Journal of Sedimentary Environments
Published by Universidade do Estado do Rio de Janeiro
3 (4): 220-233. October-December, 2018
doi: 10.12957/jse.2018.39139

RESEARCH PAPER

NEW MOLLUSCAN RECORDS AND PALAEOECOLOGY OF THE LATE PLEISTOCENE MARINE ASSEMBLAGE FROM LA CORONILLA (ROCHA, URUGUAY)

ALEJANDRA ROJAS[1]*, JUAN CARLOS ZAFFARONI[2] AND SERGIO MARTÍNEZ[1]

1 Universidad de la República, Instituto de Ciencias Geológicas, Facultad de Ciencias, Departamento de Paleontología, Montevideo, Uruguay

2 Sociedad Malacológica del Uruguay

* CORRESPONDING AUTHOR, alejandra@fcien.edu.uy

Received on 5 September 2018
Received in revised form on 28 November 2018
Accepted on 2 December 2018

Editor: Leticia Burone, Universidad de la República, Uruguai

Citation:
Rojas, A., Zaffaroni, J.C., Martínez, S., 2018. New molluscan records and palaeoecology of the Late Pleistocene marine assemblage from La Coronilla (Rocha, Uruguay). Journal of Sedimentary Environments, 3 (4): 220-233.

Abstract

The Late Pleistocene marine molluscan assemblage from La Coronilla is one of the richest Quaternary marine deposit from Uruguay. This contribution represents an update of the bivalve and gastropod species composition of this deposit and includes a palaeoecological analysis of the molluscan fauna. The ecological preferences of the recorded species allowed the reconstruction of the palaeoenvironmental conditions of the eastern Uruguayan coast and the palaeobiogeographic scenario of the area during the Late Pleistocene. The fossil assemblage of La Coronilla contains 91 bivalve and gastropod taxa of which 28 are new to this deposit and 11 are first reported for the Uruguayan Quaternary marine assemblages. The latest are *Turbonilla abrupta*, *Turbonilla* cf. *farroupilha*, *Turbonilla brasiliensis*, *Turbonilla* cf. *deboeri*, *Turbonilla penistoni*, *Turbonilla turris*, *Olivella defiorei*, *Eurytellina angulosa*, *Kellia* sp., *Paraleptopecten bavayi,* and *Pandora* sp. Almost all recorded species from the assemblage are marine and live in soft bottoms, although hard/consolidated substrate species and microgastropods that live in ecological interaction with other invertebrate taxa were also found. The high percentage of tropical-subtropical species, the absence of cold-water species, and the record of extralimital warm water northern species, adds new evidence for the inference of warmer than present conditions in the Uruguayan coast during the Late Pleistocene.

Keywords: Bivalves. Gastropods. Palaeoecology. Palaeobiogeography. MIS 5e. Southwestern Atlantic.

1. Introduction

The Pleistocene Epoch was characterized by the occurrence of global climatic oscillations and concomitant sea level changes that had strong effects on continental and marine life on Earth (e.g. Crowley and North, 1991; Pirazzoli, 1996; Petit et al., 1999; Lisiecki and Raymo, 2005; Medina-Elizalde, 2013; Murray-Wallace and Woodroffe, 2014). The study of the recent past is crucial for the understanding of the processes and events that shaped our modern biota; besides, Pleistocene records represent an important tool to predict the current and future biotic, environmental and climatic changes (Warwick and Turk, 2002; Oldfield, 2004; Meadows, 2012).

Several sources of information have been used for the reconstruction of the Pleistocene climatic changes, such as continental and marine geological and palaeontological records, ice cores, and climatic models (e.g., Emiliani, 1955; Kukla et al., 2002; Hearty et al., 2007; Jouzel et al., 2007; Van Meerbeeck et al., 2009; Lang and Wolff, 2011). Historically, most of our knowledge on Pleistocene climates, sea level changes, and fossil assemblages came from Northern Hemisphere records (e.g. Anderson et al., 2013; Hearty et al., 2007; Lang and Wolff, 2011; Lowe and Walker, 2014; Bradley, 2015), meanwhile sources of information from the Southern Hemisphere are uneven. Despite Antarctic ice cores have been extensively analysed and much knowledge of southern climates derives from them (e.g., Petit et al.,

Journal of Sedimentary Environments
Published by Universidade do Estado do Rio de Janeiro
3 (4): 220-233. October-December, 2018
doi: 10.12957/jse.2018.39139

1999; EPICA, 2006; Jouzel et al., 2007; Sime et al., 2008, 2009), geological and palaeontological data from other southern areas, such as the Southwestern Atlantic Ocean, are relatively scarce. The analysis of Pleistocene marine assemblages from this biogeographically relevant region is essential for the reconstruction of the palaeoenvironmental conditions and evolution of this dynamic area of the Southern Hemisphere.

Pleistocene littoral fossiliferous deposits are frequent in coastal areas around the world. Their faunal composition, and palaeoecological and palaeobiogeographical analyses, may reveal changes in the geographical ranges of species as a response to shifting temperature regimes driven by oceanic currents (e.g. Valentine and Jablonski, 1993; Muhs et al., 2002; Garilli, 2011). South American marine assemblages are known from the Pacific littoral (e.g. Hsu et al., 1989; Ortlieb et al., 1990; Rivadeneira and Carmona, 2008), Beagle Channel (Rabassa et al., 2009; Gordillo et al., 2010; Gordillo and Isla, 2011), from the Atlantic coast; primarily from Argentina (e.g., Aguirre and Whatley, 1995; Isla et al., 2000; Aguirre, 2003; Aguirre and Fucks, 2004; Aguirre et al., 2011; Charó et al., 2013a, b, 2014, 2015; Martínez et al., 2016), from the southern coast of Brazil (Lopes and Simone, 2012; Lopes et al., 2013, 2014; Bettinelli et al., 2018), and from Venezuela in the Caribbean Sea (Macsotay and Cáceres Hernández, 2005). In Uruguay, fossiliferous marine sediments deposited during Quaternary sea level fluctuations are exposed along a thin strip parallel to the present coastline, and yield an abundant molluscan content. Although the fossils have been long recognised since the work of Larrañaga (1819, published in 1894), d'Orbigny (1842) and Darwin (1846), until the 1970 decade few studies focused on their potential for palaeoenvironmental reconstructions, except from the pioneer research of Ihering (1907) and Teisseire (1928). Sprechmann (1978) and Martínez (1988, 1990) explicitly considered the ecologic requirements of the molluscan assemblages as an important factor to reconstruct palaeoenvironmental conditions. More recently, the incorporation of radiocarbon dating of shells from selected localities enabled a satisfactory discrimination between Pleistocene and Holocene deposits (e.g. Martínez et al., 2001, 2006; Rojas, 2002, 2007; Martínez and Ubilla, 2004; Martínez and Rojas, 2013; Rojas and Martínez, 2016).

