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BENTHIC FORAMINIFERA, OSTRACODS AND RADIOLARIANS FROM THE LACHMAN CRAGS MEMBER (SANTA MARTA FORMATION), UPPER SANTONIAN-LOWER CAMPANIAN (UPPER CRETACEOUS) OF JAMES ROSS ISLAND, ANTARCTICA

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ABSTRACT – This study presents the taxonomy of benthic foraminifera, ostracods, and radiolarians of a sedimentary succession within the Lachman Crags Member, Santa Marta Formation (upper Santonian-lower Campanian), northwestern James Ross Island. Twenty-seven benthic foraminiferal species, six ostracod species, and six radiolarian species were identified. Calcareous microfossils occurrences are restricted to few stratigraphic levels described as tuffaceous sandstones cemented by calcium carbonate, while siliceous microfossils and agglutinated foraminifera also occur in different lithofacies. This suggests a preservational bias in the occurrences of microfossils within the studied section, possibly related to the presence/absence of calcium carbonate cement. The benthic foraminiferal fauna presents a low degree of endemism with the dominance of cosmopolitan taxa (*e.g. Gyroidinoides globosus* (Hagenow), *Gavelinella sandidgei* (Brotzen). Consistent occurrences of *G. globosus* suggest the dominance of deep-neritic to upper-bathyal paleodepths. The ostracod genera identified herein have already been reported for the Cretaceous of the Gondwana region and suggest deposition on a shelf with warm water temperature and normal salinity. The studied radiolarian fauna, the first one described for the James Ross Island region, can be considered Late Cretaceous in age, also presenting the dominance of robust (dissolution resistant) cosmopolitan taxa.

Key words: benthic foraminifera, ostracods, radiolarians, upper Santonian, lower Campanian, James Ross Island.

RESUMO – Este estudo apresenta a taxonomia dos foraminíferos bentônicos, ostracodes e radiolários recuperados em uma sucessão sedimentar do Membro Lachman Crags, Formação Santa Marta (Santoniano superior-Campaniano inferior), noroeste da Ilha James Ross. Vinte e sete espécies de foraminíferos bentônicos, seis de ostracodes e seis de radiolários foram identificadas. As ocorrências de microfósseis calcários estão restritas a determinados níveis estratigráficos, descritos como arenitos tufáceos cimentados por carbonato de cálcio, enquanto microfósseis silicosos e foraminíferos aglutinantes ocorrem também em outras litofácies. Esse padrão sugere que as condições de preservação desempenharam um papel fundamental no controle das ocorrências de microfósseis na sucessão sedimentar estudada. A fauna de foraminíferos bentônicos apresenta baixo grau de endemismo e dominância de táxons cosmopolitas (*e.g. Gyroidinoides globosus* (Hagenow), *Gavelinella sandidgei* (Brotzen). Ocorrências de *G. globosus* em determinados intervalos estratigráficos sugerem a dominância de condições neríticas profundas a batiais superiores. Os gêneros de ostracodes aqui identificados já foram reportados para o Cretáceo da região gondwânica, e sugerem deposição em ambiente plataformal com águas de temperaturas quentes e salinidade normal. A fauna de radiolários estudada, a primeira descrita para a região da Ilha James Ross, é dominada por táxons robustos (resistentes à dissolução) e de distribuição cosmopolita.

Palavras-chave: foraminíferos bentônicos, ostracodes, radiolários, Santoniano superior, Campaniano inferior, Ilha James Ross.

INTRODUCTION

The James Ross Island region presents one of the most complete Cretaceous sedimentary records in austral high-latitudes, which is also particularly rich in fossil remains (Crame *et al*., 1991). The presence of diversified plant, fish, and dinosaur fossils attests that this region remained ice-free during that time interval (Richter & Ward, 1990; Salgado & Gasparini, 2006).

Micropalaeontological studies in this region are relevant for a better understanding of the evolution of high-latitude marine basins in the Mesozoic. Most works on micropaleontology carried out in the James Ross Island and surroundings are based on foraminifera (Macfadyen, 1966; Webb, 1972; Webb & Neall, 1972; Huber *et al*., 1983; Huber & Webb, 1986; Huber, 1984, 1986, 1988, 1991, 1992; Morlotti & Concheyro, 1999). Ostracods were studied by Majoran & Widmark (1998), Fauth *et al.* (2003) and Dingle (2009); nannofossils by Concheyro *et al*. (1991, 1994), Concheyro (2004) and Švábenická *et al.* (2012); and palynomorphs by Keating (1992). Studies regarding radiolarians are scarcer for the region, with Whitham & Doyle (1989) being the only one restricted to the Antarctic Peninsula.

This study aims to present the taxonomy of benthic foraminifera, ostracods, and radiolarians of a sedimentary succession attributed to the Lachman Crags Member, Santa Marta Formation (upper Santonian-lower Campanian), northwestern James Ross Island (Figure 1). The faunas are compared to ones previously described, and some paleoecological inferences are made. Benthic foraminifera showed higher abundance and diversity when compared to the other reported fossil groups; despite their scarcity, ostracods and radiolarians were included in the present contribution in face of the patchiness of works for the studied region during this time interval. It is also worth mentioning that planktic foraminifera are absent from the studied assemblages, being this pattern probably related to post-depositional dissolution processes as discussed below.

GEOLOGICAL SETTING

The studied area is inserted in the James Ross Sub-basin, which is part of the Larsen Basin, initiated as a consequence of the Gondwana breakup and subsequently evolving as a typical back-arc basin with significant volcanic contribution (Gust *et al.*, 1985; Storey *et al.*, 1992). Two stratigraphic groups encompass Cretaceous marine deposits in the James Ross Sub-basin: (i) the Gustav Group, Aptian-Coniacian in age, interpreted as submarine fans and slope deposits; (ii) the Marambio Group, Santonian-Danian in age, interpreted as a shallow-marine setting (Ineson *et al.*, 1986; Olivero *et al.*, 1986; Crame *et al.*, 1991). Within the Marambio Group, Olivero *et al.* (1986) defined the Santa Marta Formation, which is a siliciclastic sedimentary succession of late Santonian-early Campanian age (see also Richter & Ward, 1990; Olivero *et al*., 1991; Crame *et al.,* 1991; Pirrie *et al.*, 1991; Olivero, 2012). Olivero *et al.* (1986) subdivided this formation into the Alpha, Beta, and Gama members, based mainly on variations of coarse-grained lithofacies. Subsequently, Crame *et al.* (1991) segmented the Santa Marta Formation into the Lachman Grags Member (probably correlated to the Alpha and Beta members of Olivero *et al.*, 1986), Herbert Sound Member, and Rabot Member. The studied succession is attributed to the Lachman Crags Member of the Santa Marta Formation and, taking into account the occurrence of tuffaceous sandstone [*cf*. tuffites cemented by carbonate described by Scasso *et al.* (1991)] and the absence of conglomerathic lithofacies, probably placed into the Alpha Member described by Olivero *et al.* (1986).

The studied section is 126 m long within the Santa Marta Formation (Lachman Crags Member/Alpha Member), located in northwestern James Ross Island (Figure 1; 63°49'28.13''S/57°52'30.8''W - SAD-69 datum). It is dominated by the occurrence of tuffaceous sandstones interbedded with fine-grained siliciclastic facies, and less remarkable occurrences of sandstones in its uppermost portion (Figure 2).

