LATE CENOZOIC FORAMINIFERA FROM DIAMICTITES OF CAPE LAMB, VEGA ISLAND, ANTARCTIC PENINSULA

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Abstract. Foraminiferal assemblages recovered from Cape Lamb sediments on Vega Island are examined and illustrated herein. The foraminifera were discovered in Cenozoic debris and palagonitic breccia lithofacies that crop out at the southwestern tip of Cape Lamb. Among all the Cenozoic diamictite deposits recognized in this island, the studied sediments are the youngest and the most fossiliferous. Pectinids, brachiopods, and microfaunas are exceptionally well preserved and indicate little or no transport. The foraminiferal assemblage is dominated by infaunal species, with the most abundant including Globocassidulina biora, Cribroelphidium sp. aff. E. excavatum, and Cassidulinoides parkerianus, and the epifaunal Cibicides refulgens. These foraminifera suggest a normal inner shelf marine environment. microfossils and macrofauna, stratigraphical evidence observed in the field and published isotopic ages from the nearby Cape Lamb suggest a Pleistocene age for this deposit.

Key words. Foraminifera. Diamictite. James ross Island Basin. Late Cenozoic. Antarctica.

The geology of the James Ross Island Group has been extensively studied during the last century in order to improve stratigraphic and paleoenvironmental knowledge of the region and to compare this information with data obtained from several other Antarctic sites. Particularly, the Cretaceous sediments have been extensively described, while the Cenozoic diamictites have received little attention, although determination of the stratigraphic relationships between diamictites and the interbedded volcanic rocks known as the James Ross Island Volcanic Group Island (JRVGI) would help to date Cenozoic glaciations in the Antarctic Peninsula.

The first mention of diamictites in the James Ross Basin considered them as basal tills and remobilized debris flow deposits related to glacial and/or glaciomarine sequences (Andersson, 1906; Bibby, 1966; Nelson, 1975). Later, formal lithostratigraphic considerations were provided by Pirrie et al. (1997) and Lirio et al. (2003), and hence they proposed different interpretations for these deposits according to the different lithofacies.

Recently, several authors have focused their studies on the Cenozoic sequences exposed at the James Ross, Cockburn, Seymour and Vega Islands in order to obtain more information on the volume of the Cenozoic Antarctic Ice Sheet and its role in the climatic variability. Among the main contributions are those carried out by Harwood (1986), Gaždicki and Webb (1996), Dingle et al. (1997), Gaždicki et al. (2004), Ivany et al. (2006), Smellie et al. (2006) and Hambrey and Smellie (2006). Concheyro et al. (2007) summarized the known information for these deposits; later, Hambrey et al. (2008), Smellie et al. (2008), Nelson et al. (2009), Smellie et al. (2009), Marenssi et al. (2010), Nývlt et al. (2011) and Salzmann et al. (2011) analysed in detail the distribution of the diamictites and their genesis.
The Cape Lamb debris deposits were discovered during the 2007 summer Antarctic expedition by the Czech-Argentine group and it comprises two diamictite horizons interbedded with a conglomerate breccia. Preliminary reports mentioned the presence of bivalves, brachiopods and gastropods, as well as foraminifera, ostracods, serpulids, spirorhids, echinoderm spines, echinoidean plates, bryozoans and dinoflagellates (Lirio et al., 2007; Caramés et al., 2008).

The aim of this paper is to describe an interesting Late Cenozoic Antarctic foraminiferal assemblage collected at Cape Lamb, Vega Island, Antarctic Peninsula, and provide some paleoecological interpretations.

**GEOLOGICAL BACKGROUND**

Cape Lamb comprises an ice-free area located in the southwestern sector of Vega Island, James Ross Basin (Rinaldi, 1982; Elliot, 1988; del Valle et al., 1992) (Figs. 1, 2).

The general stratigraphy includes Maastrichtian marine sedimentary rocks assigned to the Santa Marta, Snow Hill Island and López de Bertodano Formations (Rinaldi, 1982; Olivero et al., 1991; Pirrie et al., 1991; Marenssi and Santillana, 1998; Marenssi et al., 2001; Olivero, 2012) overlain by Cenozoic diamictites, volcanics and volcaniclastic deposits of the James Ross Volcanic Group (Nelson, 1975; Salani, 1999; Smellie, 1999).

Marenssi et al. (2001) provided a comprehensive study dealing with the geology of Cape Lamb, proposing a stratigraphic scheme for the Cretaceous and Cenozoic units (Fig. 3).

Although information dealing with diamictites exposed at Vega Island has been limited, some of the deposits at Sand-
wich and Leal Bluffs have been mentioned by Marensi et al. (2001), Hambrey and Smellie (2006), Smellie et al. (2006, 2008), Concheyro et al. (2007), and Nelson et al. (2009).

The better known Cenozoic diamictites of Cape Lamb are located at Sandwich Bluff and Leal Bluff, with thicknesses between 0.90 m to 22 m, respectively. They exhibit a lenticular geometry and comprise poorly sorted massive matrix-supported conglomerates composed of metamorphics, granitoids, quartz, acidic volcanics and mainly basic vulcanite clasts (Marensi et al., 2001).

According to Smellie et al. (2006) sedimentary Cenozoic outcrops on Vega Island consist of a multi-story conglomerate, diamictite and minor sandstones, which resemble till deltas or subaqueous morainic banks; and also contain a boulder pavement that indicates sliding at the base of a glacier (Hambrey and Smellie, 2006).

Lirio et al. (2007) recognized another diamictite deposit interbedded with volcanic rocks of the JRVGI, and named it the Cape Lamb diamictite. This is the unit from which the studied foraminiferal assemblage was recovered.

MICROPALEONTOLOGICAL BACKGROUND OF THE JAMES ROSS BASIN

Pioneer studies about Cenozoic foraminifera from the James Ross Basin described and illustrated some foraminifera from Cenozoic deposits in the Cockburn Island Formation (Holland, 1910; Gaździcka and Gaździcki, 1994). Later, Gaździcki and Webb (1996) re-examined this microfauna, increased the number of taxa and added information on paleoenvironmental interpretations. Microfossils and bryozoans were also found on James Ross Island in diamictites of the late Miocene Hobbs Glacier Formation at Hamilton Cape and Rabot Point (Pirrie et al., 1997). This assemblage was detailed by Bertels-Psotka et al. (2001) and Concheyro et al. (2007).
Jonkers et al. (2002) and Lirio et al. (2003) described the foraminifera and ostracod assemblages of several localities of the James Ross Island, particularly the late Miocene Belén Formation, the late Pliocene Gage Formation and the late Pliocene–early Pleistocene microfauna of the Terrapin Formation.

Scarce foraminifera, reworked nannoflora and palynomorphs were mentioned from Sandwich and Leal Bluff, northern area of Cape Lamb, Vega Island, (Lirio et al., 2007; Caramés et al., 2008; Concheyro et al., 2010).

**SITE DESCRIPTION AND SAMPLES**

The Cape Lamb diamictite outcrop is exposed at the southernmost tip of Cape Lamb, Vega Island (63°54′S–57°37′W), situated few meters above sea level; it is 10 m thick and is discontinuously exposed along 100 m of outcrop (Fig. 3).

Three different lithofacies are identified, corresponding to the base, middle and top of the section (Fig. 4).