The Late Pleistocene molluscan assemblages from Uruguay were firstly identified by Martínez et al. (2001) through the record of (minimum) radiocarbon ages in shells from Puerto de Nueva Palmira (western Uruguay, Colonia county) and La Coronilla (eastern Uruguay, Rocha county). Later, Rojas (2007) reached to similar results for the Zagarzazú fossil assemblage located in Colonia county. The ^{14}C ages from the three mentioned deposits range between 29500 and 35500 years BP, and were interpreted by the authors as minimum ages. In consequence, the assemblages were considered to be older than the numerical ages obtained and probably deposited during the Last Interglacial (see discussion in Rojas and Martínez, 2016).

The fossil content of the La Coronilla assemblage was studied by Martínez et al. (2001), where the molluscan taxonomic composition, and palaeoenvironmental information of the assemblage was presented. The authors recorded 22 molluscan taxa (11 bivalves and 11 gastropods) being the oyster *Ostrea equestris* (= *Ostrea stentina* according to Shilts, 2007) the most abundant species. Due to the tropical-subtropical affinities of the molluscs, including few extralimital northern species (*sensu* Roy et al. 1995), Martínez et al. (2001) inferred warmer temperatures during the Pleistocene than those recorded today in the Uruguayan coast. Rojas and Urteaga (2011) identified four chiton species in the assemblage, including the warm water *Ischnochiton striolatus*, which current southernmost distributional limit in Santa Catarina (Brazil), agree with the thermal inferences made by Martínez et al. (2001). Regarding salinity, the vast majority of the molluscs recorded by Martínez et al. (2001) support the development of marine conditions. Lorenzo and Verde (2004) dealt with the ichnofossil record from shells and reported three ichnotaxa in the assemblage: *Oichnus paraboloides* and *Caulostrepsis taenicola* on *Ostrea stentina* and *Entobia* sp. on *Plicatula gibbosa*. Rojas et al. (2014) recorded the presence of *Oichnus simplex* on a plate of the chiton *Chaetopleura angulata*, the first report of this ecological interaction in the fossil record. Recently, Rojas and Martínez (2016) updated the molluscan content and discussed the age of Pleistocene assemblages from Uruguay. Regarding the La Coronilla deposit, the authors listed 26 gastropod and 40 bivalve species derived from the review of the specimens studied in Martínez et al. (2001) and from the unpublished thesis by Rojas (2007). In summary, considering the previous works dealing with the La Coronilla fossil assemblage, 70 molluscan species represented by polyplacophorans, gastropods and bivalves have been reported.

During the summer of 2004, the La Coronilla outcrop became exposed enabling a sampling that provided new molluscan taxa for this assemblage and for the Quaternary marine deposits from Uruguay. The aim of this paper is to update the species composition of the La Coronilla deposit and to discuss its contribution for the reconstruction of the palaeoenvironmental and palaeobiogeographic scenarios of the Uruguayan coast during the Late Pleistocene.

2. Study area and geological setting

The Quaternary marine deposits from Uruguay are included in the Chuy and Villa Soriano formations (Goñi and Hoffstetter, 1964; Goso, 1972). These lithostratigraphic units include a similar lithologic composition, that varies from clays to coarse sands, and even conglomerates (Preciozzi et al., 1988; Goso, 2006; Ubilla and Martínez, 2016). For this reason, other criteria such as stratigraphic relationships or fossiliferous content have been invoked to distinguish between both units (see discussion in Martínez and Ubilla, 2004; Rojas and Martínez, 2016; Ubilla and

Martínez, 2016). In a recent review of the geology and palaeontology of the Uruguayan Quaternary strata, Ubilla and Martínez (2016) referred the La Coronilla deposit to the Chuy Formation.

The studied deposit crops out in the abrasion platform of the La Coronilla beach in Rocha county, Atlantic coast of Uruguay (Fig. 1). The degree of exposition of this fossiliferous horizon relies on littoral dynamic processes, and it may be covered by sand or temporarily remain under the water. The lithology corresponds to a greenish-greyish muddy sandstone. Fossils are mostly well preserved and some of them can be found in life position. Articulated bivalve shells and unbroken specimens are common. Shell debris are also present, and abrasion is almost absent (Rojas et al. 2018).

A predominantly autochthonous–parautochthonous assemblage, and a proximal depositional environment protected from waves have been inferred (see Martínez et al., 2001; Rojas, 2007; Rojas and Martínez, 2016; Rojas et al. 2018).