MATERIAL AND METHODS

During the austral summer of 2007, 99 samples were collected, mainly composed of very fine to medium-grained tuffaceous sandstones [*cf*. tuffites cemented by carbonate

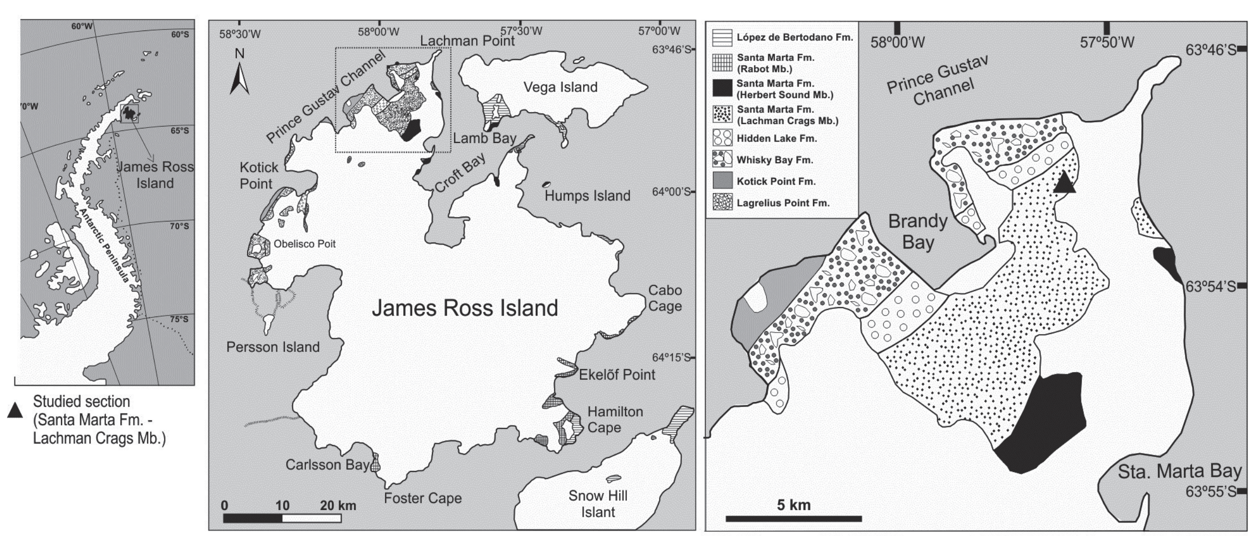

Figure 1. Location map of the studied section (black triangle) (modified from Pirrie *et al*., 1992).

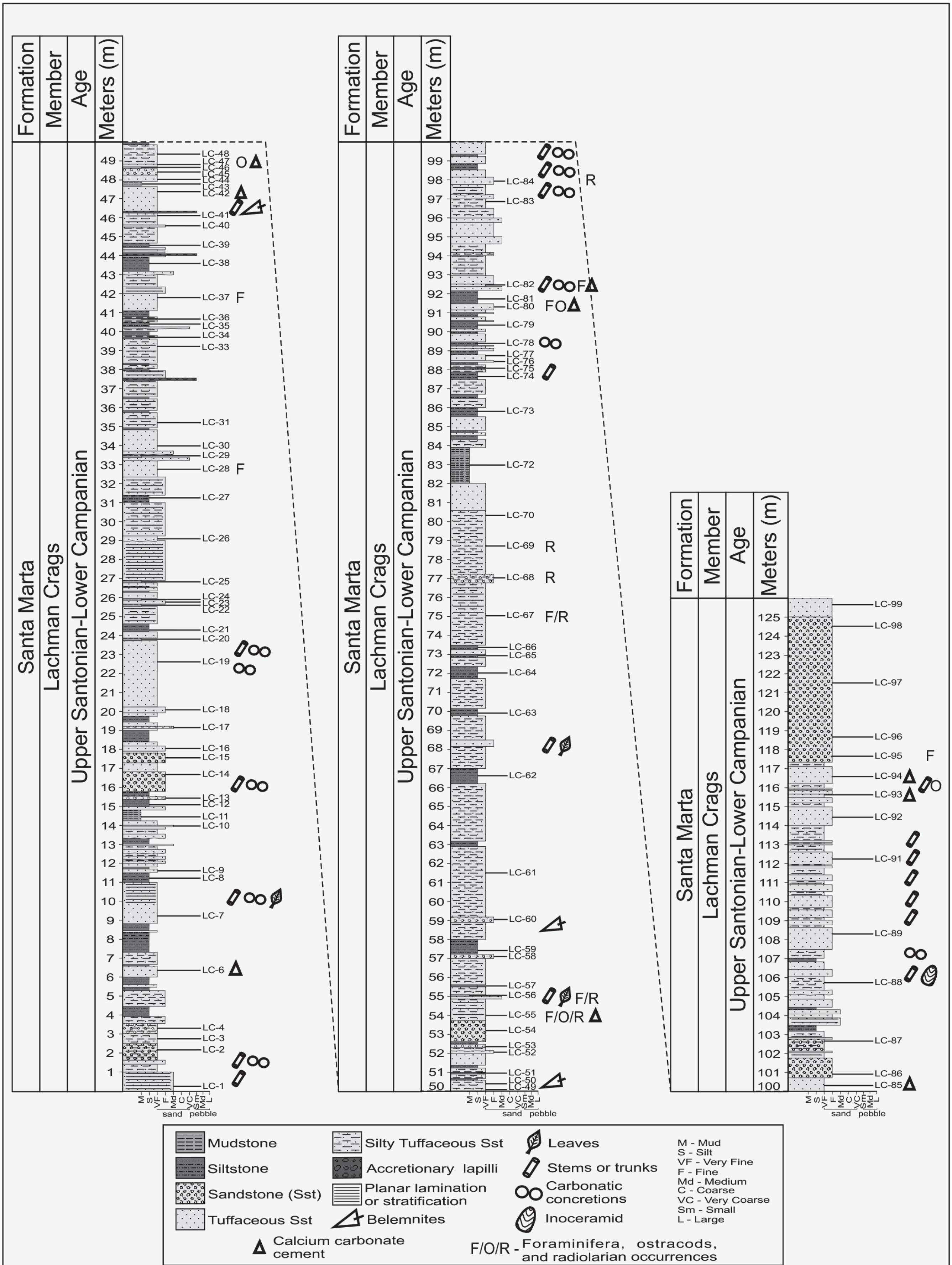

Figure 2. Studied section (lithostratigraphic profile) with the position of the studied samples (LC-number).

described by Scasso *et al.* (1991)], claystones, and siltstones. Only 13 samples yielded microfossils, as follow: LC-28, LC-37, LC-47, LC-55, LC-56, LC-67, LC-68, LC-69, LC-80, LC-82, LC-84, LC-94 and LC-95 (Figure 2).

Approximately 50 g of dried rock were crushed and soaked in 200 ml of a hydrogen peroxide solution (H_2O_2), at a concentration of 29%, for 24 hours. Residues were then washed and divided into the grain fractions 45, 63, 150, and 250 µm. Because of the scarcity of microfossil occurrences and low abundances, the total amounts of benthic foraminifera, ostracods, and radiolarians were hand-picked under stereomicroscope from each grain-size fraction. Selected specimens were imaged by means of scanning electron microscope (SEM) and Zeiss Discovery V20 stereomicroscope, using multidimensional acquisition with extended focus (computation from Z-stack in the software AxioVision 4.8).

TAXONOMY

All species of benthic foraminifera, ostracods, and radiolarians identified in this study are presented and discussed below. Synonymies are restricted to the original description, including those references relevant to the understanding of the species concept used herein and the stratigraphic ranges. Remarks were made under each species entry in order to clarify the main distinguishing features. Stratigraphic ranges are based on the references cited in synonymies. The specimens figured herein will be held in the collections of the Museu de História Geológica do Rio Grande do Sul, Universidade do Vale do Rio dos Sinos (UNISINOS), Brazil, under the curatorial numbers ULVG-9779 to ULVG-9817 (entries given after each species in Figures 3-6). Stratigraphic distributions of the identified species within the studied section are given in Figure 7.

Foraminifera

Suprageneric classification follows that of Loeblich & Tappan (1987) as modified by Loeblich & Tappan (1992), for calcareous benthic foraminifera, and Kaminski (2004), for the agglutinated taxa. Modes of life of benthic foraminifera were inferred after Koutsoukos & Hart (1990) and Cetean *et al.* (2011), based on foraminiferal morphogroup analysis and the functional morphology concept.

Class FORAMINIFERA d'Orbigny, 1826
Order LITUOLIDA Lankester, 1885
Suborder LITUOLINA Lankaster, 1885
Superfamily LITUOLACEA Brady, 1881
Family HAPLOPHRAGMOIDIDAE Maync, 1952

Haplophragmoides Cushman, 1910

Haplophragmoides sp.
(Figures 3A-C)

Description. Planispiral biumbilicate test, with a finely agglutinated and smooth wall. Sides somewhat flattened. Peripheral outline circular and somewhat lobulate, with eight slightly inflated chambers in the last forming whorl. Sutures depressed and slightly curved. Aperture an elongate equatorial slit at the base of the last forming chamber.
Material. 4 specimens in sample LC-55.
Inferred mode of life. Surficial epifaunal to shallow infaunal.