The basal lithofacies consists of a 0.50 m thick matrix-supported greenish or brownish diamictite that lies unconformably over a hyaloclastic breccia. It is constituted, at the base, by poorly sorted subangular volcanic pebbles immersed in a fine to medium sandy matrix. Parallel lamination is frequent followed by some horizons with convolute stratification disrupting the normal bedding, as shown in Sample 2. This lithofacies contains encrusting bryozoans on shelly fragmented macrofauna or volcanic clasts, echinoid spines, abundant benthic foraminifera and large pelecypods, sometimes with articulated shells in life position. The uppermost 0.5 m consist of a chaotic deposit formed by almost disintegrated scallop shells, disturbed by convoluted stratification.

The middle lithofacies unconformably overlies the disrupted diamictite. It includes a 6 m thick barren yellow brownish hyaloclastic breccia exhibiting an upwards-thinning bedding, and mainly composed of pyroclastic sands with zoned plagioclase and palagonitic glass, visible in Sample 7. Upwards in the section (Samples 3 and 6), it contains fragmented, articulated pelecypods, entire and fragmented terebratulid brachiopods, encrusting bryozoans and echinoid spines. Microfossils are represented by rare foraminifera and palynomorphs that are mostly reworked (Caramés et al., 2008).

The upper lithofacies consists of 0.30 m greenish fine sandstone with abundant fragmented bivalves, encrusted bryozoans, serpulids and spirorbids, a rich foraminiferal microfauna and scarce ostracods, including Oculocytheropteron sp., Xestoleberis sp., and Loxoreticulatum fallax (G.W. Müller) (Ballent, pers. comm., 2010). The latter species is recorded as a fossil during the Pleistocene and are also found in Antarctic and Subantarctic waters today. It also carries echinoderm spines and mostly reworked palynomorphs (Caramés et al., 2008).

The top of the sedimentary section is unconformably overlain by a basaltic caprock.

**MATERIAL AND METHODS**

Five samples were studied. Sample size was approximately 100 g. All samples were disaggregated in 5% hydrogen peroxide (100 vol) solution and washed over 74 μm and 297 μm sieves. The washed samples were dried and the biogenic components were picked. Paleoecological methods include the use of α index values (Alpha diversity index; Fisher et al., 1943) and H(S) (Shannon-Weiner Diversity index, Shannon, 1948) on samples with enough foraminifera tests. The life position to each species was assigned considering morphologies and ecological behavior of living foraminifera according to Bernhard (1986), Corliss and Chen (1988), Hunt and Corliss (1993), Murray (2006) and Majewski (2010).
SYSTEMATIC PALEONTOLOGY

A total of 34 benthic taxa were recognized, almost all with calcareous tests, except for one which has an agglutinated test. No planktonic species were recovered from any sample. Species occurrence and their distribution are shown in the range chart (Fig. 1).

The suprageneric and generic taxonomic classification used follows Loeblich and Tappan (1987) with the addition of the genus Conolagena. Open nomenclature has been used for taxa that do not closely correspond to published descriptions. The synonymy list of each species includes the original description and some antarctic records with figured specimens. These lists omit papers in which the species were only mentioned. However, these were considered in Figure 6 showing the records of Cape Lamb species in other sites from West Antarctica (WA) and East Antarctica (EA).

Figured specimens are housed in the micropaleontological collections of the Facultad de Ciencias Exactas y Natura-

Figure 7.1a–b

Order Foraminifera Eichwald, 1830
Suborder Textulariina Delage and Hérouard, 1896
Superfamily Rzehakinoidea Cushman, 1933
Family Rzehakiniidae Cushman, 1933
Genus Miliammina Heron-Allen and Earland, 1930

Figure 4

Geological section of Cape Lamb diamictite deposit, Cape Lamb, Vega Island, Antarctic Peninsula/Perfil geológico del depósito diamictítico Cabo Lamb, cabo Lamb, isla Vega, península Antártica.

Order Foraminifera Eichwald, 1830
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Type species. Miliammina earlandi Loeblich and Tappan, 1955.

Miliammina earlandi Loeblich and Tappan, 1955

Figure 7.1a–b

1916. Miliolina oblonga (Montagu) var. arenacea Chapman, p. 59, pl. 1, fig.7.
1930. Miliammina oblonga (Chapman); Heron-Allen and Earland, p. 41, pl. 1, figs. 1–6, 22–23; Igarashi et al., 2001, p. 159, pl. 2, fig. 11a–b.
1933. *Miliammina oblonga* Heron-Allen and Earland, p. 92, pl. 3, fig. 17, pl. 5, figs. 1–5, 7, 8.

1955. *Miliammina earlandi* Loeblich and Tappan, p. 12, pl. 1, figs. 15a–c; 16; Murray and Pursey, 2004, p. 79, pl. 1, figs. 8–9.

1974. *Miliammina arenacea* (Chapman), Fillon, p. 140, pl. 3, fig. 1–3; Anderson, 1975, p. 90, pl. 2, figs. 3a–b; Finger and Lipp, 1981, p. 129, pl. 1, fig. 10; Gazdzicki and Majewski, 2003, fig. 3.6a–b; Majewski, 2005, p. 188, fig. 12.6a–b; Majewski and Anderson, 2009, p. 146, fig. 3.2.

**Remarks.** Although some authors still use the specific name *M. arenacea*, we follow Loeblich and Tappan (1955) who proposed *M. earlandi* as the correct name for the type species of the genus *Miliammina* due to the loss of the type species of *Miliolina oblonga arenacea* (Chapman), citation errors when the genus *Miliammina* was defined (Heron-Allen and Earland, 1930) and homonymy problems. *Miliammina oblonga arenacea* (Chapman) was originally described from the Ross Sea (WA).

Suborder *Spirilllinina* Hohenegger and Piller, 1975
Family *Patellinidae* Rhumbler, 1906
Genus *Patellina* Williamson, 1858

**Type species.** *Patellina corrugata* Williamson, 1858.

*Patellina corrugata* Williamson, 1858

**Figure 7.2**

1858. *Patellina corrugata* Williamson, p. 46, pl. 3, figs. 86–89; Anderson, 1975, p. 92, pl. 9, figs. 1a–b; 2; Igarashi et al., 2001, p. 159, pl. 6, fig. 4a–c; Majewski, 2005, p. 189, fig. 16.6. 1974. *Patellina antarctica* Williamson; Fillon, p. 140, pl. 5, figs. 1–2.

**Remarks.** *Patellina corrugata* is considerably smaller than *Patellina antarctica* Parr and possesses a more concave ventral side. In our opinion, the specimens from the Pleistocene of the Ross Sea identified as *Patellina antarctica* Williamson by Fillon (1974) are probably better referred to *P. corrugata*.

Suborder *Miliolina* Delage and Hérouard, 1896
Superfamily *Milioloidae* Ehrenberg, 1839
Family *Hauerinidae* Schwager, 1876
Subfamily *Hauerininae* Schwager, 1876
Genus *Quinqueloculina* d’Orbigny, 1826

**Type species.** *Serpula seminulum* Liné, 1758.

*Quinqueloculina* sp.

**Figure 7.3**

**Remarks.** Resembles *Q. weaveri* Rau illustrated by Majewski (2005, fig. 17.4a–c) with a subtriangular cross-section and circular aperture with a flattened base, but differs by its smaller test.

