated foraminifera can be found at least in some of its strata.

Key words: Antarctica, Marambio Island, Paleogene, microfossils, taphonomy.

Introduction

Despite being one of the most abundant group of microfossils, the knowledge on the pre-Quaternary foraminifera of Antarctica is still fragmentary. Even so, at least one foraminiferal assemblage was reported for each Cenozoic epoch in West Antarctica, *e.g.*, Paleocene (Huber 1988), Eocene (Gaździcki and Majewski 2012), Oligocene (Majewski and Gaździcki 2014), Miocene (Birkenmajer and Łuczkowska 1987), Pliocene (Gaździcki and Webb 1996), and Pleistocene (Caramés and Concheyro 2013).

Foraminiferal remains can easily be obliterated by ordinary chemical and physical processes, such as dissolution by interstitial fluids or fragmentation by reworking (Martin 1999). However, their scarceness in West Antarctica should

be a consequence of both taphonomic and research biases, as most of the terrain is covered by ice and the remoteness and harsh climate make it difficult to visit and collect samples from many areas.

It is somewhat surprising that even the Eocene La Meseta Formation – the most fossiliferous unit of Antarctica (Stilwell and Zinsmeister 1992) – failed to yield abundant and diverse foraminiferal assemblages. The formation crops out in the northeastern portion of Seymour Island (also known as Marambio Island) and in the Cockburn Island, reaching up to 720 m in thickness in the former; and its siliciclastic rocks (mostly siltstones and sandstones) and shell beds were accumulated in an incised valley, in shallow marine deltaic to possibly estuarine settings (Sadler 1988; Askin *et al*. 1991; Marenssi *et al*. 2002). Biostratigraphic data and strontium isotope stratigraphy (SIS) based on bivalve shells indicate that the La Meseta Formation was deposited from the late early to the late Eocene (see Marenssi 2006 for a brief review) and *in situ* bivalves and scaphopods yielded SIS ages of 34 to 36 Ma for its uppermost strata (A. Tatur, personal communication), adding evidence for a latest Eocene (Priabonian) age.

The La Meseta Formation presents an abundant and diverse record of Eocene marine and terrestrial life, including crustaceans, brachiopods, molluscs, echinoderms, cartilaginous and bony fishes, turtles, palaeognath and sphenisciform birds, ungulates, and whales, as well as conifer woods and pollen grains that indicate a relatively warm and temperate paleoclimate (*e.g*., Long 1992; Stilwell and Zinsmeister 1992; Tambussi *et al*. 1994; Torres *et al*. 1994; Fuente *et al*. 1995; Bitner 1996a; Feldman and Gaździcki 1997; Jadwiszczak 2006; Cabrera and Olivero 2011; Gelfo *et al*. 2015). Nevertheless, except for rare brachiopod-incrusting foraminifera (Bitner, 1996b), the only known foraminiferal assemblages were reported by Gaździcki and Majewski (2012) for the base of the formation, near the contact with the underlying Cretaceous-Paleocene López de Bertodano Formation on Seymour Island.

In order to contribute to the still-fragmentary knowledge on the Paleogene foraminifera of West Antarctica, here are reported textulariid foraminifera from the La Meseta Formation on Seymour Island, the first undoubtedly indigenous agglutinated taxa known for this geological unit.

Materials and methods

The samples were collected by Antonio C. Rocha Campos (USP) and his team in the austral summers of 2011 and 2012, during stratigraphic survey on Seymour Island. Rocha Campos' team's activities focused on the Hobbs Glacier (Miocene) and Weddell Sea (Plio-Pleistocene) formations and their contact with the underlying La Meseta Formation, and for this reason only the topmost portion of the latter was sampled, presumably representing unit Telm 7 of Sadler

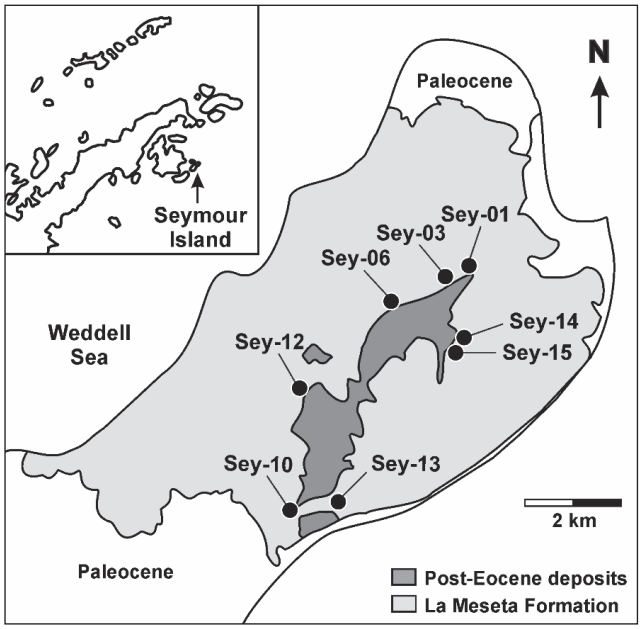

Fig. 1. Geological map of the northeastern portion of Seymour Island, West Antarctica, showing the locations of the analyzed material. Based on Montes *et al.* (2013).