Suborder SPIROPLECTAMMININA Mikhalevich, 1992
Superfamily SPIROPLECTAMMINACEA Cushman, 1927
Family SPIROPLECTAMMINIDAE Cushman, 1927
Subfamily SPIROPLECTAMMININAE Cushamn, 1927

Spiroplectinella Kisel'man, 1972

Spiroplectinella ex gr. *dentata* (Alth, 1850)
(Figure 3D)

1850 *Textularia dentata* Alth, p. 262, pl. 13, fig. 13.
1953 *Spiroplectammina dentata* (Alth) var. *tenuisa* Gauger, p. 59, pl. 6, figs. 1, 2.

Remarks. This species is characterized by its cuneate test, with dentate margins and a small quadrate planispiral microspheric stage.
Material. 2 specimens in sample LC-55; 1 specimen in sample LC-80.
Inferred mode of life. Surficial epifaunal.
Stratigraphic range. Late Cretaceous (Gauger, 1953).

Spiroplectinella sp.
(Figure 3E)

Description. Test finely agglutinated, smooth, and with early planispiral microspheric stage followed by a biserial stage increasing rapidly in breadth. Test lozenge shape in section, with the last chambers somewhat globular (inflated). Aperture a low arch at the base of the apertural face.
Material. 1 specimen in sample LC-28.
Inferred mode of life. Surficial epifaunal.

Suborder VERNEUILININA Mikhalevich & Kaminski, 2004
Superfamily VERNEUILINACEA Cushman, 1911
Family PROLIXOPLECTIDAE Loeblich & Tappan, 1985

Karrerulina Finlay, 1940

Karrerulina sp.
(Figure 3F)

Description. Test elongate, slender and circular in section. Test presents three stages: first trochospirally coiled, then triserial and finally biserial. Sutures slightly depressed. Wall agglutinated of fine to medium-sized particles.
Material. 1 specimen in sample LC-37.
Remarks. Apertural features are masked by poor preservation in the studied specimen.
Inferred mode of life. Deep infaunal.

Order TEXTULARIIDA Delage & Herouard, 1896
Suborder TEXTULARIINA Delage & Herouard, 1896
Superfamily EGGERELLACEA Cushman, 1937
Family EGGERELLIDAE Cushman, 1937
Subfamily DOROTHIINAE Balakhmatova, 1972

Marssonella Cushman, 1933

Marssonella? sp.
(Figure 3G)

Description. Test conical and circular in section. Tiny early trochospiral stage followed by a biserial stage. Wall finely agglutinated.
Remarks. Poor preservation prevents a more precise identification.
Material. 1 specimen in sample LC-55; 2 specimens in sample LC-80.
Inferred mode of life. Deep infaunal.

Dorothia Plummer, 1931

Dorothia retusa (Cushman, 1926)
(Figure 3H)

1926 *Gaudryina retusa* Cushman, p. 588, pl. 16, fig. 10a, 10b.

Material. 1 specimen in sample LC-55; 12 specimens in sample LC-80; 1 specimen in sample LC-82.
Inferred mode of life. Deep infaunal.
Stratigraphic range. Late Cretaceous (Cushman, 1926).

Dorothia sp. 1
(Figure 3I)

Description. Conical finely agglutinated test. Early stage trochospirally coiled, followed by a biserial stage. Aperture a slit at the apertural face.
Remarks. It differs from *Dorothia* sp. 2 by having a conical shaped test throughout.
Material. 1 specimen in sample LC-67.
Inferred mode of life. Deep infaunal.

Dorothia sp. 2
(Figure 3J)

Description. Test robust and finely agglutinated. Early stage trochospiral followed by a biserial one, subcircular in section. Chambers in the biserial stage increasing slowly in size as added. Sutures depressed. Aperture a slit at the base of the last forming chamber.
Remarks. The figured specimen is deformed (twisted).
Material. 1 specimen in sample LC-80.
Inferred mode of life. Deep infaunal.

Order MILIOLIDA Lankester, 1885
Superfamily CORNUSPIRACEA Schultze, 1854
Family CORNUSPIRIDAE Schultze, 1854
Subfamily CORNUSPIRINAE Schultze, 1854

Cornuspira Schultze, 1854

Cornuspira? sp.
(Figure 3K)

Description. Discoidal test, with globular proloculus followed by an undivided planispirally-coiled evolute tubular second chamber. Wall calcareous, porcelaneous and imperforate. Surface smooth. Aperture at the end of the second tubular chamber.
Remarks. Since the globular proloculus is missing in all studied specimens, this identification remains as tentative.
Material. 1 specimen in sample LC-80.
Inferred mode of life. Unknown.

Order LAGENIDA Lankester, 1885
Superfamily NODOSARIACEA Ehrenberg, 1838
Family NODOSARIIDAE Ehrenberg, 1838
Subfamily NODOSARIINAE Ehrenberg, 1838

Chrysalogonium Schubert, 1908

Chrysalogonium? sp.
(Figure 3L)

Remarks. Poor preservation of the apertural region prevents a more precise identification.
Material. 1 specimen in sample LC-80.
Inferred mode of life. Epifaunal to shallow infaunal.

Laevidentalina Loeblich & Tappan, 1986

Laevidentalina sp. aff. *L. gracilis* (d'Orbigny, 1840)
(Figure 3M)

Remarks. It differs from *L. gracilis* by having slightly oblique sutures. Also, the apertural features are masked by poor preservation.
Material. 1 specimen in sample LC-80.
Inferred mode of life. Epifaunal to shallow infaunal.

Family VAGINULINIDAE Reuss, 1860
Subfamily LENTICULININAE Chapman *et al.*, 1934

Lenticulina Lamarck, 1804

Lenticulina sp. 1
(Figures 3N-P)

Description. Planispiral involute-coiled test, with about seven chambers in the last-forming whorl. Test lenticular in section. Sutures radial, curved and flush. Periphery slightly carinate. Aperture radial at the peripheral angle, with a longer slit at the center of the apertural face.

Material. 1 specimen in sample LC-55; 1 specimen is sample LC-67; 9 specimens in sample LC-80.
Inferred mode of life. Epifaunal.

Lenticulina sp. 2
(Figures 3Q-R)

Description. Large planispiral involute-coiled test, with about ten chambers in the last forming whorl. Test lenticular in section. Sutures radial, slightly curved and flush. Periphery acute; peripheral outline angulate. Aperture radial at the peripheral angle.
Material. 1 specimen in sample LC-80.
Inferred mode of life. Epifaunal.

Saracenaria Defrance, 1824

Saracenaria sp. aff. *S. cretacea* Dailey, 1970
(Figures 3S-U)

Remarks. It differs from *S. cretacea* by having a more sinuous uniserial stage.
Material. 2 specimens in sample LC-55; 1 specimen in sample LC-80; 1 specimen in sample LC-82.
Inferred mode of life. Epifaunal to shallow infaunal.

Saracenaria sp.
(Figures 3V-X)

Description. Test with a planispiral involute coil in the early stage, later becoming linear. Seven chambers in the last forming whorl. Late stage roughly triangular in section, with a broad and flat apertural face. Sutures radial, curved and slightly elevated, mainly between the early chambers. Periphery carinate. Aperture a series of radial slits at the peripheral angle, produced on a short neck.
Material. 2 specimens in sample LC-55; 3 specimens in sample LC-80.
Inferred mode of life. Epifaunal to shallow infaunal.

Subfamily MARGINULININAE Wedekind, 1937

Hemirobulina Stache, 1864

Hemirobulina texasensis (Cushman, 1938)
(Figure 3Y)

1938 *Marginulina texasensis* Cushman, p. 61, pl. 21, figs. 21-29, 38, 40.
1983 *Marginulinopsis texasensis* (Cushman). Basov & Krasheninnikov, p. 762, pl. 6, figs. 6.

Remarks. This species is herein attributed to *Hemirobulina* due to its smooth surface.
Material. 1 specimen in sample LC-80.
Inferred mode of life. Epifaunal to shallow infaunal.
Stratigraphic range. Coniacian-Maastrichtian (Basov & Krasheninnikov, 1983).