Subfamily *Miliinellinae* Vella, 1957
Genus *Pyrgo* Defrance, 1824

**Type species.** *Pyrgo laevis* Defrance, 1824.

*Pyrgo depressa* (d’Orbigny, 1826)

**Figure 7.4**

1826. *Biloculina depressa* d’Orbigny, p. 298; Parker, Jones and Brady, 1871, p. 247, pl. 8, fig. 5.

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**Figure 5.** Foraminifera range distribution and species diversity assemblages from the Cape Lamb diamictite deposits/ Cuadro de distribución de species y diversidad de las asociaciones halladas en los depósitos diamictíticos de Cabo Lamb.

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[Table and figures as provided in the document]
1975. *Pyrgo depressa* (d’Orbigny); Anderson, p. 92, fig. 6; Igarashi et al., 2001, p. 159, pl. 6, fig. 8a–c; Majewski, 2005, p. 189, figs. 19.4a–c–5.

1996. *Pyrgo fornasinii* (Chapman and Parr); Gaździcki and Webb, p. 159, pl. 34, figs. 1–3.

**Remarks.** Some specimens with a more rounded aperture resemble the species originally described as *Biloculina muralhina* Schwager and *Biloculina bradyi* Fornasini, but we do not separate them because all of our specimens have more ovate early chambers. *Biloculina ringens* Brady (1884) is synonymous with *Pyrgo fornasinii* Chapman and Parr (1935), but differs by having a more rounded periphery. In our opinion the specimen illustrated as *Pyrgo fornasinii* by Gaździcki and Webb (1996) would belong to *Pyrgo depressa*.

*Pyrgo elongata* (d’Orbigny, 1826)  
**Figure 7.5**

1826. *Biloculina elongata* d’Orbigny, p. 298, pl. 8, fig. 6.

1839. *Biloculina patagonica* d’Orbigny, p. 65, pl. 3, figs. 15–17.

1960. *Pyrgo patagonica* (d’Orbigny); Crespin, p. 22, pl. 1, fig. 1.

2001. *Pyrgo elongata* (d’Orbigny); Igarashi et al., p. 159, pl. 6, fig. 7a–c; Gaździcki and Majewski, 2003, fig. 5. 1a–b; Majewski, 2005, p. 189, fig. 19.2a–c.

1974. *Pyrgo williamsoni* (Silvestri); Fillon, p. 140, pl. 3, fig. 11; Anderson, 1975, p. 92, pl. 4, fig. 7.

**Remarks.** It is very similar to *P. williamsoni*, but compared to the original illustrations of *Biloculina elongata* d’Orbigny and *Biloculina williamsoni* Silvestri, the first species has a pyriform compressed test and the second one, an oval test, more circular in section. Thus, the specimens illustrated and identified as *Pyrgo williamsoni* (Silvestri) by Fillon (1974) from the Pleistocene of the Ross Sea (EA), and from the Recent of the Weddell Sea (WA) by Anderson (1975), in our opinion, belong to *Pyrgo elongata*.

*Pyrgo?* sp.  
**Figure 7.6**

**Remarks.** This species is represented by one specimen that probably corresponds to a juvenile form without a biloculine early stage.

**Laevidentalina** sp.  
**Figure 7.7**

**Remarks.** This species is represented by one specimen. The test is large, elongated, arcuate and apiculate, with 10 uniserial chambers separated by depressed and oblique sutures. The aperture is terminal, rounded and radiate.


**Remarks.** The species is characterized by its large, smoothly finished test with 6–7 chambers, flush, oblique and slightly curved sutures, and a sharp periphery.

*Lenticulina* sp.  
**Figure 7.8**


**Remarks.** The species is represented by one specimen. The test is large, compressed, biumbonate and with a sharp periphery. The planispiral test consists of a proloculus followed by 12 chambers separated by flush, curved sutures. The last two chambers tend to uncoil.

*Subfamily Marginulininae* Wedekind, 1937  
**Genus** *Marginalina*  
**Type species.** *Astacolus crepidulatus* de Montfort, 1808

*Astacolus crepidulatus* (Fichtel and Moll, 1798)  
**Figure 7.10**

1798. *Nautilus crepidula* Fichtel and Moll, p. 107, pl. 19, figs. g–i.

1986. *Astacolus crepidulatus* (Fichtel and Moll); Leckie and Webb, p. 1111, pl. 19, figs. 6–7.

**Remarks.** Compressed test consisting of about 9 chambers separated by steep, oblique and flush sutures. This species was originally described from the Recent of Italy.
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<td>Lentilina sp. 1</td>
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<td>Astacoculus crepidulus</td>
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<td>Lapenea laevis</td>
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| Number of common species | 4 | 10 | 6 | 14 | 12 | 14 | 14 | 9 | 13 | 5 | 21

121
Genus *Conolagena* Malumíán, Náñez and Caramés, 1991

**Type species.** *Conolagena argentina* Malumíán, Náñez and Caramés 1991.

*Conolagena squamososulcata* (Heron-Allen and Earland, 1922)

**Figure 7.12**

1922. *Lagena squamososulcata* Heron-Allen and Earland, p. 151, pl. 5, figs. 15, 19.

2005. *Lagena squamososulcata* Heron-Allen and Earland; Majewski, p. 188, fig. 20.11a–b.

**Remarks.** The species was originally described from the Recent of the Ross Sea (EA). Webb and Strong (1998a) reported this species as *Oolina squamososulcata*.

*Conolagena epibathra* (Patterson and Richardson, 1988)

**Figure 7.13**


**Remarks.** Test ovate, sculptured by 11–13 longitudinal ribs and 7 transverse alternating bars forming rectangular reticular cells, which become less rectangular and more rounded towards the apertural end. Aboral structure polygonal with a central ring. Apertural end truncated. The conus shaped neck is poorly developed. *Lagena squamosa* Montagu illustrated by Brady (1884, pl. 58, fig. 30) may belong to this species.

Family **Ellipsolagenidae** A. Silvestri, 1923

Subfamily *Oolininae* Loeblich and Tappan, 1961

Genus *Oolina* d’Orbigny, 1839a

**Type species.** *Oolina laevigata* d’Orbigny, 1839.

*Oolina caudigera* (Wiesner, 1931)

**Figure 7.14**

1931. *Lagena (Entosolenia) ovata* (Terquem) var. caudigera Wiesner, p. 119, pl. 18, fig. 215.

2005. *Oolina globosa caudigera* (Wiesner); Majewski, p. 188, pl. 21, fig. 2a–b; Igarashi et al., 2001, p. 158, pl. 8, fig. 1a–c.

**Remarks.** Originally described from the Recent of the Bellingshausen Sea (WA).

*Oolina globosa* (Montagu, 1803)

**Figure 7.15**

1803. *Vermiculum globosum* Montagu, p. 523, pl. 1, fig. 8.

1975. *Oolina globosa* (Montagu); Anderson, p. 90, pl. 7, fig. 14; Leckie and Webb, 1986, p. 1112, pl. 4, fig. 10 and pl. 18, fig. 17; Quilty et al., 1990, p. 3, pl. 1, fig. 5; Gaździcki and Webb, 1996, p. 161.