(1988). The analyzed samples of the La Meseta Formation consist of poorly consolidated sandstones and were collected in eight localities of the northeastern portion of Seymour Island (Fig. 1): Sey-01 (64°14'02.8'', 56°36'54.7''), Sey-03 (64°14'05.2'', 56°37'12.7''), Sey-06 (64°14'18.7'', 56°38'09.5''), Sey-10 (64°15'26.8'', 56°39'22.2''), Sey-12 (64°14'43.4'', 56°39'27.3''), Sey-13 (64°15'31.6'', 56°38'52.9''), Sey-14 (64°14'28.6'', 56°37'09.3'') and Sey-15 (64°14'32.6'', 56°37'10.2'') (preserving the same nomenclature of Rocha Campos' team's field notes). All samples come from 10 to 100 cm below the contact with the diamictites of post-Eocene glacial sediments.

For each sample, approximately 500 g of rock was disaggregated with water and the resulting sediment passed through sieves of 0.5 mm and 63 μm. Due to the large amount of sediment retained in the sieve of 63 μm, trichloroethylene (a heavy liquid of 1.46 g/cm^3 at 20°C) was used to separate by flotation any small and unfilled microfossils that could be present in this portion, as in the procedure for heavy liquid separation of calcareous microfossils described by Harris and Sweet (1989).

Only 20 g of washed and dried sieved sediments was processed at a time, adding two times this volume of trichloroethylene. The mixture was then gently but continuously stirred with a glass rod and floating particles were transferred to a filter-lined funnel, with the same trichloroethylene reused to repeat the

process four more times. Around 10 g of the processed waste was screened to ensure that common and non-floated microfossils were detected.

All foraminifera were recovered from the floated material of the > 63 μm fraction and, except for fragments of invertebrates, no microfossils were found in sediments from the > 0.5 fraction. Also, no recognizable microfossils were found in the processed waste.

Results

Foraminifera were found only in sample from the low-angled cross-bedded sandstone of the Sey-01 locality, although fragments of bivalves and echinoderms occurred in the Sey-10 and Sey-12 localities. Four agglutinated tests were recovered. Despite their overall good state of preservation, the specimens were very fragile and suffered light to moderate disintegration even when picking and allocating into microslides or on electron microscope stubs.

The agglutinated tests are bisserial and have an aperture as a low arch in the base of the last chamber, indicating they belong to the genus *Textularia*. Based on the geometry of the chambers, these *Textularia* sp. specimens can be divided into two distinct forms: morphotype 1, with chambers wider than taller (Fig. 2.1), represented by two specimes; and morphotype 2, with globose chambers (Fig. 2.2), with also only two specimens. Both morphotypes have slightly distinct, depressed sutures.

Discussion

Taphonomy

The overall good state of preservation of the specimens in combination with their fragility and a lack of sedimentary filling strongly suggest their autochthonous or parautochthonous nature. They certainly would have not endured being exhumed and redeposited, and even small-scale reworking processes seem unlikely. In fact, the tests seem to have barely survived the sample disaggregation and sieving and it is highly probable that other specimens were destroyed during processing.

Agglutinated foraminifera are particularly susceptible to disintegration due to the compaction of the sediments in which they are buried or by the early diagenetic decay of their organic cement (Berkeley *et al*. 2007). Thus, although calcareous tests can withstand light to moderate compaction, small agglutinated tests can be easily obliterated by such process, particularly those lacking calcareous cement and which would be instantaneously disassembled after the decay of the proteinaceous material that hold their grains together.

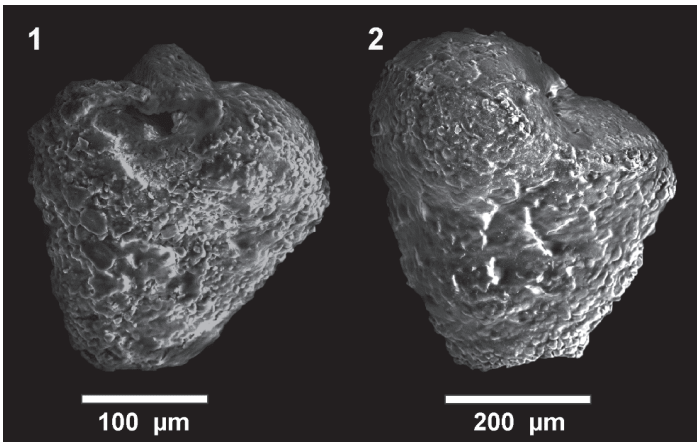

Fig. 2. SEM images of *Textularia* sp. from the Eocene La Meseta Formation on Seymour Island. **1.** Morphotype 1; specimen lacking most of the last chamber. **2.** Morphotype 2.