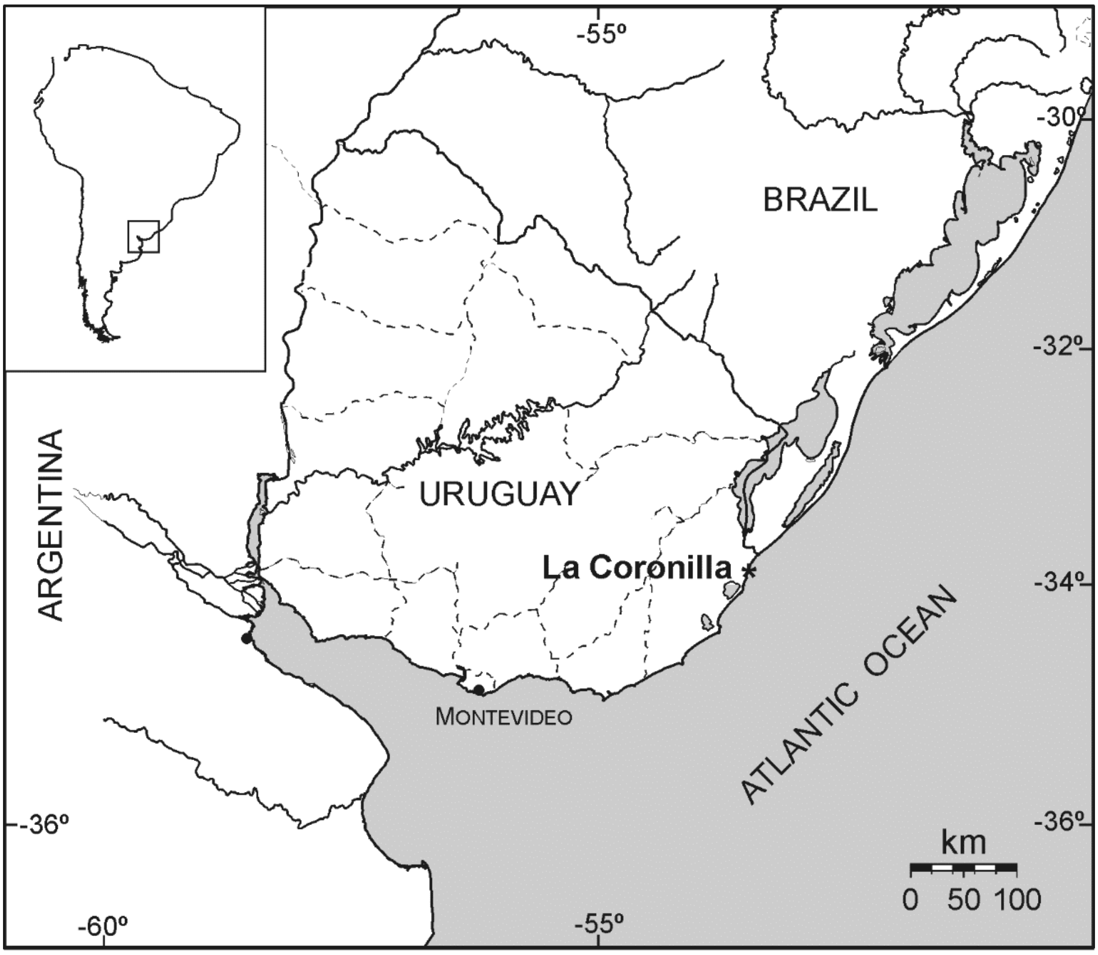

Fig. 1. Geographic location of the La Coronilla Late Pleistocene molluscan assemblage.

3. Material and methods

The samples studied herein were collected by F. Scarabino and members of Karumbé (Centro de Tortugas Marinas) Team in January 2004 by a non-random sampling procedure. Specimens were preferentially collected by hand, and not in bulk samples, which precludes any statistical comparison with previous results, such as those presented by Martínez et al. (2001), and a quantitative analysis of the samples. Despite of this, a qualitative assessment of the taxonomic composition and ecological preferences is feasible. In the laboratory, samples were first dried and then sieved in water to facilitate the picking of specimens. The collected sediments were also inspected after sieving for the record of micromolluscs. All specimens are housed at the Colección Paleontológica at Facultad de Ciencias, Universidad de la República, Montevideo, Uruguay (FCDPI).

Taxa were grouped according to salinity, temperature and substrate preferences. Following Martínez et al. (2006), two categories were considered for the salinity requirements: estuarine (taxa restricted to brackish waters), and marine, without considering the tolerance to salinity changes.

In order to perform temperature inferences, the recent geographic distribution of the involved taxa was taken into account. As the geographic range of marine species mostly reflects its thermal tolerance through latitudinal gradients

Journal of Sedimentary Environments
Published by Universidade do Estado do Rio de Janeiro
3 (4): 220-233. October-December, 2018
doi: 10.12957/jse.2018.39139

(e.g. Spalding et al., 2007; Belanger et al., 2012), studied taxa were grouped according to their biogeographic origin. The categories used were: tropical-subtropical for species shared with northern warmer areas with a distribution influenced by the warm Brazilian Current; cold, for taxa shared with the southern colder areas with a distribution controlled by the cold Malvinas Current; and endemic, for those species restricted to the Argentinean Province. The current percentage of each category in the Uruguayan coast was taken after Sicardi (1967), and considered in previous publications (Martínez et al., 2001, 2006).

Taxa were classified according to their substrate preferences as soft, hard, and consolidated ground dwellers, and an additional category was used for those species that develop an ecological interaction with other invertebrates (e.g. parasites).

Data on ecological preferences and geographic distribution was obtained from Figueiras and Sicardi (1972), Ríos (1994, 2009), Pimenta and Absalão (2002), Scarabino and Zaffaroni (2004), Demicheli and Scarabino (2006), Scarabino et al. (2006 a and b), Mikkelsen and Bieler (2007), Figueira and Pimenta (2008), Pimenta et al. (2009), Rosenberg (2009), Rosenberg et al. (2009), Turgeon et al. (2009), Huber (2010), Signorelli and Scarabino (2010), Pastorino and Bagur (2011), Forcelli and Narosky (2015) and Scarabino et al. (2015).

4. Results and discussion

4.1. Taxonomic composition and new records

The molluscs herein recorded in the La Coronilla assemblage comprises 91 taxa of gastropods (38 species) and bivalves (53 species) (Table 1 and Table 2).

The richness of this assemblage is higher than previously assessed, since Martínez et al. (2001) had reported only 22 taxa, and Rojas and Martínez (2016) summarised 66 species of bivalves and gastropods based on previous unpublished data of Rojas (2007). The present contribution adds 28 new records to the La Coronilla deposit, becoming this, one of the most diverse Quaternary assemblages from Uruguay, and by far, the richest of the Pleistocene ones. The 13 new recorded gastropods were *Buccinanops cochlidium*, *Bulla occidentalis*, *Calliostoma jucundum*, *Cerithiopsis* cf. *fusiformis*, *Epitonium* (*Asperiscala*) sp., *Olivella defiorei* (= *Olivella* sp. in Rojas and Martínez, 2016), *Turbonilla abrupta*, *T.* cf. *farroupilha*, *T. brasiliensis*, *T.* cf. *deboeri*, *T. penistoni*, *T. turris* (some of them included as *Turbonilla* spp. by Rojas and Martínez, 2016) and indeterminated (indet.) Turridae. The specimens recorded herein as *Turbonilla* cf. *deboeri* are comparable to the specimen depicted in Fig.d by Pimenta and Absalão (2002). The 15 new bivalve records were *Amiantis purpurata*, *Anadara chemnitzii*, *Barnea lamellosa*, *Brachidontes rodriguezii* (as *Brachidontes* sp. in Rojas and Martínez, 2016), *Corbula lyoni*, *C. patagonica*, *Eurytellina angulosa*, *Kellia* sp., *Mactra guidoi*, *Ostrea puelchana*, *Pandora* sp., *Paraleptopecten bavayi*, *Petricola* cf. *lapicida*, *Raeta plicatella* and *Transennella* sp. (as *Clausinella gayi* in Martínez et al., 2001; as indet. Veneridae in Rojas and Martínez, 2016).