**Remarks.** The species is represented by one specimen in our sample.
Subfamily Parafissurininae R.W. Jones, 1984

Genus *Parafissurina* Parr, 1947

*Type species.* *Lagena ventricosa* A. Silvestri, 1904, p. 10.

Parafissurina *aventricosa* McCulloch, 1977

Figure 7.16


Remarks. This species was recorded in high latitudes, in the late Oligocene-late Miocene of DSDP Site 360, Cape Basin; Pliocene of DSDP Site 329, Falkland Outer Basin, and Pliocene of South Atlantic Islands and South Atlantic Ocean (Boltovskoy and Giussani de Kahn, 1982).

Family Glandulinidae Reuss, 1860

Subfamily Glandulinianae Reuss, 1860

Genus *Glandulina* d’Orbigny, 1839b

*Type species.* *Nodosaria* (les Glandulines) *laevigata* d’Orbigny, 1826.

*Glandulina?* sp.

Figure 7.17

Remarks. Test elongate, ovate, fusiform, tapering at both ends, circular in section, translucent wall with a nearly horizontal white collar over the first-third of test length, likely as a result of a reabsorbed chamber; surface smooth; aperture terminal, rounded with radiating slits at the end of a short neck, with a long and straight entosolenian tube attached to the wall. Some specimens are symmetrical and others are asymmetrical.

Symmetrical specimens resemble *Glandulina laevigata* (d’Orbigny) from the Eocene to Oligocene of CIROS-1 Core, McMurdo Sound, Ross Sea (EA), illustrated by Coccioni and Galeotti (1997). This species differs from *Glandulina antarctica* Parr (1950) in having a more delicate test.

Suborder Robertinina Loeblich and Tappan, 1984

Superfamily Ceratobuliminoidea Cushman, 1927

Family Ceratobuliminidae Cushman, 1927

Subfamily Ceratobulimininae Cushman, 1927

Genus *Lamarckina* Berthelin, 1881

*Type species.* *Pulvinulina erinacea* Karrer, 1868.

Lamarckina *sp.*

Figure 7.18–20

Remarks. Previously referred as *Heronallenia?* sp. by Caranés *et al.* (2008) but the recent finding of additional and better preserved specimens allowed us to observe the smooth or rugose umbilical view without radial grooves. Also a broken specimen allowed us to see an internal partition or division of the chambers.

*Lamarckina* sp. resembles *Heronallenia wilsoni* (Heron-Allen and Earland) illustrated by Earland (1934, pl. 8, figs. 30–32) from Antarctica, with a rugose dorsal surface, and limbate sutures with elevated marginal edges. However it is distinguished from the original illustration of *Dicorbina wilsoni* Heron-Allen and Earland (1922), which is the type species of genus *Heronallenia*, and *Heronallenia wilsoni* illustrated by Finger and Lipps (1981), by the absence of umbilical radial grooves that characterize the genus, as well as the shape of dorsal sutures, flush with high edges, instead of them being completely raised as ribs.

Superfamily Robertinoidea Reuss, 1850

Family Robertinidae Reuss, 1850

Subfamily Alliatininae McGowran, 1966

Genus *Pseudobulimina* Earland, 1934

*Type species.* *Bulimina chapmani* Heron-Allen and Earland, 1922.

Pseudobulimina *chapmani* (Heron-Allen and Earland, 1922)

Figure 7.21–22

1922. *Bulimina chapmani* Heron-Allen and Earland, p. 130, pl. 4, figs. 18–20; Anderson, 1975, p. 84, pl. 7, fig. 22a–b. 2001. *Pseudobulimina chapmani* (Heron-Allen and Earland); Igarashi *et al.*., p. 158, pl. 10, fig. 4a–b; Majewski, 2005, p. 189, fig. 22.5a–c.

Remarks. Originally described from the Recent of Antarctica.

Suborder Rotaliina Delage and Hérouard, 1896

Superfamily Cassidulinioidea d’Orbigny, 1839

Family Cassidulinidae d’Orbigny, 1839

Subfamily Cassidulininae d’Orbigny, 1839

Genus *Cassidulinoides* Cushman, 1927

*Type species.* *Cassidulina parkeriana* Brady, 1881.

Cassidulinoides *parkerianus* (Brady, 1884)

Figure 7.23

1884. *Cassidulina parkeriana* Brady, p. 432, pl. 54, figs. 11–16. 1990. *Cassidulinoides cf. parkerianus* (Brady); Quilty *et al.*., p. 3, pl. 1, fig. 10.
1974. *Cassidulinoides parkeri*an*us* (Brady); Fillon, p. 139, pl. 4, fig. 5; Anderson, 1975, p. 84, pl. 7, fig. 20; Gaździcki and Webb, 1996, p.161, pl. 35, figs. 4–6; Jonkers et al., 2002, p. 590, fig. 11d; Gaździcki and Majewski, 2003, fig. 6.3a–b; Quilty, 2010, p. 197, fig. 3.13.


**Remarks.** We follow Quilty (2010) who considers *Ehrenbergina parva* Earland (1934) and *Cassidulinoides parva* (Earland) by Nomura (1984) as a synonym of *C. parkeri*anus, but the latter has priority.

*Cassidulinoides parkeri*anus differs from *Cassidulinoides bradyi* (Norman) by possessing more inflated chambers, and from *C. porrectus* (Heron-Allen and Earland) by the more delicate test, smaller diameter and more chambers in the unrolled biserial portion.

Our specimens differ from *Cassidulinoides parkeri*anus illustrated by Majewski (2005, fig. 23.1a–b) and Majewski and Anderson (2009, fig. 4.11), both located in West Antarctica, by the more robust test with less globose chambers, less marked sutures, smoother surface and less perforated wall.

**Genus Globocassidulina** Voloshinova, 1960

**Type species.** *Cassidulina globosa* Hantken, 1876.

**Globocassidulina biora** (Crespin, 1960)

**Figure 7.24–25**


1974. *Globocassidulina biora* (Crespin); Fillon, p. 139, pl. 1, figs. 9–12, 14–15; Finger and Lippis, 1981, p. 129, pl. 2, fig. 6a–c; Leckie and Webb, 1986, p. 1115, pl. 12, fig. 10; Igarashi et al., 2001, p. 156, pl. 10, fig. 13a–b; Gaździcki and Majewski, 2003, figs. 6.4a–b, 5a–b; Majewski, 2005, p. 188, figs. 23.4–7; Majewski and Anderson, 2009, fig. 4.10; Quilty, 2010, p. 196, figs. 3.8–10.

1966. *Cassidulina crassa* d’Orbigny; Gaździcki and Webb, p. 161, pl. 35, figs. 2–3.

1966. *Globocassidulina subglobosa* (Brady); Gaździcki and Webb, p. 161, pl. 35, fig. 7.

2002. *Cassidulina crassa* d’Orbigny; Jonkers et al., p. 590, figs. 11.f–h.

2003. *Globocassidulina crassa biora* (Crespin); Quilty, p. 24, pl. 1, fig. 9.

**Remarks.** *Globocassidulina biora* is the most abundant species in Sample 2. It is recognized on the basis of its large and compressed test, a broadly rounded periphery, moderately inflated chambers, a protruding last chamber and aperture partly obscured by a broad thin plate surrounded by two elongated openings, one along the lower edge and other along the upper edge. The lower opening is oriented parallel to the basal suture and is more elongated than the upper one.