The almost exclusive calcareous and benthic-dominated assemblages occurring in sandstones from Telm 1 (Gaździcki and Majewski 2012), whose association with megabreccia, shell beds, and sandy conglomerates is evidence of a high energy marine depositional setting (Sadler 1988), indicate no sedimentological reason for the scarcity of foraminifera throughout the deposits of the La Meseta Formation. Even if younger biocenoses were dominated by taxa with fragile agglutinated or proteinaceous tests that have an extremely low potential for fossilization, such as the modern allogromiids that thrive in a wide range of environments, including estuaries (see Gooday 2002 for an overview), the assemblages reported by Gaździcki and Majewski (2012) make it rather likely that such communities were at least partially calcareous, especially because they contain *Cribroelphidium* spp. that, as other elphidiids, are known to flourish in shallow deltaic and estuarine settings (*e.g.*, Debenay and Guillou 2002; Cusminsky *et al*. 2009; Laut *et al*. 2017). Therefore, the complete absence of foraminifera in the majority of the strata seems to represent a diagenetic bias.

While agglutinated tests may have been shattered by the compaction process, calcareous tests may have been dissolved by acid interstitial fluids, which could have originated through the degradation of the organic material, including cements of agglutinated forms (Berkeley *et al*. 2007). Nonetheless, the modern weathering zone over the Paleogene organic-rich mudstones of Seymour Island, including the lower portion of the La Meseta Formation, is characterized by a microbially induced oxidation of sulfides that can potentially generate sulfuric acid during weathering (Tatur *et al*. 1993) and constitute a more plausible source for such hypothetical acid fluids. Moreover, this weathering condition was probably already present during the Eocene (Tatur *et al*. 2011) and may have been an

important factor behind the dissolution of the La Meseta Formation calcareous microfossils.

In addition, the carbonate compensation depth (CDD) could be very shallow at least in some parts of the Southern Ocean by at least the Miocene, as suggested by the contrast between the abundant and well-preserved foraminifera of extremely shallow paleoenvironments with the scarce and poorly preserved specimens of slightly deeper-water settings in Miocene sediments of the Fisher Bench Formation (East Antarctica) (Majewski *et al*. 2017) and of the Weddell Sea (Majewski *et al*. 2012). In fact, the shallow Antarctic CCD could have its roots in the Paleogene, what would help to explain the predominance of shallow-water assemblages over deeper ones in the Cenozoic foraminiferal record of Antarctica (see Majewski *et al*. 2017 for further discussion).

Taxonomy

Only one poorly-preserved agglutinated foraminifera, identified as *Trochammina* sp., was reported by Gaździcki and Majewski (2012) for the La Meseta Formation, but the authors considered the possibility that the specimen was reelaborated from the underlying Cretaceous-Paleocene deposits, where agglutinated foraminifera (including *Trochammina* spp. and *Textularia*? sp.) are more common (see Huber 1988). However, the herein reported *Textularia* sp. specimens seem far more fragile and certainly would not endure the more aggressive method of disaggregation used by Gaździcki and Majewski (2012), based on successive salt crystallizations. Moreover, *Textularia*? sp. described by Huber (1988) differs from *Textularia* sp. of the La Meseta Formation by having a more subangular periphery, chambers overlapping in a higher angle, and an overall less triangular shape.

It would be necessary to recover more and better-preserved specimens in order to make a precise identification, but it is possible to affirm that the morphotype 1 resembles *Textularia gramen* d'Orbigny 1846, while the morphotype 2 is similar to *Textularia candeina* d'Orbigny 1939. Both these species are common in Recent deposits of South Atlantic inner shelves (*e.g*., Boltovskoy *et al*. 1980; Vieira *et al*. 2014) and correspond to tropical or subtropical taxa (*e.g*., Montaggioni and Vénec-Peyré 1993; Eichler *et al*. 2012).

Conclusion

Although rare, the *Textularia* sp. specimens represent a significant addition to the knowledge on the La Meseta Formation foraminifera, for which only indigenous calcareous taxa were known.

The very low diversity and number of specimens prevent formulation of paleoenvironmental or paleoecological hypotheses, but their presence shows the

potential of the La Meseta Formation to yield agglutinated foraminifera. This is particularly significant because calcareous microfossils are rare or absent throughout these Eocene strata, probably due to a major diagenetic dissolution, and agglutinated forms may be the only ones remaining in fossil record.

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