Hemirobulina sp. aff. *H. schloenbachi* (Reuss, 1863)
(Figures 3.Z-AA)

Remarks. It differs from *H. schloenbachi* by having a less developed coiling in the early developmental stage.
Material. 2 specimens in sample LC-55; 2 specimens in sample LC-80.
Inferred mode of life. Epifaunal to shallow infaunal.

Hemirobulina sp.
(Figures 3AB-AC)

Diagnose. Smooth calcareous test composed of five chambers, early planispirally coiled stage followed by a sinuous uniserial stage. Sutures oblique. Aperture terminal at the dorsal angle, with a series of radial slits.
Material. 1 specimen in sample LC-55; 2 specimens in sample LC-80; 1 specimen in sample LC-82.
Inferred mode of life. Epifaunal to shallow infaunal.

Family LAGENIDAE Reuss, 1862

Lagena Walker & Jacob, 1798

Lagena sulcata (Walker and Jacob, 1798)
(Figures 3AD)

1798 *Serpula (Lagena) sulcata* Walker & Jacob *in* Kanmacher, p. 634, pl. 14, fig. 5.

Remarks. The possibility of contamination cannot be ruled out for explaining the occurrence of this species. It was originally described for unconsolidated shore sands and it could well be considered a contaminant from unconsolidated overlying Cenozoic sediments. This proposition is in accordance with the unconsolidated nature of some of the Cretaceous strata studied herein, as well as displaced Cenozoic calcareous nannofossils occurring in samples LC 79 and LC 81 (R.M. Guerra pers. com. 2013).
Material. 1 specimen in sample LC-80.
Inferred mode of life. Epifaunal to infaunal.
Stratigraphic range. Recent (Kanmacher, 1798).

Superfamily POLYMORPHINACEA d'Orbigny, 1839
Family POLYMORPHINIDAE d'Orbigny, 1839
Subfamily POLYMORPHININAE d'Orbigny, 1839

Pyrulina d'Orbigny, 1839

Pyrulina sp.
(Figure 4A)

Description. Oval-shaped smooth calcareous test, with subcircular section slightly compressed laterally and sub-acuminate base. Chambers arrangement as described for the genus, with flush sutures between chambers. Aperture terminal and radiate.

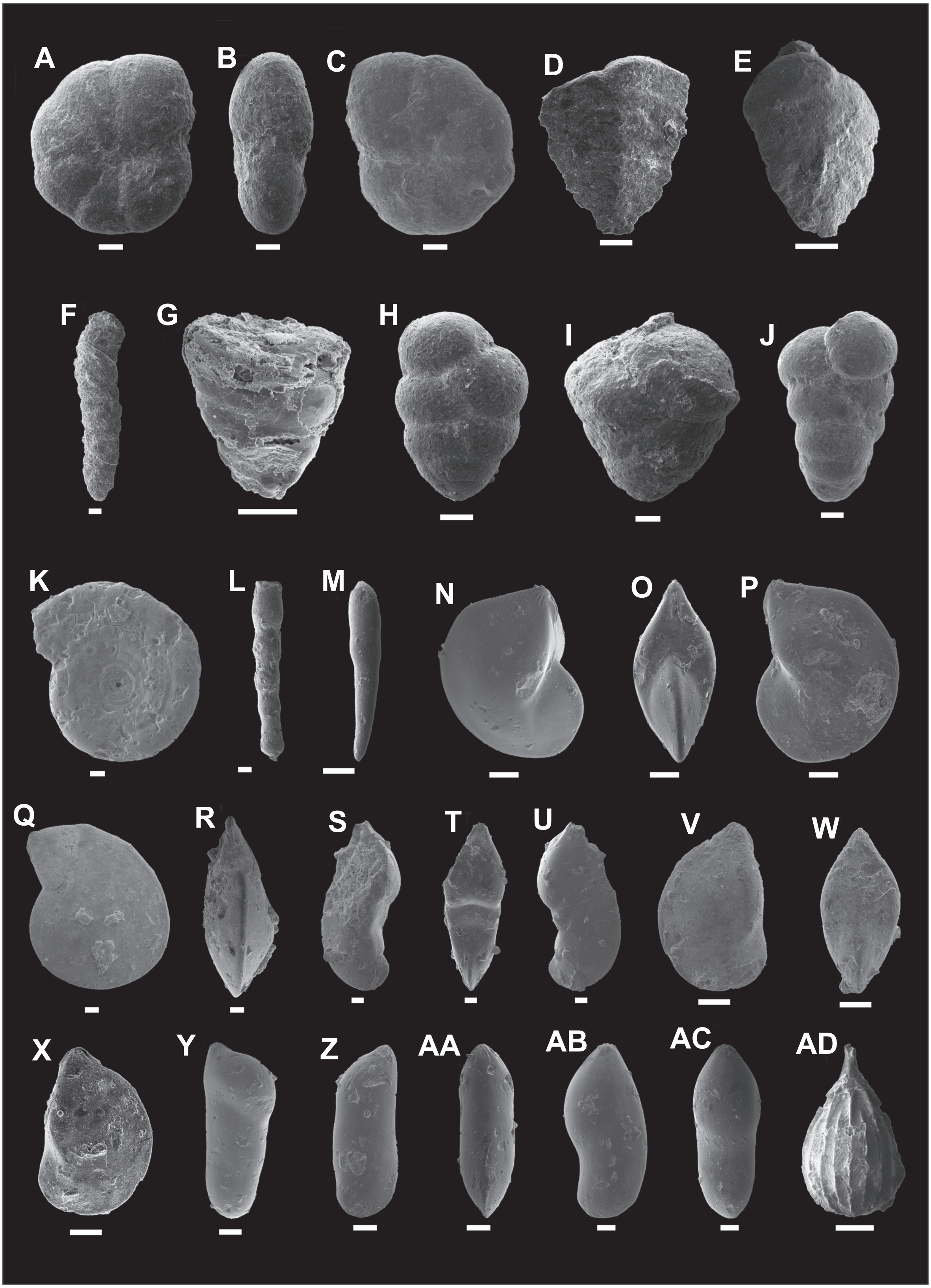

Figure 3. Foraminifers. **A-C**, *Haplophragmoides* sp., LC-55 (ULVG-9779); **D**, *Spiroplectinella* ex gr. *dentata*, LC-55 (ULVG-9780); **E**, *Spiroplectinella* sp., LC-28 (ULVG-9781); **F**, *Karrerulina* sp., LC-37 (ULVG-9782); **G**, *Marssonella*? sp., LC-55 (ULVG-9783); **H**, *Dorothia retusa*, LC-55 (ULVG-9784); **I**, *Dorothia* sp. 1, LC-67 (ULVG-9785); **J**, *Dorothia* sp. 2, LC-80 (ULVG-9786); **K**, *Cornuspira*? sp., LC-80 (ULVG-9787); **L**, *Chrysalogonium*? sp., LC-80 (ULVG-9788); **M**, *Laevidentalina* sp. aff. *L. gracilis*, LC-80 (ULVG-9789); **N-P**, *Lenticulina* sp. 1, LC-80 (ULVG-9790); **Q-R**, *Lenticulina* sp. 2, LC-80 (ULVG-9791); **S-U**, *Saracenaria* sp. aff. *S. cretacea*, LC-80 (ULVG-9792); **V-X**, *Saracenaria* sp., LC-55 (ULVG-9793); **Y**, *Hemirobulina texasensis*, LC-80 (ULVG-9794); **Z-AA**, *Hemirobulina* sp. aff. *H. schloenbachi*, LC-80 (ULVG-9795); **AB-AC**, *Hemirobulina* sp., LC-80 (ULVG-9796); **AD**, *Lagena sulcata*, LC-80 (ULVG-9797). Scale bars = 100 µm.

Material. 1 specimen in sample LC-55.
Inferred mode of life. Epifaunal to shallow infaunal.

Order BULIMINIDA Fursenko, 1958
Superfamily BULIMINACEA Jones, 1875
Family SIPHOGENERINOIDIDAE Saidova, 1981
Subfamily SIPHOGENERINOIDINAE Saidova, 1981

Siphogenerinoides Cushman, 1927

Siphogenerinoides sp. aff. *S. bramlettei* Cushman, 1929
(Figure 4B)

Remarks. It differs from *S. bramlettei* by having costae extending until the aperture on the last forming chamber.
Material. 1 specimen in sample LC-55.
Inferred mode of life. Infaunal.