Taking into account recent compilations (Clavijo et al., 2005; Martínez et al., 2006; Rojas and Martínez, 2016), 11 taxa are recorded by the first time in the Quaternary of Uruguay. These are *Turbonilla abrupta*, *T.* cf. *farroupilha*, *T. brasiliensis*, *T.* cf. *deboeri*, *T. penistoni*, *T. turris*, *O. defiorei*, *Eurytellina angulosa*, *Kellia* sp., *Paraleptopecten bavayi,* and the genus *Pandora* (Fig. 2). It is noticeable that most of the new gastropod records are micromolluscs, highlighting the need of future collections and sample processing methods to increase the probability of finding small-sized species.

The studied samples allow to extend the chronologic range of nine taxa back to the Pleistocene since they were only previously known in Uruguay from Holocene or probable Holocene deposits. They are *Ostrea puelchana,* mentioned by Ihering (1907), and *Amiantis purpurata*, reported by Ihering (1923) for Punta Carretas and the latter also for Buceo (Montevideo); *Brachidontes rodriguezii*, known from Colonia del Sacramento (Teisseire, 1928); *Barnea lamellosa*, reported by Figueiras (1962) in Areneras de Carrasco; *Calliostoma jucundum*, *Corbula patagonica* and *Raeta plicatella* known from Arenales de Carrasco (de Mata, 1947); *Petricola lapicida*, known from Isla de Tala (Martínez, 1988) (although the specimens herein reported were determined as *Petricola* cf. *lapicida*); and *Mactra guidoi*, reported by Figueiras (1961) in the Areneras de Carrasco (as *Mactra patagonica*), and as *Mactra* sp. in a subsequent contribution (Figueiras, 1962), as commented by Signorelli and Scarabino (2010). All of them are currently living in the Uruguayan coast (Scarabino, 2003, 2004).

4.2. Palaeoecology

All recorded taxa are marine in a broad sense except for *Tagelus plebeius*, an estuarine species living today in the area of the Río de la Plata estuary, in coastal lagoons and in the mouth of the rivers of the Atlantic Uruguayan coast (Scarabino et al., 2006 b; 2015). Other species, such as the gastropods *Heleobia australis*, *Cylichnella bidentata* and *Buccinanops cochlidium*, and the bivalves *Barnea lamellosa*, *Brachidontes rodriguezii*, *Macoma uruguayensis*, *Mactra isabelleana*, *Ostrea puelchana* and *Pitar rostratus* are eurihaline. These species currently occupy a variety of sub environments in the Rio de la Plata, and other low salinity habitats of the Uruguayan coast (Scarabino et al., 2006a, b, 2015).

The remaining and majority of species are mostly regarded as marine and therefore, the molluscan assemblage is considered to represent a coastal marine environment.

In reference to the substrate, the molluscs from La Coronilla show a wide range of preferences (Fig. 3), being most of them soft-substrate inhabitants. Some prefer sandy substrates (e.g. *Amiantis purpurata*, *Corbula lyoni*, *Crassinella lunulata*, *Cyclinella tenuis*, *Gouldia cerina*, and the *Anadara* and *Olivella* species recorded), and a few inhabit muddy bottoms (*Corbula patagonica*, *Macoma uruguayensis*).

Journal of Sedimentary Environments
Published by Universidade do Estado do Rio de Janeiro
3 (4): 220-233. October-December, 2018
doi: 10.12957/jse.2018.39139

However, the majority can live in sandy-muddy substrates (e.g. *Anomalocardia flexuosa*, *Corbula caribaea*, *Mactra isabelleana*, *Semele* aff. *proficua*, *Tellina gibber*, *Acteocina candei*, *Bulla occidentalis*, *Cylichnella bidentata*, *Zidona dufresnei*). These preferences are consistent with the lithology of the deposit and it can be assumed that the muddy fine sand was the original substrate where the community settled. Moreover, the shells good preservation indicates that the species lived in or near of their burial emplacement (see Rojas et al., 2018).