We had the opportunity of examining specimens coming from Fiordo Belén belonging to Belén and Terrapin Formations that were identified as *G. crassa* (the same microfossils that were reported in Lirio et al., 2003), but they should have been designated as *G. biora* based on the apertural characters. Taking into account that the Belén Formation is late Miocene in age (Jonkers et al., 2002; Lirio et al., 2003; Concheyro et al., 2007) based on the presence of *Globigerinita glutinata* (Egger), and the $^{87}$Sr/$^{86}$Sr dating that indicates 6.8±1.3 –0.5 Ma obtained on *Zygochlamys anderssoni* (Jonkers, 1998), the oldest record of *G. biora* could span the late Pliocene (Quilty, 2010) to the late Miocene.

**Globocassidulina sp.**

**Figure 7.26–28**

1960. *Cassidulina sp*. Crespin, p. 29, pl. 3, fig. 11.

1960. *Cassidulina crassa* d’Orbigny; Crespin, p. 29, pl. 3, figs. 12–13.

1974. *Globocassidulina biora* (Crespin); Fillon, p. 140, pl. 1, figs. 8, 13.

1981. *Globocassidulina sp.* Fingers and Lippis, p. 129, pl. 4, fig. 1a–c; Igarashi et al., 2001, pl. 11, fig. 2a–b.

1986. *Globocassidulina crassa* (d’Orbigny), Leckie and Webb, p. 1115, pl. 12, figs. 7–9; Quilty et al., 1990, p. 3, pl. 1, fig. 9; Strong and Webb, 2001, p. 356, pl. 1, fig. 17.

2001. *Globocassidulina subglobosa* (Brady); Strong and Webb, p. 1, fig. 18; Murray and Pudsey, 2004, p. 80, pl. 2, figs. 12–13; Concheyro et al., 2007, p. 580, fig. 5.d; Quilty, 2010, p. 197, fig. 3.12.

1975. *Cassidulina subglobosa* (Brady); Anderson, p. 84, pl. 11, fig. 1a–b; Jonkers et al., 2002, p. 590, fig. 11.i.

2003. *Globocassidulina crassa rossensis* Kennett; Quilty, p. 24, pl. 1, fig. 10.


**Remarks.** This study agrees with Nomura (1983) and Belford (1966) who concluded, based on observations of the holotype, that specimens previously referred to *G. subglobosa* with a tripartite aperture, L-shaped or V-shaped, must be excluded from the that species.

*Globocassidulina sp.* differs from *Globocassidulina crassa* by the longer areal apertural branch and shorter basal apertural branch, and from *G. rossensis* by the shorter basal apertural branch and the globular and inflated test.

It seems likely that the specimens here included in *Globocassidulina sp.* May correspond to more than one species, but scarcity of well preserved specimens precludes a more certain identification. Some of them resemble those illustrated by Nomura (1983) as *G. oriangulata* Belford and *Globocassidulina parva* (Asano and Nakamura).

Superfamily Fursenkoinoidea Löeblich and Tappan, 1961

Family Fursenkoinidae Löeblich and Tappan, 1961
Genus *Fursenkoina* Loeblich and Tappan, 1961

**Type species.** *Virgulina squammosa* d’Orbigny, 1826.

*Fursenkoina fusiformis* (Williamson, 1858)

**Figure 7.29**


1981. *Fursenkoina earlandi* (Parr); Finger and Lipps, p. 129, pl. 3, fig. 5.

1996. *Fursenkoina* cf. *earlandi* (Parr); Gaździcki and Webb, p. 162, pl. 35, figs. 8–9; Jonkers et al., 2002, p. 594, fig. 11.a–b.

1975. *Fursenkoina fusiformis* (Williamson); Anderson, p. 88, pl. 10, fig. 11. Gaździcki and Majewski, 2003, fig. 5.5. Majewski, 2005, p. 187, fig. 23.9–12; Majewski and Anderson, 2009, p. 147, fig. 4.5–6.

**Remarks.** This small and variable species has been mentioned as *Fursenkoina* cf. *earlandi* (Parr) from the late Miocene of Hobbs Glacier Formation, James Ross Island (Jonkers et al., 2001), and from the Pliocene Pecten Conglomerate, Cockburn Island (WA) (Gaździcki and Webb, 1996), but these specimens, like those reported herein, differ from Parr’s species by the twisted plane of biseriality. *Bolivina earlandi* Parr in its original illustration and a good SEM photograph (Igarashi et al., 2001, pl. 10, fig. 5a–b) lacks a twisted biserial arrangement; in consequence, according to Igarashi et al. (2001), *Bolivina earlandi* Parr belongs in the genus *Bolivinella*. In our opinion, the recovered specimens as those included in the synonymy with twisted biserial arrangement, match the original description of *B. pupoides* var. *fusiformis*.

Superfamily Discorbinelloidea Sigal, 1952

Family Pseudoparrellidae Voloshinova, 1952

Subfamily Pseudoparrellininae Voloshinova, 1952

Genus *Epistominella* Husezima and Maruhasi, 1944

**Type species.** *Epistominella pulchella* Husezima and Maruhasi, 1944.

*Epistominella vitrea* Parker, 1953

**Figure 8.2–4**


**Remarks.** *Epistominella vitrea* is similar to *E. exigua*. It differs in having a more inflated test in side view, a rounded periphery, and it usually has more chambers in the final whorl (6–6.5 vs. 5). Pawlowski et al. (2007) discussed their identification and reported that the two species are fairly distinct whether morphologically or at a molecular level.


Family Discorbinellidae Sigal, 1952

Subfamily Discorbinellininae Sigal, 1952

Genus *Discorbinella* Cushman and Martin, 1935

**Type species.** *Discorbinella montereynensis* Cushman and Martin, 1935.
21. *Aubignyna*? sp., Sample 2/Muestra 2 (LM-FCEN 3179); 21a, apertural view/vista apertural; 21b, ventral side/lado ventral; 21c, spiral side/lado espiral. 22–24, *Cribroelphidium* sp. aff. *E. excavatum* Terquem; 22, lateral view/vista lateral, Sample 2/Muestra 2 (LM-FCEN 3180); 23a–b, Sample 2/Muestra 2 (LM-FCEN 3181); 23a, lateral view/vista lateral; 23b, apertural view/vista apertural; 24, lateral view/vista lateral, Sample 2/Muestra 2 (LM-FCEN 3182).
Discorbinella dispers (d’Orbigny, 1839)
Figure 8.5–11
1839a. Truncatulina dispers d’Orbigny, p. 38, pl. 5, figs. 25–27; Heron-Allen and Earland, 1932, p. 420, pl. 14, figs. 32–34.
Remarks. Test small, trochospiral, compressed, concavo-convex, circular to ovate in outline, with an acute periphery and earlier whorls centrally visible on both sides. Spiral face convex with proloculus and 1.5–2 whorls visible, 6–8 chambers in the final whorl separated by depressed and strongly curved sutures. Concave umbilical side, with deep umbilicus, sutures strongly curved backwards. The aperture is an interiomarginal slit from the umbilicus to the periphery. The ventral surface is coarsely perforated.