Superfamily PLEUROSTOMELLACEA Reuss, 1860
Family PLEUROSTOMELLIDAE Reuss, 1860

Pleurostomella Reuss, 1860

Pleurostomella subnodosa Reuss, 1860
(Figure 4C)

1860 *Pleurostomella subnodosa* Reuss, p. 204, pl. 8, fig. 2.
1983 *Pleurostomella subnodosa* Reuss. Basov & Krasheninnikov, p. 204, pl. 8, fig. 2.

Remarks. This species is characterized by its low hood projection on one side of the aperture.
Material. 1 specimen in sample LC-55; 1 specimen in sample LC-80.
Inferred mode of life. Infaunal.
Stratigraphic range. Late Cretaceous (Basov & Krasheninnikov, 1983).

Superfamily STILOSTOMELLACEA Finlay, 1947
Family STILOSTOMELLIDAE Finlay, 1947

Stilostomella Guppy, 1894

Stilostomella? sp.
(Figure 4D)

Description. Uniserial elongate, and slightly arcuate, calcareous test. Chambers subglobular (usually numbering six), somewhat embracing each other, and separated by distinctly constricted sutures.
Remarks. All described specimens present the last forming chamber broken. Hence, the identification remains as tentative.
Material. 1 specimen in sample LC-55; 2 specimens in sample LC-80.
Inferred mode of life. Epifaunal to shallow infaunal.

Nodogenerina Cushman, 1927

Nodogenerina sp.
(Figure 4E)

Description. Test narrow, elongate, uniserial, and slightly arcuate. Chambers ovate (wider at the basal half), separated by slightly depressed sutures. Wall hyaline, finely perforate and with small downwardly-directed spines at the base of the last-forming chambers.
Remarks. All recovered specimens were broken, hampering the identification of apertural features. Loeblich & Tappan (1987) suggested that this genus is restricted to the Campanian.
Material. 2 specimens in sample LC-80.
Inferred mode of life. Epifaunal to shallow infaunal.

Order ROTALIIDA Lankester, 1885
Superfamily CHILOSTOMELLACEA Brady, 1881
Family HETEROLEPIDAE Gonzáles-Donoso, 1969

Anomalinoides Brotzen, 1942

Anomalinoides sp. aff. *A. piripaua* (Finlay, 1939)
(Figures 4F-H)

Remarks. Differs from *A. piripaua* by having a more angled peripheral margin.
Material. 1 specimen in sample LC-80; 5 specimens in sample LC-82.
Inferred mode of life. Epifaunal.

Family GAVELINELLIDAE Hofker, 1956
Subfamily GYROIDINOIDINAE Saidova, 1981

Gyroidinoides Brotzen, 1942

Gyroidinoides globosus (Hagenow, 1842) emend.
Alegret & Thomas, 2001
(Figure 4I-N)

1842 *Nonionina globosa* Hagenow, p. 574.
1983 *Gyroidinoides globosa* (Hagenow). Basov & Krasheninnikov, p. 764, pl. 9, figs. 2-3.
1989 *Gyroidinoides globosa* (Hagenow). Koutsoukos, p. 175, pl. 16, figs. 12-18.
2001 *Gyroidinoides globosus* (Hagenow). Alegret & Thomas, p. 288, pl. 16, figs. 12-18.

Remarks. *Gyroidinoides globosus* differs from *G. infracretaceus* by having a distinctive globular test, and a broadly rounded equatorial periphery without a clearly defined peripheral shoulder. Apertural face is about four times broader than high.
Material. 2 specimens in sample LC-55; 1 specimen in sample LC-56; 13 specimens in sample LC-80.
Inferred mode of life. Epifaunal.
Stratigraphic range. Late Aptian (Kochhann, 2012) to Maastrichtian (Koutsoukos, 1989).

Subfamily GAVELINELLINAE Hofker, 1956

Gavelinella Brotzen, 1942

Gavelinella sandidgei (Brotzen, 1936)
(Figures 4O-R)

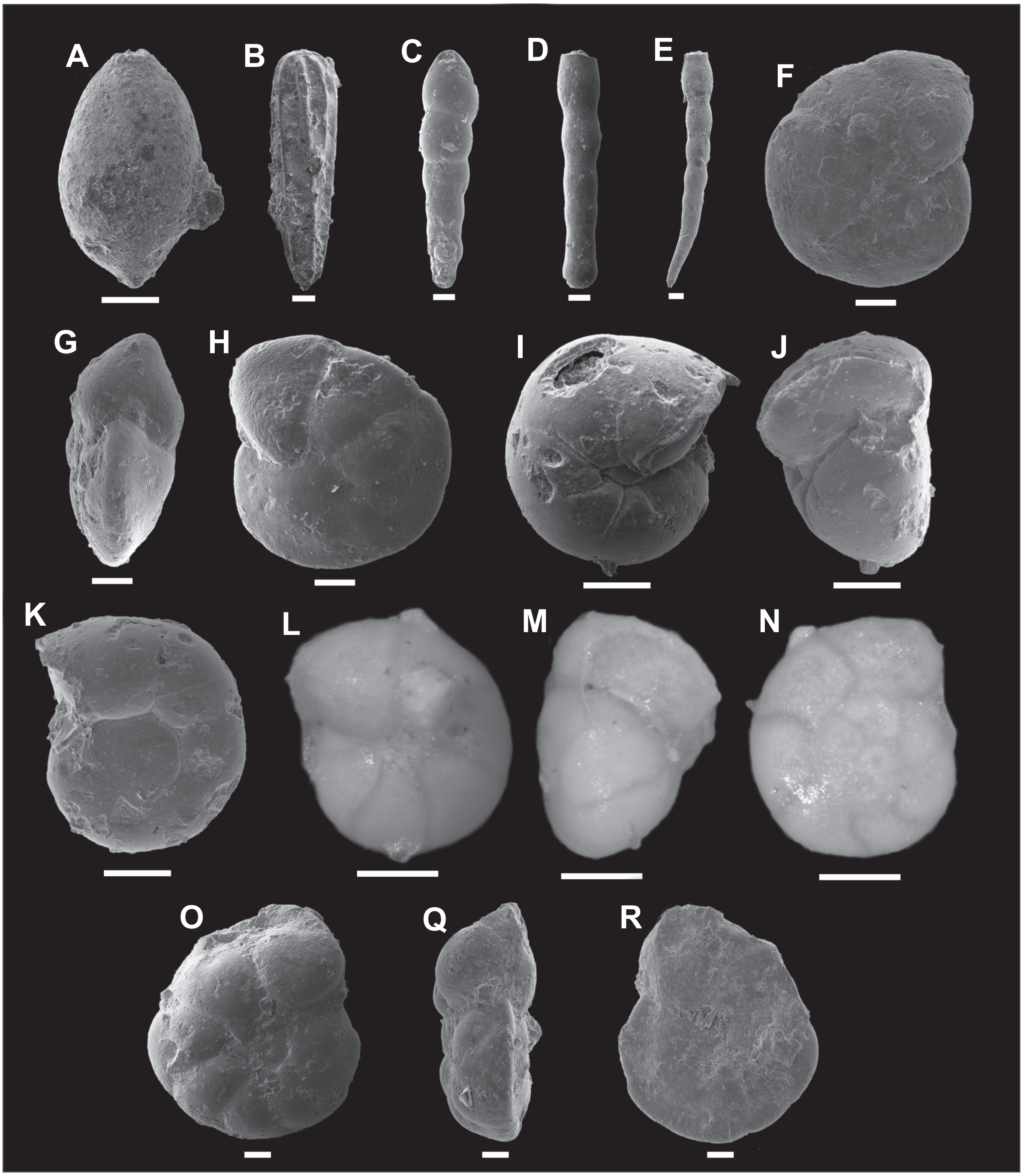

Figure 4. Foraminifers. **A**, *Pyrulina* sp., LC-55 (ULVG-9798); **B**, *Siphogenerinoides* sp. aff. *S. bramlettei*, LC-55 (ULVG-9799); **C**, *Pleurostomella subnodosa*, LC-80 (ULVG-9800); **D**, *Stilostomella*? sp., LC-80 (ULVG-9801); **E**, *Nodogenerina* sp., LC-80 (ULVG-9802); **F-H**, *Anomalinoides* sp. aff. *A. piripaua*, LC-82 (ULVG-9803); **I-N**, *Gyroidinoides globosus*, both specimens from sample LC-80 (ULVG-9804); **O-R**, *Gavelinella sandidgei*, LC-80 (ULVG-9805). Scale bars = 100 µm.