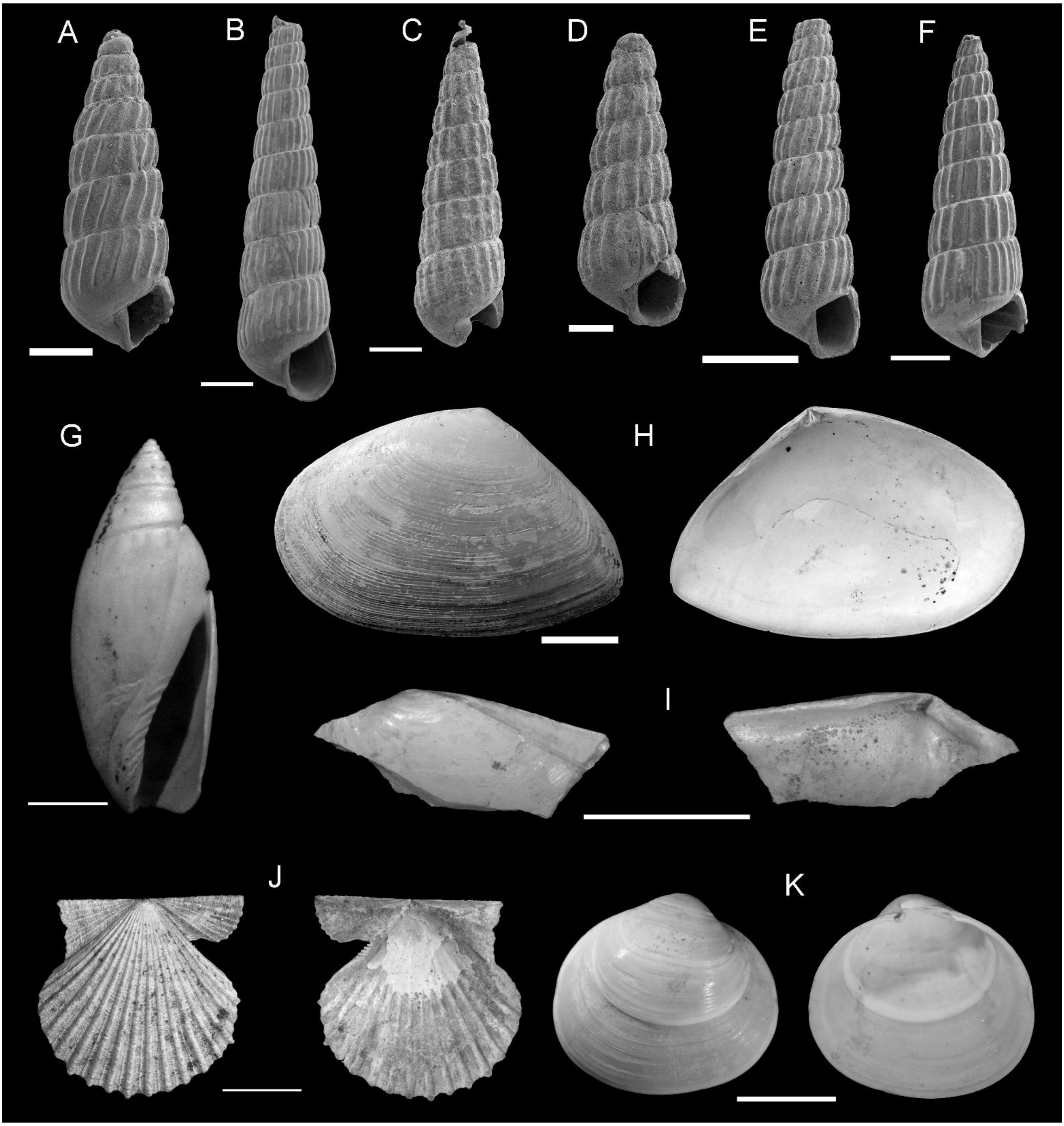

Fig. 2. Mollusks recorded for the first time in the Quaternary marine assemblages from Uruguay. (A) *Turbonilla abrupta*, scale bar = 500 µm. (B) *Turbonilla* cf. *farroupilha*, scale bar = 1 mm. (C) *Turbonilla brasiliensis*, scale bar = 1mm. (D) *Turbonilla* cf. *deboeri*, scale bar = 500 µm. (E) *Turbonilla penistoni*, scale bar = 1 mm. (F) *Turbonilla turris*, scale bar = 1 mm. (G) *Olivella defiorei*, scale bar = 2 mm. (H) *Eurytellina angulosa*, scale bar = 10 mm. (I) *Pandora* sp., scale bar = 5 mm. (J) *Paraleptopecten bavayi*, scale bar = 5 mm. (K) *Kellia* sp., scale bar = 5mm.

The La Coronilla assemblage also includes more than 20% of species that prefer hard substrates, where they live freely or attached by different strategies (e.g. *Brachidontes rodriguezii*, *Ostrea stentina* and *O. puelchana*, *Plicatula gibbosa*, *Bostrycapulus odites*, *Diodora patagonica*, *Urosalpinx haneti*). These hard substrates were probably provided by the accumulation of shells on the sea bottom (Rojas et al., 2018). Almost all of the recorded microgastropods are known to live in association with other invertebrates (e.g. sponges, cnidarians) through parasitism or epibiosis. Within this group, pyramidellids are the more diverse, and are mostly represented by the genus *Turbonilla*. The presence of their hosts must be inferred to have lived in the La Coronilla community, probably facilitated by the development of the shelly hard substrate. Few species bore into hard or consolidated substrates, such as *Barnea lamellosa*, *Lamychaena* sp. and *Petricola* cf. *lapicida*. Scarabino et al. (2015) found that the bivalve communities that currently live in the coastal and platform areas of the Uruguayan coast are more diverse when mud is present in a sandy bottom. Thus, those all evidences lead us to conclude that an appropriate substrate availability was probably one of the factors that played an important role in the high species richness of the La Coronilla assemblage.

4.3. Palaeobiogeography

Compared to the biogeographic composition of the molluscs that currently inhabit the Uruguayan coast, the La Coronilla deposit includes a higher percentage of molluscs with tropical-subtropical affinities, and a slightly lower proportion of endemic species (Fig. 4). Similar proportions of endemic and warm water taxa were obtained by Martínez et al. (2001) despite the lower number of recorded species. Regarding the cold-water species, almost 20% of magellanic taxa reach nowadays the Uruguayan coast (Sicardi, 1967) meanwhile none of them were present in the La Coronilla assemblage.

As stated by Rojas and Martínez (2016), the only putative cold-water species reported by Martínez et al. (2001) for this deposit was *Clausinella gayi* (= *Tawera elliptica*), specimens which in fact correspond to *Transennella* sp., and not to a cold-water species. Thus, the results indicate that the Pleistocene molluscan fauna of La Coronilla lived during warmer conditions than today, as previously suggested (Martínez et al., 2001; Rojas, 2007; Rojas and Martínez, 2016). In addition to the global analysis of thermal preferences, it must be stressed that some of the warm water recorded molluscs, live currently northwards from the Uruguayan coast, with a southern geographic range boundary in Brazilian waters. Some of these warm extralimital species, such as *Fargoa bushiana* (as *Chrysallida gemmulosa*), *Laevicardium* sp. and *Limaria* sp. were recorded by Martínez et al. (2001). Later, Rojas and Urteaga (2011) added the chiton *Ischnochiton striolatus* to these warm water species. More recently, Rojas and Martínez (2016) summarised the record of 14 northern extralimital species for the La Coronilla assemblage by the incorporation of the gastropod *Bittiolum varium* and the bivalves *Anatina anatina*, *A. flexuosa*, *C. tenuis*, *Ervilia concentrica*, *G. cerina*, *Chione subrostrata*, *Pitar palmeri*, *Anadara brasiliana* and *Merisca martinicensis*.

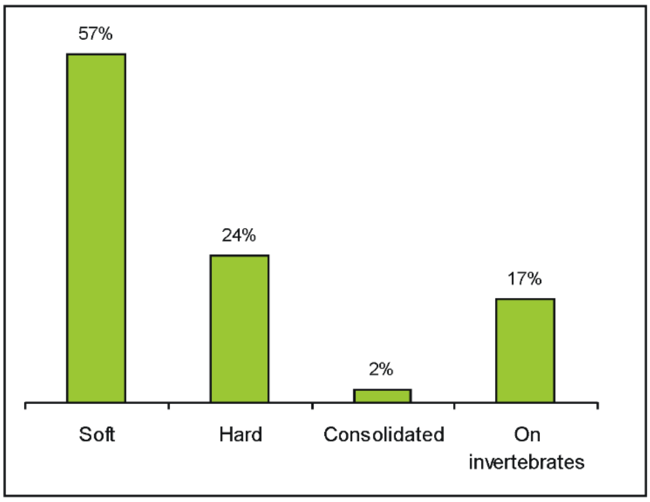

Fig. 3. Substrate preferences (in percentages) of the molluscan species recorded in the La Coronilla assemblage.