Our specimens agree very well with those described and illustrated by Heron-Allen and Earland (1932) as Truncatulina dispers d’Orbigny. Some specimens also resemble Discorbinella bertheloti d’Orbigny illustrated by Brady (1884, pl. 92, figs. 10–12), but differ by the coarsely perforated ventral surface.

Superfamily Planorbuloidea Schwager, 1877
Family Cibicididae Cushman, 1927
Subfamily Cibicidinae Cushman, 1927
Genus Cibicides de Montfort, 1808
Type species. Cibicides refulgens de Montfort, 1808.

Cibicides refulgens de Montfort, 1808
Figure 8.12–15
1808. Cibicides refulgens de Montfort, p. 123, pl. 92, figs. 7–9; Anderson, 1975, p. 84, pl. 10, fig. 3a–c; Finger and Lipp, 1981, p. 129, pl. 3, fig. 1a–c; Leckie and Webb, 1986, p. 1115, pl. 11, figs. 13–15; Quilty et al., 1990, p. 3, pl. 1, fig. 17; Gądzicki and Webb, 1996, p. 162, pl. 36, figs. 4, 5a–b, 6; Igarashi et al., 2001, p. 156, pl. 12, fig. 4a–c; Gądzicki and Majewski, 2003, fig. 5.4a–c; Majewski, 2005, p. 187, fig. 25.1a–c; Quilty, 2010, p. 201, figs. 5.9a–b, 10a–b.
1884. Truncatulina refulgens (de Montfort); Brady, p. 659, pl. 92, figs. 7–9.
1996. Cibicides lobatulus (Walter y Jacob); Gądzicki and Webb, p. 163, pl. 36, figs. 1–3; Strong and Webb, 2001, p. 356, pl. 1, figs. 7–8; Jonkers et al., 2002, p. 590, fig. 12.c–f.
Remarks. Great confusion exists between C. lobatus and C. refulgens, probably because of the brief original descriptions and the schematic original drawings. We based our classification on Brady (1884). This author included in Truncatulina refulgens a form with a lobulate periphery that tends to spread laterally, with dorsal sutures gently curved and the last suture strongly curved back near the periphery (Brady, 1884, pl. 92, fig. 8a–c), as well as a form with higher and convex umbilical side and periphery less acute and not lobulate (Brady, 1884, pl. 92, fig. 7a–c). He also separated Truncatulina lobatula as a form circular in outline, with strongly convex umbilical side, small and deeper umbilicus and more radial dorsal sutures (Brady, 1884, pl. 92, fig. 10, pl. 93, fig. 1a–c).

Our specimens match those figured as Truncatulina refulgens Montford by Brady (1884).

Superfamily Nonionoidea Schultze, 1854
Family Nonionidae Schultze, 1854
Subfamily Nonioninae Schultze, 1854
Genus Nonionella Cushman, 1926

Nonionella bradii (Chapman, 1916)
Figure 8.16
1884. Nonionina(?) scapha (Fitchel and Moll); Brady, p. 730, pl. 109, figs. 14–16.
1916. Nonionina scapha (Fitchel and Moll) var. bradii Chapman, p. 71, pl. 5, fig. 42.
1932. Nonionella iridea Heron-Allen and Earland, p. 438, pl. 16, figs. 14–16; Crespin, 1960, p. 26, pl. 3, fig. 16; Fillon, 1974, p. 140, pl. 5, figs. 11, 14; Anderson, 1975, p. 90, pl. 11, figs. 7a–b; Leckie and Webb, 1986, p. 1115, pl. 13, figs. 3–4, pl. 23, figs. 5–7; Strong and Webb, 2000, p. 470, pl. 2, figs. 7–8; Strong and Webb, 2001, p. 357, pl. 1, figs. 23, 25; Igarashi et al., 2001, p. 158, pl. 12, figs. 6a–c; Murray and Pursey, 2004, p. 80, pl. 2, figs. 15–17; Majewski, 2005, p. 189, figs. 25.2a–c–3; Webb and Strong, 2006, p. 99, figs. 3.18; Majewski and Anderson, 2009, p. 146, fig. 4.15a–b.
1974. Nonionella bradii Chapman; Fillon, p. 140, pl. 5, figs. 12–13; Finger and Lipp, 1981, p. 130, pl. 3, fig. 4a–d; Anderson, 1975, p. 90, pl. 11, figs. 6a–b; Leckie and Webb, 1986, p. 1115, pl. 13, fig. 6, pl. 23, figs. 1–2; Strong and Webb, 1998, p. 520, pl. 1, fig. 12; Gądzicki and Webb, 1996, p. 163, pl. 36, figs. 7–8; Strong and Webb, 2000, p. 520, pl. 2, fig. 6; Strong and Webb, 2001, p. 357, pl. 1, figs. 21–22; Igarashi et al., 2001, p. 520, pl. 12, fig. 5a–c; Jonkers et al., 2002, p. 594, fig. 11.n–p; Majewski, 2005, p. 189, figs. 25.4.a–c–5; Webb and Strong, 2006, p. 99, figs. 3.17; Majewski and Anderson, 2009, p. 146, fig. 4.17a–b.
2009. Nonionella cf. iridea Heron-Allen and Earland, Majewski and Anderson, fig. 4.16.

Remarks. In most of the Antarctic literature consulted, N. bradii Chapman and N. iridea Heron-Allen and Earland are considered two different species, and there is a tendency to separate as N. bradii those forms with a more involute test, without an umbilical boss and with chambers increasing greatly in width as added, and as N. iridea those forms which have a more evolute test, an umbilical boss and chambers that rapidly increase their height. Contrarily, we adopt a broad taxonomic definition to account for the range of mor-
phological variability encountered, and we consider that *N. bradii* and *N. iridea* are extreme forms of the same species for the following reasons. On the one hand, all the specimens of *Nonionina(?) scapha* (Fitchel and Moll) illustrated by Brady (1884) were included by Chapman (1916) in the list of synonyms for his variety *Nonionina scapha var. bradii*, which was later raised to specific rank as *Nonionella bradii*. However, one of the figured specimens in Brady’s paper matches the original illustration of *Nonionina iridea* Heron-Allen and Earland. On the other hand, *N. bradii* and *N. iridea* show a similar distribution, and they both were described for the Recent, the former from nearby the Malvinas (Falkland) Islands and the second one from Ross Sea (WA).

**Nonionella** sp.

*Figure 8.17*


1975. *Nonionella bradii* (Chapman), Anderson, p. 90, pl. 11, fig. 6a–b.

**Remarks.** This species is represented by one small specimen that differs from *N. turgida* (Williamson) by a lesser development of the last chamber over the umbilicus. It differs from *N. bradii* (Chapman) by having a more compressed, elongated and tapering test, the rapid increment in width as the chambers as added, and by the more extended last chamber over the umbilicus.

Subfamily Astrononioninae Saidova, 1891

**Genus Astrononion** Cushman and Edwards, 1937

**Type species.** *Nonionina stelligera* d’Orbigny, 1839.

*Figure 8.18*

1950. *Astrononion antarcticum* Parr, p. 371, pl. 15, figs. 13–14; Fillon, 1974, p. 139, pl. 6, figs. 4–6; Anderson, 1975, p. 84, pl. 11, fig. 3a–b; Quilty, 2010, p. 201, fig. 5.11.