1936 *Cibicides sandidgei* Brotzen, p. 191, pl. 14, figs. 2-4.
2011 *Gavelinella sandidgei* (Brotzen). Cetean *et al.*, pl. 3, fig. 6.

Material. 9 specimens in sample LC-55; 3 specimens in sample LC-80; 6 specimens in sample LC-82.
Inferred mode of life. Epifaunal.
Stratigraphic range. Late Cretaceous (Huber, 1988; Cetean *et al.*, 2011).

Ostracoda

Suprageneric nomenclature is in accordance to Benson *et al.* (1961). The following **abbreviations** are used: **l** = length; **h** = height; **w** = width; **C** = carapace; **RV** = right valve; **LV** = left valve.

Subclass OSTRACODA Latreille, 1802
Order PLATYCOPIDA Sars, 1866
Superfamily CYTHERELLOIDEA Sars, 1866
Family CYTHERELLIDAE Sars, 1866

Cytherella Jones, 1849

Cytherella sp.
(Figures 5A-B)

Description. Subeliptical and elongated carapace. Surface smooth. Dorsal margin slightly convex and ventral margin almost straight. Anterior and posterior margins symmetrically rounded. Right valve bigger than the left one, less marked and overlapping on the posterior region.
Material. 1C in sample LC-47; 1C in sample LC-80.
Dimensions. l = 0.796 mm; h = 0.534 mm; w = 0.375 mm.

Order PODOCOPIDA Sars, 1866
Suborder BAIRDICOPINA Gründel, 1967
Superfamily BAIRDIOIDEA Sars, 1888
Family BYTHOCYPRIDIDAE Maddocks, 1969

Bythocypris Brady, 1880

Bythocypris sp.
(Figures 5C-D)

Description. Carapace surface smooth. Left valve strongly overlapping the right one. Anterior and posterior margins asymmetrically rounded. Dorsal margin slightly concave. Greatest width of the carapace found at the median portion. Ventral margin concave at the center.
Material. 1C in sample LC-80.
Dimensions. l = 0.625 mm; h = 0.325 mm; w = 0.250 mm.

Suborder CYTHEROCOPINA Gründel, 1967
Superfamily CYTHERIDEOIDEA Baird, 1850
Family PROGONOCYTHERIDAE Sylvester-Bradley, 1948
Subfamily PROGONOCYTHERINAE
Sylvester-Bradley, 1948

Majungaella Grekoff, 1963

Majungaella sp. aff. *M. pseudonymos*
Whatley *et al.*, 2005
(Figures 5E-F)

Remarks. It differs from *M. pseudonymos* by having more numerous costae at the anterior portion.
Material. 1C in sample LC-80.
Dimensions. l = 1.150 mm; h = 0.750 mm; w = 0.675 mm.

Majungaella sp. 1
(Figure 5G)

Remarks. It differs from *M.* sp. aff. *M. pseudonymos* by having an antero-ventral margin that is wider and turned towards the ventral margin.
Material. 1C in sample LC-80.
Dimensions. l = 1.064 mm; h = 0.764 mm; w = 0.580 mm.

Majungaella? sp. 2
(Figure 5H)

Description. Sub-triangular valve. Reticulate surface with sub-concentric costae. Anterior margin rounded and posterior margin tapered. Ventral margin convex and postero-dorsal margin rectilinear.
Remarks. The figured specimen is probably a juvenile form.
Material. 1RV in sample LC-55.
Dimensions. l = 0.775 mm; h = 0.512 mm.

Suborder CYPRIDOCOPINA Jones, 1901
Superfamily CYPRIDOIDEA Baird, 1845
Family CANDONIDAE Baird, 1845
Subfamily PARACYPRIDINAE Sars, 1923

Paracypris Sars, 1866

Paracypris sp.
(Figures 5I-J)

Description. Elongate and smooth carapace. Normal canal-pores are more abundant on the antero-ventral region. Dorsal margin convex. Ventral margin sub-rectilinear, with a concavity at the central area. Anterior margin rounded and posterior margin acuminated. Left valve overlaps the right one, with maximum overlap at the dorsal region. There is a slight concavity at the postero-dorsal region.
Material. 1C in sample LC-94.
Dimensions. l = 1.075 mm; h = 0.462 mm; w = 0.437 mm.

Radiolaria

Suprageneric nomenclature is in accordance to De Wever *et al*. (2001).

Subclass RADIOLARIA Müller, 1858
Order NASSELLARIA Ehrenberg, 1875
Family ARCHAEODICTYOMITRIDAE Pessagno, 1976

Archaeodictyomitra Pessagno, 1976

Archaeodictyomitra sp. cf. *A. squinaboli* Pessagno, 1976
(Figure 6A)

1976 *Archaeodictyomitra squinaboli* Pessagno, p. 50, pl. 5, figs. 2-8.

Material. 1 specimen in sample LC-67.

Archaeodictyomitra sp.
(Figure 6B)

Description. Conical skeleton with nine segments. Nine costae (in lateral view) cover the surface of all segments, being linear and continuous. Constrictions are poorly developed and have no effect on the costae's outline.
Remarks. This species differs from *A. squinaboli* by not having a fusiform outline.
Material. 1 specimen in sample LC-55.