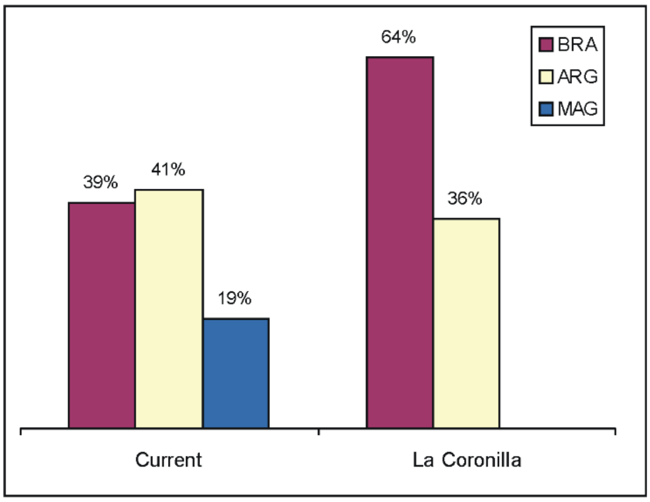

Fig. 4. Temperature ranges (in percentages) of the molluscan species currently living on the Uruguayan coast (according to Sicardi, 1967) compared to those of the La Coronilla assemblage. BRA: warm-water taxa; ARG: endemic taxa; MAG: cold-water taxa.

The present study adds the record of other nine new warm water extralimital species for the La Coronilla assemblage: *Bulla occidentalis*, which was previously reported in the Pleistocene assemblage of Puerto de Nueva Palmira (Rojas and Martínez, 2016) and in the Arroyo Chuy Holocene deposit (Martínez et al., 2006); *Cerithiopsis* cf. *fusiformis* that was reported as *Cerithiopsis* aff. *C. emersoni* (Piñeiro et al., 1992) and as *Cerithiopsis greeni* (Martínez et al., 2006) for Saglia, and *Anadara chemnitzii* that was mentioned by Figueiras and Sicardi (1968) for the Uruguayan Holocene but that record was not precise or confirmed later (see Clavijo et al., 2005).

Tab. 1. Gastropod species recorded in the La Coronilla assemblage, Collection number (FCDPI), ecological preferences, and current presence in the Uruguayan coast. Bra: influenced by the warm Brazilian Current; Arg: endemic to the Argentinian Province.

Gastropods	FCDPI	Substrate	Temperature	Uruguayan coast
Acteocina candei (d'Orbigny, 1841)	4236; 4730	sand-mud	Bra	yes
Bittiolum varium (Pfeiffer, 1840)	4856; 4761	soft	Bra	no
Boonea jadisi (Olsson & McGinty, 1958)	4275; 4740	on invert.	Bra	yes
Boonea seminuda (C. B. Adams, 1839)	6115; 6120	on invert.	Bra	yes
Bostrycapulus odites R. Collin, 2005	4197; 4703	hard	Bra	yes
Buccinanops cochlidium (Dillwyn, 1817)	4762	sand-mud	Arg	yes
Buccinanops globulosus (Kiener, 1834)	4696	sand	Arg	yes
Bulla occidentalis A. Adams, 1850	4693	sand-mud	Bra	no
Calliostoma jucundum (Gould, 1849)	4736	hard	Arg	yes
Cerithiopsis cf. *fusiformis* (C. B. Adams, 1850)	4745	on invert.	Bra	no
Costoanachis sertulariarum (d'Orbigny, 1839)	4276; 4698	hard	Arg	yes
Crepidula plana Say, 1822	4218; 4759	hard	Bra	yes
Crepidula protea (d'Orbigny, 1841)	4219	hard	Arg	yes
Cylichnella bidentata (d'Orbigny, 1841)	4234; 4729	sand-mud	Bra	yes
Diodora patagonica (d'Orbigny, 1839)	4212; 4721	hard	Bra	yes
Epitonium (*Asperiscala*) sp.	4749	on invert.		
Eulimidae indet.	4283	on invert.		
Fargoa bushiana (Bartsch, 1909)	4274; 4733	on invert.	Bra	no
Finella dubia (d'Orbigny, 1840)	4272; 4741	sand-mud	Bra	not confirmed
Heleobia cf. *australis* (d'Orbigny, 1835)	4237; 4728	sand-mud	Arg	yes
Iselica globosa (H. C. Lea, 1843)	4238; 4731	on invert.	Bra	yes
Lucapinella henseli (Martens, 1900)	4214; 4751	hard	Arg	yes
Olivella defiorei Klappenbach, 1964	6125; 4792	sand	Bra	no
Olivella tehuelcha (Duclos, 1835)	4277; 4722	sand -shells	Arg	yes
Parvanachis sp.	4235; 4724	sand-mud		
Tegula patagonica (d'Orbigny, 1835)	4211; 4690	hard	Arg	yes
Turbonilla abrupta Bush, 1899	6123; 6117	on invert.	Bra	yes
Turbonilla brasiliensis Clessin, 1902	6114	on invert.	Bra	no
Turbonilla cf. *deboeri* Jong & Coomans, 1988	6121	on invert.	Bra	no
Turbonilla cf. *farroupilha* Pimenta & Absalão, 2004	6119	on invert.	Bra	yes
Turbonilla multicostata (C. B. Adams, 1850)	4273; 4742	on invert.	Bra	yes
Turbonilla penistoni Bush, 1899	6124	on invert.	Bra	no
Turbonilla turris (d'Orbigny, 1840)	4271	on invert.	Bra	no
Turbonilla uruguayensis Pilsbry, 1897	4732	on invert.	Arg	yes
Turridae indet.	4758			
Urosalpinx haneti (Petit, 1856)	4209; 4726	hard	Arg	yes
Vitrinellidae indet.	4284; 4747	soft		
Zidona dufresnei (Donovan, 1823)	4240; 4700	sand-mud	Arg	yes

Tab. 2. Bivalve species recorded in the La Coronilla assemblage, Collection number (FCDPI), ecological preferences, and current presence in the Uruguayan coast. Bra: influenced by the warm Brazilian Current; Arg: endemic to the Argentinian Province.