1960. *Astrononion antarcticum* Parr; Crespin, p. 26, pl. 2, fig. 9; Igarashi *et al.*, 2001, p. 156, pl. 12, fig. 10a–b; Gażdzicki and Majewski, 2003, fig. 5.6a–b; Quilty, 2003, p. 24, pl. 1, fig. 11; Jonkets *et al.*, 2002, p. 590, fig. 11.j–k; Majewski, 2005, p. 187, fig. 25.8; Majewski and Anderson, 2009, p. 146, fig. 4.18.

**Remarks.** The specimens from Cape Lamb and the others included in the preceding list of synonyms have more regular planispiral coiling, are more compressed and have more oblique sutures than the holotype illustration.

*Figure 8.19*

1967. *Astrononion echolsi* Kennett, p. 134, fig. 7a–b; 8; Fillon, 1974, p. 139, pl. 6, figs. 1–3; Anderson, 1975, p. 84, pl. 11, fig. 4a–b; Finger and Lipps, 1981, p. 129, pl. 3, fig. 6a–b; Leckie and Webb, 1986, p. 1115, pl. 13, figs. 1–2; Igarashi *et al.*, 2001, p. 156, pl. 12, fig. 11a–b; Quilty, 2003, table T4, pl. 1, fig. 12; Gażdzicki and Majewski, 2003, fig. 5.7a–b; Murray and Pudsey, 2004, p. 79, pl. 2, fig. 8; Majewski and Anderson, 2009, p. 146, fig. 4.19; Quilty, 2010, p. 201, fig. 5.12.


**Remarks.** The specimens from Cape Lamb have 7–8 chambers in the last whorl. The elongated sutural plates are barely visible over the limbated sutures and their distal part is marked by a pit.

Originally described from the Recent of Ross Sea (Kennett, 1967).

Superfamily Chilostomelloidea Brady, 1881

**Family Heterolepidae** Gonzáles-Donoso, 1969

**Genus Anomalinoidea** Brotzen 1942

**Type species.** *Anomalinoidea plummerae* Brotzen, 1942.

*Figure 8.20*

1950. *Anomalina tasmanica* Parr, p. 363, pl. 15, fig. 4a–c.

**Remarks.** We only found one specimen that matches the description of *Anomalina tasmanica* Parr, with entire and rounded periphery, evolute spiral side showing a last whorl and a translucent central plug that permits the observation of the proloculus and the first whorl, which is formed by 8 chambers separated by flush curved sutures. The involute umbilical side is deeply umbilicate and shows 12 chambers separated by radial sutures. Wall perforated.

It closely resembles *Anomalinoidea alazanensis spissiformis* (Cushman and Stainforth, 1945) reported from the Eocene to Miocene of Trinidad, but it is distinguished by the fewer chambers and more curved dorsal sutures.

*Anomalinoidea tasmanicus* is also related to *Anomalina glabrata* described by Cushman (1924), but the former has more chambers and a smoother periphery than *A. glabrata*.

*Anomalina macraglabra* Finlay (1940) possesses a finely punctuated wall.

*Anomalinoidea tasmanicus* was originally described from the Recent of Tasmania.

**Family Trichohyalidae** Saidova, 1981

**Genus Aubignyna** Margerel, 1970

**Type species.** *Aubignyna mariei* Margerel, 1970.
Aubignyna? sp.

Remarks. Tiny test with a low trochospiral coil, biconvex and slightly asymmetrical. Spiral side less convex than the umbilical side; apparently, a small plug covers the beginning of the spire; sutures weakly depressed, straight and radial. Umbilical side involute with six chambers separated by curved sutures, deeply incised from the umbilicus midway, becoming weakly depressed towards the periphery. Smooth surface except for numerous and prominent pustules that cover the lower part of the apertural face and the sutures near the umbilical area. The interiomarginal aperture is hidden by pustules. Retral processes, bridges and fossettes were not seen.

This species is represented by a single small specimen.

Superfamily ROTALIOIDEA Ehrenberg, 1839
Family Elphidiidae Galloway, 1933
Subfamily Elphidiinae Galloway, 1933
Genus Cribroelphidium Cushman and Brönnimann, 1948
Type species. Cribroelphidium vadescens Cushman and Brönnimann, 1948.

Cribroelphidium sp. aff. E. excavatum Terquem

Remarks. The specimens assigned to Cribroelphidium sp. aff. E. excavatum Terquem are strictly planispiral and symmetrical. They are characterized by their relatively large size, lobulate outline, rounded periphery, 6–8 chambers in the final whorl, depressed radial sutures with retral processes, ponticuli and at least 7 fossettes per side and small papillae which usually hide the ponticuli and fossettes. They do not have an umbo. Our specimens differ from E. excavatum illustrated by Heron-Allen and Earland (1932) by the lower number of chambers (6–8 vs. 9). They resemble E. magellanicum also illustrated by Heron-Allen and Earland (1932, pl. 16, figs. 26–28), by the number of chambers and the small papillae that fill the sutural depression, but our specimens differ by the less inflated chambers.

The general morphology of Cribroelphidium sp. aff. E. excavatum and their straight sutures closely resemble Elphidium ex. gr. excavatum from the late Oligocene–early Miocene of the CRP-2/2A drillhole at Cape Roberts, Victoria Land Basin (EA), illustrated by Strong and Webb (2000) but ponticuli and fossettes seem to be less prominent.

This species is distinguished from Elphidium (Cribronion) sp. 1 (Quilty, 2010, p. 202, fig. 5.14; erroneously mentioned in the text as fig. 5, 15, Quilty, pers. comm. 2011), from Elphidium magellanicum s.l. Heron–Allen and Earland illustrated by Leckie and Webb (1986) which was included by Quilty (2010) as a synonym of his species, and from Elphidium magellanicum illustrated by Strong and Webb (2000, p. 469, pl. 1, figs. 13–14) by its larger and more compressed test, less inflated chambers and straighter sutures.

It also differs from Elphidium (Cribronion) sp. 2 (Quilty, 2010, p. 202, figs. 5.16a–c, 17; erroneously mentioned in the text as fig. 5, 17a–18, Quilty, pers. comm. 2011) from the late Pliocene of Heidemann Valley, Vestfold Hills (EA), and from Cribroelphidium sp. (Strong and Webb, 1998, pl. 1, figs. 5–7) from the early Miocene of CRP-1 drillhole, Victoria Land Basin (EA), by the strictly planispiral and less inflated test.

The Cape Lamb species closely resembles E. excavatum from Terrapin Formation (WA) mentioned in Lirio et al. (2003).

DISCUSSION

Foraminiferal assemblage and paleoenvironmental inferences

Of the five studied samples, four yielded foraminifers and a moderately diverse accompanying biota that includes echinoid spines, spiroribids, serpulids, and bryozoans (Fig. 5). The recovered biota indicates fully marine conditions.

Foraminiferal test preservation was variable. It was regular in samples 2 and 3 and poorer in samples 5 and 6. Under binocular microscope the microfauna coming from samples 2 and 3 showed a smooth appearance but under the SEM, they exhibited irregular rough surfaces resulting from dissolution processes. All tests recovered from samples 5 and 6 have a dull and rough appearance under the binocular microscope, and SEM photographs reveal strong dissolution and recrystallization processes. The preservation of foraminiferal tests in sample 5, located at the top of the sedimentary section, could be influenced by the chemistry of the fluids leaking down from the overlying basaltic lava.