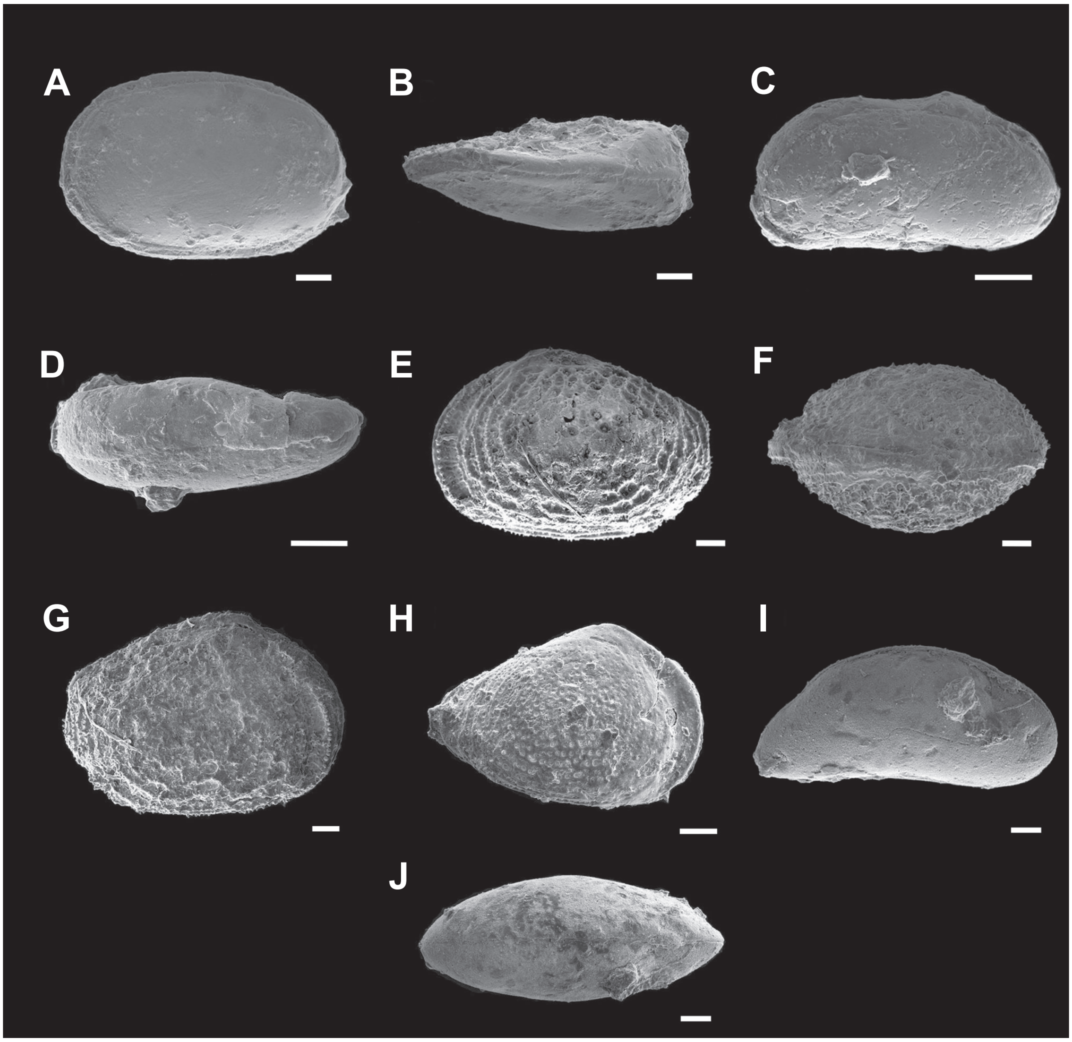

Figure 5. Ostracods. **A-B**, *Cytherella* sp. (A: LV view; B: dorsal view), LC-80 (ULVG-9806); **C-D**, *Bythocypris* sp. (C: RV view; D: dorsal view), LC-80 (ULVG-9807); **E-F**, *Majungaella* sp. aff. *M. pseudonymos* (E: LV view; F: dorsal view), LC-80 (ULVG-9808); **G**, *Majungaella* sp. 1 (RV view), LC-80 (ULVG-9809); **H**, *Majungaella*? sp. 2 (RV view), LC-55 (ULVG-9810); **I-J**, *Paracypris* sp. (H: RV view; I: dorsal view), LC-94 (ULVG-9811). Scale bars = 100 µm.

Family PSEUDODICTYOMITRIDAE Pessagno, 1977

Pseudodictyomitra Pessagno, 1977

Pseudodictyomitra sp. cf. *P. pentacolaensis* Pessagno, 1977
(Figure 6C)

Remarks. The costae of the specimen figured herein are less massive than in those specimens of Pessagno (1977) and Ling and Lazarus (1990), however this characteristics seems dependent on silica availability and preservation patterns.
Material. 1 specimen in sample LC-69.

Family EUCYRTIDIIDAE Ehrenberg, 1847

Stichomitra Cayeux, 1897

Stichomitra stocki (Campbell & Clark)
sensu O'Dogherty, 1994
(Figure 6D)

1944 *Stichocapsa*(?) *stocki* Campbell & Clark, p. 44, pl. 8, figs. 31-33.
1994 *Stichomitra stocki* (Campbell & Clark). O'Dogherty, p. 147, pl. 18, figs. 9-15.

Material. 1 specimen in sample LC-84.
Stratigraphic range. Late Cretaceous (O'Dogherty, 1994).

Order SPUMELLARIA Ehrenberg, 1875 *emend*.
De Wever *et al.,* 2001

Spumellaria gen. et sp. indet. A
(Figure 6E)

Description. Subspherical skeleton with latticed wall.
Remarks. It is difficult to determine this specimen. It is not *Cryptamphorella spherica*, that is a small nassellarian species with large pores and with a visible cephalothorax.
Material. 1 specimen in sample LC-56.

Spumellaria gen. et sp. indet. B
(Figure 6F)

Description. Subspherical skeleton with probably seven three-bladed spines of which six are visible (five around the periphery and one upward directed).
Remarks. It is impossible to accurately determine this species due to its preservation, but if the number of spines is really seven, it could belong to an undescribed genus of the family Quinquecapsulariidae, the range of which is Tithonian to Paleocene (P. Dumitrica, pers. com. 2013).
Material. 1 specimen in sample LC-68.

DISCUSSION

It is remarkable that significant calcareous microfossils occurrences (benthic foraminifera and ostracods) are restricted to few stratigraphic levels described as tuffaceous sandstones cemented by calcium carbonate [Figures 2 and 7; *cf*. tuffites cemented by carbonate described by Scasso *et al*., (1991)], while siliceous microfossils (radiolarians) and agglutinated foraminifera occur in sandstone levels in addition to the tuffaceous sandstone (Figures 2, 7). This pattern of occurrences, besides the absence of microfossils in the expected fine-grained lithofacies, suggests a preservational bias in the occurrences of microfossils within the studied section. Calcium carbonate bioclasts may have been preferentially preserved in the tuffaceous sandstones cemented by carbonate, while dissolution may have played an important role in their absence from the remaining lithofacies (which do not possess the above stated cement). This pattern of occurrences may also explain the absence of planktic foraminifera from the studied assemblages (in a probable deep neritic environment; see discussion below), since their thinner and more porous tests are believed to be more susceptible to dissolution than the thicker and smooth tests of benthic foraminifera, greatly affecting the ratio between these two foraminiferal groups in both Mesozoic and Cenozoic deposits elsewhere (*e.g.* Friedrich & Hemleben, 2007; Kucera, 2007; Nguyen *et al*., 2009). It is also worth mentioning that benthic foraminiferal species recovered herein are predominantly represented by morphotypes with sturdy tests, which are probably dissolution-resistant taxa. Huber (1988) also suggested that diagenesis may have largely biased foraminiferal distribution data in the James Ross Island region. Furthermore, the occurrences of microfossils in the coarser-grained lithofacies (high-energy facies) could explain their low abundances and richness in the studied succession. Benthic foraminifera are the most abundant organisms recovered in the present study (*e.g.* samples LC-55, LC-80, LC-82), and when the number of specimens recovered in 50 g of sediments (see the taxonomic section above) is compared to data reported by Huber (1988) for the James Ross Island region (based on about 1,200 g of residue), data presented herein become relevant in the regional context.

Consistent occurrences of *Gyroidinoides globosus* in samples LC-55, LC-56, and LC-80 suggest the dominance of deep-neritic to upper-bathyal paleodepths at these stratigraphic

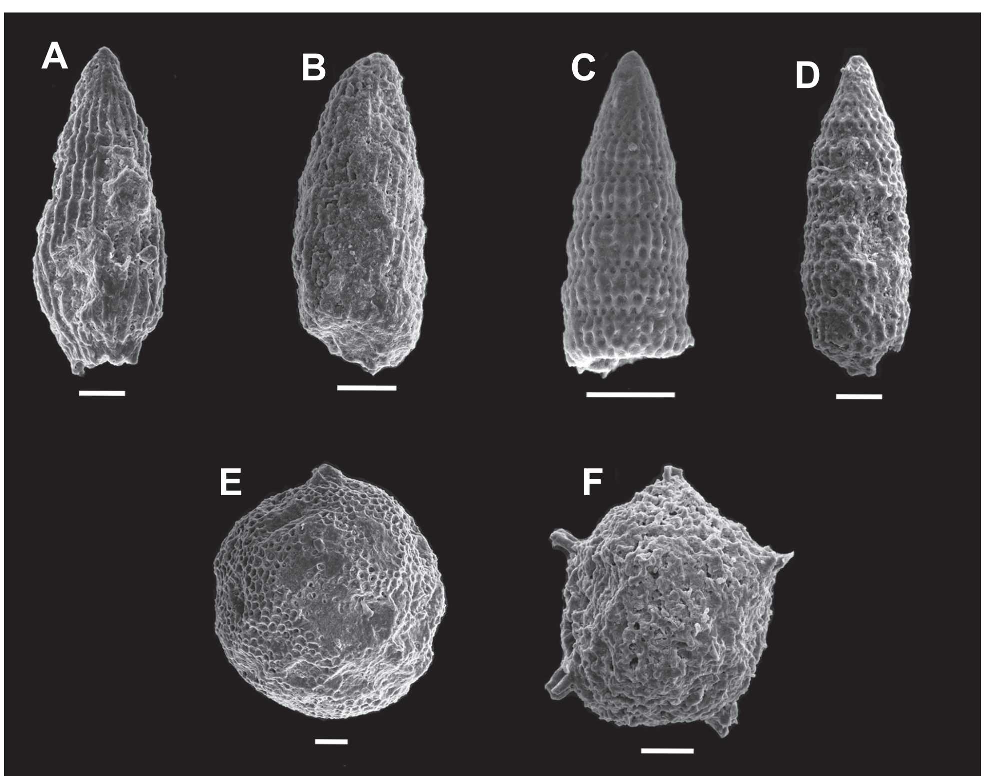

Figure 6. Radiolarians. **A**, *Archaeodictyomitra* sp. cf. *A. squinaboli*, LC-67 (ULVG-9812); **B**, *Archaeodictyomitra* sp., LC-55 (ULVG-9813); **C**, *Pseudodictyomitra* sp. cf. *P. pentacolaensis*, LC-69 (ULVG-9814); **D**, *Stichomitra stocki*, LC-84 (ULVG-9815); **E**, Spumellaria gen. et sp. indet. A, LC-56 (ULVG-9816); **F**, Spumellaria gen. et sp. indet. B, LC-68 (ULVG-9817). Scale bars = 50 µm.