Bivalves	FCDPI	Substrate	Temperature	Uruguayan coast
Abra cf. *uruguayensis* (Pilsbry, 1847)	4226; 4718	sand-mud	Arg	yes
Aequipecten tehuelchus (d'Orbigny, 1842)	4199; 4701	sand-mud	Arg	yes
Amiantis purpurata (Lamarck, 1818)	4711	sand	Arg	yes
Anadara brasiliana (Lamarck, 1819)	4702	sand	Bra	no
Anadara chemnitzii (Philippi, 1851)	4210; 6126	sand	Bra	no
Anatina anatina (Spengler, 1802)	4192	sand	Bra	no
Anomalocardia brasiliana (Gmelin, 1791)	4205; 4705	sand-mud	Bra	no
Atrina seminuda (Lamarck, 1819)	4239; 4694	sand-mud	Bra	yes
Barnea lamellosa (d'Orbigny, 1841)	4709	consolidated	Arg	yes
Brachidontes rodriguezii (d'Orbigny, 1842)	4233; 4725	hard	Arg	yes
Bushia rushii (Pilsbry, 1897)	4225; 4727	sand-mud	Bra	yes
Cardiomya sp.	4230	sand-mud		
Chione subrostrata (Lamarck, 1818)	4206; 4692	sand-mud	Bra	no
Corbula caribaea (d'Orbigny, 1853)	4200; 4697	sand-mud	Bra	yes
Corbula lyoni Pilsbry, 1897	4712	coarse sand, shells	Arg	yes
Corbula patagonica d'Orbigny, 1846	4752	sand-mud	Arg	yes
Crassinella lunulata (Conrad, 1834)	4228; 4723	sand	Bra	yes
Cyclinella tenuis (Récluz, 1852)	4221; 4707	sand	Bra	no
Ennucula puelcha (d'Orbigny, 1842)	4207; 4720	sand-mud, shells	Arg	yes
Ennucula uruguayensis (E. A. Smith, 1880)	4224; 4755	mud	Arg	yes
Ervilia concentrica (Holmes, 1858)	4217; 4715	sand	Bra	no
Eurytellina angulosa (Gmelin, 1791)	4753	sand	Bra	no
Gouldia cerina (C. B. Adams, 1845)	4220; 4713	sand	Bra	no
Kellia sp.	4750	sand		
Laevicardium sp.	4204; 4691	sand	Bra	no
Lamychaena sp.	4231; 4737	hard		
Limaria sp.	4738		Bra	not confirmed
Lunarca ovalis (Bruguière, 1789)	4739	hard	Bra	yes
Macoma uruguayensis (E. A. Smith, 1885)	4232; 4756	mud	Arg	yes
Mactra guidoi Signorelli & Scarabino, 2010	4743	sand-mud	Arg	yes
Mactra isabelleana d'Orbigny, 1846	4201; 4699	sand-mud	Arg	yes
Merisca martinicensis (d'Orbigny, 1853)	4223; 4717	sand	Bra	no
Musculus sp.	4285	hard		
Mytilidae indet.	4282	hard		
Noetia bisulcata (Lamarck, 1819)	4208; 4710	hard	Bra	yes
Nucula semiornata d'Orbigny, 1842	4215; 4754	sand	Arg	yes
Nuculana decora (A. Adams, 1856)	4216; 4714	sand-mud	Arg	yes
Ostrea puelchana d'Orbigny, 1842	4744	hard	Arg	yes
Ostrea stentina Payraudeau, 1826	4194; 4689	hard	Bra	yes
Pandora sp.	4748	sand-mud		

Journal of Sedimentary Environments
Published by Universidade do Estado do Rio de Janeiro
3 (4): 220-233. October-December, 2018
doi: 10.12957/jse.2018.39139

Tab. 2. (cont.). Bivalve species recorded in the La Coronilla assemblage, Collection number (FCDPI), ecological preferences, and current presence in the Uruguayan coast. Bra: influenced by the warm Brazilian Current; Arg: endemic to the Argentinian Province.

Bivalves	FCDPI	Substrate	Temperature	Uruguayan coast
Paraleptopecten bavayi (Dautzenberg, 1900)	4763	hard	Bra	yes
Petricola cf. *lapicida* (Gmelin, 1791)	4213; 4734	consolidated	Bra	yes
Phlyctiderma semiaspera (Philippi, 1836)	4222	sand-mud, hard	Bra	yes
Pitar cf. *palmeri* Fischer-Piette & Testud, 1967	4193	sand	Bra	no
Pitar rostratus (Philippi, 1844)	4195; 4695	sand-mud	Arg	yes
Plicatula gibbosa Lamarck, 1801	4704	hard	Bra	yes
Raeta plicatella (Lamarck, 1818)	4202; 4735	sand-mud	Bra	yes
Semele aff. *proficua* (Pulteney, 1799)	4227; 4708	sand-mud	Bra	yes
Sphenia fragilis (H. & A. Adams, 1854)	4203; 4746	hard, shells	Bra	yes
Tagelus plebeius (Lightfoot, 1786)	4198; 4716	sand-mud	Arg	yes
Tellina gibber Ihering, 1907	4196; 4706	sand-mud	Bra	yes
Trachycardium muricatum (Linnaeus, 1758)	4229; 4688	sand-mud	Bra	yes
Transennella sp.	4757	soft		

The remaining extralimital northern species, such as *O. defiorei*, *T. brasiliensis*, *Turbonilla* cf. *deboeri*, *Turbonilla penistoni*, *T. turris* and *E. angulosa* are reported by the first time for the Uruguayan Quaternary marine deposits as was previously stated. Moreover, the living status of certain species in the Uruguayan coast must be confirmed, such as *Finella dubia*, which was reported by Figueiras and Sicardi (1980) in Rocha and Maldonado County and by Layerle and Scarabino (1984).

Empty and abraded shells of this species have been mentioned by Scarabino et al. (2006a) and for this reason the authors cast doubt on the living status of *F. dubia*. Also, Forcelli and Narosky (2015) excluded the Uruguayan coast from the southern boundary of distribution of this species. Regarding another taxon, specimens of the genus *Limaria* were recently collected alive in the Uruguayan coast and housed in the personal collection of one of the authors of the present study (JCZ). The status of the recorded specimens assigned to *Limaria* sp. in Martínez et al. (2001), should be further analysed in order to establish if the fossil and the living record of *Limaria* correspond to the same species. Therefore, the extralimital status of this taxon remains uncertain.

The 22 warm extralimital species found represent 24% of the bivalve and gastropod species recorded from La Coronilla. This is a great increase in the percentage of molluscan species that show this biogeographical pattern from the initial report of a few warm water species by Martínez et al. (2001). Therefore, a strong environmental signal for the reconstruction of the thermal conditions during the Pleistocene in the area is suggested. The southernmost limit of the majority of extralimital species is located in the coasts of Santa Catarina and Rio Grande do Sul. Thus, it can be inferred that the temperature regime in the Uruguayan coast during the Late Pleistocene was warmer than today and similar to the current thermal conditions found in the southern region of the Brazilian coast (at least 600 km northwards). However, some of them, such as *T. deboeri* and *T. penistoni* currently live at even lower latitudes, northwards from Rio de Janeiro.