The mixed size and diversity of foraminifera species indicate that the original environment that they inhabited was moderately oxygenated. According to Kaiho (2013) oxic indicators such as large tested (≥0.35 mm) and thick walled Cibicides allow to estimate paleodissolved oxygen >1 ml/l.

The fauna is highly dominated by species with an infaunal lifestyle that suggests a soupy substrate (Murray, 2006).
Hence, the existence of dissolved oxygen levels that are high enough to allow the development of many infaunal and a few epifaunal forms suggests mesotrophic conditions (Jorissen et al., 1992, 1995).

The fossil-bearing samples contain many damaged tests with a broken last chamber or circular holes attributed to predation. The presence of fragmented tests (more than 30%) testifies to the action of vigorous marine currents and remobilization before final burial. An interesting point is that there is a mixture of sizes for all species of foraminifera, which means that transport did not cause a size selection. Furthermore, all tests found in these samples have a similar color that allows us to hypothesize that the foraminifera were coeval and that the reworking could have taken place in situ or from a nearby area. Thus, it is possible to consider that the studied foraminifera are the remains of a marine biocenosis contemporaneous with the sediment that incorporated it.

The foraminiferal fauna —with the exception of an agglutinated specimen identified as Miliammina earlandi (Fig. 5)— is calcareous; thus the community lived and was deposited above the calcite compensation depth (CCD).

The absence of planktonic foraminifera and other deeper water indicators, such as some dominantly arenaceous microfauna and benthic genera as Oridorsalis or some bolivinids and bultiminids, suggest a sublittoral zone (Fillon, 1974; Quilty, 2010).

The Cassidulinidae, Elphidiidae, Cibicididae and Pseudoparrellidae families are highly dominant, and the high occurrence of Globocassidulina, Cribroelphidium, Cibicides, Epistominella and Astrononion probably indicate inner shelf environments below 100 m depth.

In samples 2 and 5 (Figs. 4–5) more than 300 foraminiferal tests from 35–45 g of washed sample were counted according to standard statistical methods. Samples 3 and 6 yielded fewer foraminifera than samples 2 and 5. Sample 7 was barren. Foraminifera tests from samples 3 and 6 were too rare to carry out quantitative analyses, but samples 2 and 5 were quantitatively analysed. The low abundance obtained from samples 3 and 6 may be due to dilution produced by a higher sedimentation rate or stressful conditions and food scarcity from the original environment. The \( \alpha \) index values (Alpha diversity index; Fisher et al., 1943) are about 5.5 and H(S) (Shannon-Weiner Diversity index, Shannon, 1948) about 2.1–2.5 for the samples 2 and 5, which are typical values for sea shelves with normal salinity. Observing their specific composition, the main components are present in the two samples, but they exhibit different proportions. Sample 2 is dominated by Globocassidulina biora (25%) and Cribroelphidium sp. aff. E. excavatum (24.7%), accompanied by Cibicides refugens (18.9%), Globocassidulina sp. (10.7%) and some accessory species (each of them less than 4%). Sample 5 has a more even distribution; it is dominated by Cribroelphidium sp. aff. E. excavatum (23%), Cassidulinoides parkerianus (12.6%) and Epistominella vitrea (11.2%), accompanied by Globocassidulina sp. (7.9%), Astrononion antarcticum (7.6%), Cibicides refugens (5.6%), Nonionella bradii (5.3%), Astrononion echolsi (5.0%) and some accessories species (each of them less than 5%). The differences observed between these faunas were possibly due to environmental changes.

Globocassidulina biora, which is dominant in sample 2, has been associated with Quaternary Antarctic shallow water, and has also been found in deeper parts of the eastern Weddell Sea shelf (Milam and Anderson, 1981). Other authors have attributed the occurrence of this taxon to a subice shelf environment and/or a habitat influenced by strong marine currents (Mellis and Salvi, 2009). Cribroelphidium sp. aff. E. excavatum is another important species showing the same proportions in samples 2 and 5. It is similar to Cribroelphidium webbi, a subrecent elphidid foraminifer commonly found in waters shallower than 100 m, associated with the retreating tide water glaciers, and considered as a sensitive glacial proximal indicator (Majewski, 2005; Majewski and Tatur, 2009).

Cassidulinoides parkerianus, which increases its proportion in the younger samples, is a typical taxon found in Recent sediments from proximal coastal areas of main channels in Almiraitly Bay, South Shetland Island (Majewski, 2005).

The accompanying biota, represented by serpulids and bryozoans, has an attached epifaunal lifestyle by anchoring on or encrusting shelly fragmented macrofauna and rocks, and they colonized the diamicrite after its deposition, suggesting clear waters, with low turbidity and low sedimentation rates.

**Age constraints**

The foraminiferal species recorded in the Cape Lamb (Vega Island) section are long-ranging benthic taxa. Most of the more abundant species and some of the accessory ones are typical among Cenozoic microfaunas described from West Antarctica and East Antarctica (Fig. 6).

This microfauna does not contain Ammobaculites sp., a species considered a late Miocene marker by Jonkers et al. (2002), recorded in Fiordo Belén, and Hamilton and Rabot points (Jonkers et al., 2002; Concheyro et al., 2007). Ammobaculites antarctica, an index species for Pliocene deposits.
of Cockburn Island, Cape Gage and Prospect Mesa Gravel in Wright Valley, Victoria Land, Larsenmaa Hills (Conato and Segre, 1974; Webb, 1974; Quilty et al., 1990, Gałdzicki and Webb, 1996, Webb and Strong, 1998b, 2000, Jonkers et al., 2002) was not recorded either.

Cape Lamb and Terrapin Hills are two nearby localities that contain Adammusium colbecki and in which the genus Ammoepilphiida has not been reported to date.

The $^{87}$Sr/$^{86}$Sr isotopic age obtained from Adammusium colbecki in the nearby locality of Terrapin indicates a Plio-Pleistocene age (1.95±1.12/0.52 Ma; Lirio et al., 2003). It is likely that these deposits are coeval with those at Cape Lamb; at this locality the only isotopic age known to date comes from a basal layer possibly underlying the studied diamictite, and this yielded an age of 2.09±0.11 Ma. This date, together with the age of the Terrapin beds, would indicate a Pleistocene age, but further evidence is needed to state this for certain.

CONCLUSIONS

A new foraminifera assemblage was recovered from Cenozoic debris and palagonitic breccia lithofacies exposed at the southwestern tip of Cape Lamb. This assemblage includes 34 benthic taxa with benthic infaunal species such as Globocassidulina biora, Cribroelphidium sp. aff. E. excavatum and Cassidulinoides parkerianus, and the epifaunal Cibicides refugienus, which are the most representative ones. These benthic foraminiferal genera suggest an infralittoral zone, probably inner shelf environment below 100 m depth. Specimen preservation and occurrence in the Cape Lamb diamictite deposits indicate that the original fossiliferous levels could have suffered short-range transport and the specimens originated from the nearby area.

Finally, this microfauna represents a new record of the very poorly known high latitude late Cenozoic foraminiferal fauna from the James Island Basin.

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CARAMÉS and CONCHEYRO: LATE CENOZOIC FORAMINIFERA FROM ANTARCTICA