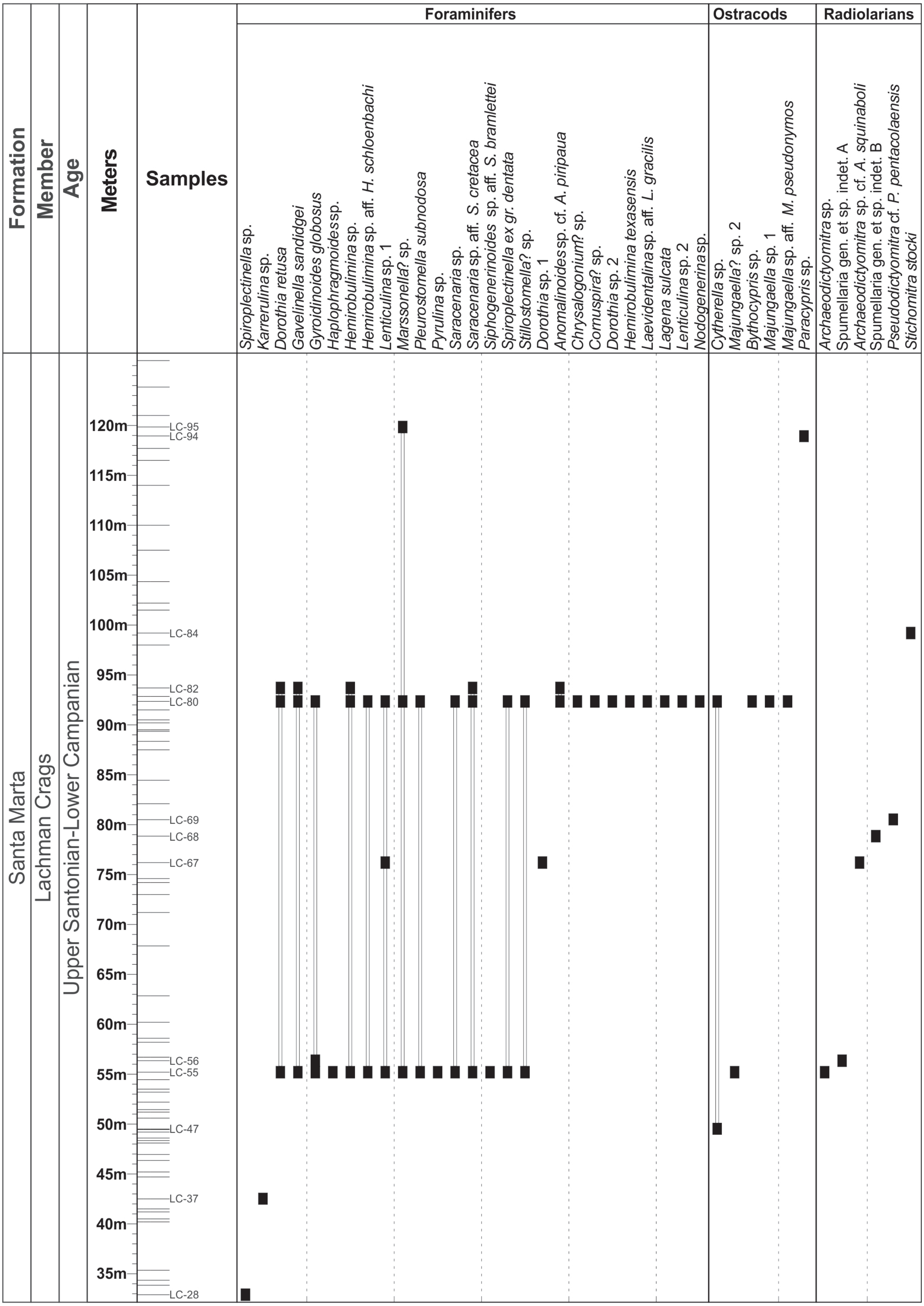

Figure 7. Distribution chart of benthic foraminifera, ostracods and radiolarians in the studied section (Santa Marta Formation, Lachman Crags Member). Samples with microfossils occurrences are named.

levels (Koutsoukos, 1989; Alegret & Thomas, 2001). This suggestion is in accordance to the outer shelf setting suggested by Crame *et al.* (1991) and Olivero (2012) for the Santa Marta Formation. When the generic and specific composition of the studied benthic foraminiferal fauna is evaluated, a low degree of endemism can be detected, with the dominance of cosmopolitan taxa such as *Gyroidinoides globosus* and *Gavelinella sandidgei* (*cf.* Sliter, 1977; Basov & Krasheninnikov, 1983; Huber, 1988, 1992; Alegret & Thomas, 2001; Ceten *et al.*, 2011).

The ostracod genera *Cytherella*, *Majungaella*, *Paracypris*, and *Bythocypris* identified herein have already been reported for the Cretaceous of the Gondwana in the works of Rossi de Garcia & Proserpio (1980), Fauth *et al*. (2003), Whatley *et al*. (2005), and Dingle (2009), being also considered cosmopolitan taxa (in the same way as the foraminiferal taxa reported above). Despite their scarcity, the occurrence of the genus *Majungaella*, which paleobiogeographic distribution is restricted to the southern hemisphere (Piovesan *et al*., 2012), also suggests deposition on a shelf with warm water temperature and normal salinity (Fauth *et al*., 2003; Seeling *et al.*, 2004; Dingle, 2009), being in accordance with the outer shelf depositional setting suggestion based on foraminifera (see discussion above) and previous works (Crame *et al.*, 1991; Olivero, 2012). This interpretation corroborates the high paleotemperature estimatives for the Late Cretaceous of the James Ross Island presented by Pirrie & Marshall (1990) and southern high latitude regions (Huber, 1988; MacLeod *et al*., 2001). Samples that yielded ostracodes are LC-47, LC-55, LC-80, and LC-94.

This study presents the first record of radiolarians for the James Ross Island. Taking into account the stratigraphic ranges of the radiolarian species described in the taxonomic section above, the studied radiolarian fauna can be considered Late Cretaceous in age, presenting some cosmopolitan taxa. Since Ling & Lazarus (1990) reported a diverse and well preserved Campanian-Maastrichtian radiolarian fauna from Deep Sea Drilling Project (DSDP) Leg 113 (Weddell Sea), the scarcity of radiolarian occurrences in the studied section might be a result of a preservation bias (only species with sturdy skeletons are preserved mainly in coarse-grained lithofacies) and/or due to environmental restrictions (related to the probable shelf setting). Samples that yielded radiolarians are LC-55, LC-56, LC-67, LC-68, LC-69, and LC-84.

CONCLUDING REMARKS

This study presents the first record of radiolarians for the James Ross Island, the occurrence of ostracod genera that had already been reported for the Antarctic Peninsula, and a relatively diverse foraminiferal fauna (when evaluated in its regional context). Calcareous microfossils occurrences are restricted to few stratigraphic levels described as tuffaceous sandstones cemented by calcium carbonate, while siliceous microfossils and agglutinated foraminifera also occur in different lithofacies. This suggests a preservational bias in the occurrences of microfossils within the studied section, possibly related to the presence/absence of calcium carbonate cement. Even in face of this preservational bias, it is possible to infer that all recovered fossil groups are cosmopolitan in character and that deep-neritic paleodepths (outer shelf settings) dominated the studied interval.

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