As proposed by Martínez et al. (2001) and further discussed by Rojas and Martínez (2016), the more likely temporal framework for the development of the warm water molluscan fauna preserved in La Coronilla is the Last Interglacial, or Marine Isotope Stage 5e (MIS 5e). This interval, around 126,000 years BP, is globally regarded as having had higher temperatures than today from different sources of information (e.g. Masson-Delmotte et al., 2006; Otto-Bliesner et al., 2006; Jouzel et al., 2007; Turney and Jones, 2010; Miller et al., 2013). In addition, worldwide MIS 5e molluscan assemblages record warm water extralimital species, such as in La Coronilla (e.g. Meco et al., 2002; Garilli, 2011; Zazo et al., 2013; Muhs et al., 2014; Ávila et al., 2015). Many studies invoke changes in ocean currents to account for the biogeographic range modifications of the stenothermal species. The presence of 22 extralimital molluscs in the Uruguayan coast (Southwestern Atlantic Ocean) during the Last Interglacial can be explained by a southwards influence of the warm Brazilian Current.

The Confluence Zone between this oceanic current and the cold Malvinas (Falkland) Current might have been located at a higher latitude than today during MIS 5e. This mechanism has been previously invoked by Martínez et al. (2001), Rojas (2007) and Rojas and Martínez (2016), and the present study provides further supporting evidence of this assumption. Moreover, Martínez et al. (2016) considered the

Journal of Sedimentary Environments
Published by Universidade do Estado do Rio de Janeiro
3 (4): 220-233. October-December, 2018
doi: 10.12957/jse.2018.39139

presence of a MIS 5e stronger than the Recent Brazilian Current as the cause of the biogeographical range changes verified for seven molluscan species from the Ezeiza assemblage in Argentina, all of them shared with the La Coronilla assemblage. A southwards displacement of the Brazilian Current has also been considered for other intervals during the Quaternary. Lopes and Simone (2012) and Lopes et al. (2013) proposed this mechanism for the presence of northern extralimital molluscan species in Middle Pleistocene deposits of the southern coastal plain of Rio Grande do Sul, Brazil. Additionally, Holocene molluscan assemblages from Argentina (especially from the Buenos Aires Province) and Uruguay also record out of range warm water species, which presence was explained by shifting ocean current regimes (e.g., Sprechmann, 1978; Aguirre, 1991; Aguirre and Farinati, 2000; Aguirre et al., 2005; Martínez et al., 2006; Rojas, 2007).

5. Conclusion

The La Coronilla fossiliferous deposit contains a highly diverse molluscan fauna, being this, one of the richest Quaternary marine assemblages of Uruguay. It is composed by 91 bivalve and gastropod taxa, of which 28 are herein reported by the first time and 11 consist of new records for the Uruguayan Quaternary marine deposits. It is noticeable that the majority of those new records correspond to micromolluscs. Most of the taxa are marine species inhabiting soft substrates. The development of shell bottoms must have been important for the settlement of the hard substrate dwellers, and of other invertebrate taxa that allowed the presence of most recorded microgastropods. The high proportion of tropical- subtropical species, the lack of cold-water taxa, and the new records of extralimital northern species, add further evidence for Late Pleistocene warmer conditions than those developed today in the Uruguayan coast, reinforcing a probable MIS 5e age for the studied assemblage.

The molluscan assemblage from La Coronilla represents an important source of information to disentangle the palaeobiogeography of the molluscan faunas and palaeoenvironmental evolution of the Uruguayan coast and the Southwestern Atlantic Ocean during the Late Pleistocene. The new records of molluscan species and the palaeoecological analysis of the fauna highlight the need of focusing in future standardised sampling efforts to enable a quantitative diversity analysis, in order to allow the comparison with similar molluscan rich assemblages from Uruguay and the SW Atlantic region.

Acknowledgment

We thank to F. Scarabino and the Karumbé team (Centro de Tortugas Marinas, Uruguay) for collecting the samples. F. Scarabino and A. Dias Pimenta provided useful bibliography and contributed to the identification of some molluscs reported herein. We acknowledge L. Burone for the invitation to contribute to this volume of JSE and to the editor in chief M. V. Alves Martins. We thank C. del Río and an anonymous reviewer for significantly improving the original manuscript. This research was supported by the Programa de Desarrollo de las Ciencias Básicas (PEDECIBA-Biología and PEDECIBA-Geociencias), Comisión Sectorial de Investigación Científica (CSIC) and Agencia Nacional de Investigación e Innovación (ANII).

References

Aguirre, M.L., Donato, M., Richiano, S., Farinati, E.A., 2011. Pleistocene and Holocene interglacial molluscan assemblages from Patagonia and Bonaerensian littoral (Argentina, SW Atlantic): Palaeobiodiversity and palaeobiogeography. Palaeogeogeography Palaeoclimatology Palaeoecology 308, 277-292. https://doi.org/10.1016/j.palaeo.2011.05.032

Aguirre, M.L., Negro Sirch, Y., Richiano, S., 2005. Late Quaternary molluscan assemblages from the coastal area of Bahía Bustamante (Patagonia, Argentina): Paleoecology and paleoenvironments. Journal of South American Earth Sciences 20, 13-32. https://doi.org/10.1016/j.jsames.2005.05.006

Aguirre, M.L., Fucks, E., 2004. Moluscos y paleoambientes del Cuaternario marino en el sur de Entre Ríos y litoral bonaerense. *In*: Aceñolaza, F.G. (ed.), Temas de la Biodiversidad del litoral fluvial argentino, vol. 12, INSUGEO, Miscelánea, Entre Ríos, pp. 55-70.

Aguirre, M.L., 2003. Late Pleistocene and Holocene palaeoenvironments in Golfo San Jorge, Patagonia: molluscan evidence. Marine Geology 194, 3-30. https://doi.org/10.1016/S0025-3227(02)00696-5

Aguirre, M.L., Farinati, E.A., 2000. Moluscos del Cuaternario marino de la Argentina. Boletín de la Academia Nacional de Ciencias, Córdoba 64, 235-333.

Aguirre, M.L., Whatley, R.C., 1995. Late Quaternary marginal marine deposits and palaeoenvironments from northeastern Buenos Aires Province, Argentina: a review. Quaternary Sciencie Reviews 14, 223-254. https://doi.org/10.1016/0277-3791(95)00009-E

Aguirre, M.L., 1991. Holocene macrobenthic molluscan associations from northeastern Buenos Aires Province, Argentina. Quaternary of South America and Antartic Peninsula 7, 161-195.

Anderson, D.E., Goudie, A.S., Parker, A.G., 2013. Global environments through the Quaternary. Exploring environmental change, Oxford University Press, Oxford, 424 p.

Ávila, S.P., Melo, C., Silva, L., Ramalho, R.S., Quartau, R., Hipólito, A., Cordeiro, R., Rebelo, A.C., Madeira, P., Rovere, A., Hearty, P.J., Henriques, D., Marques da Silva, C., de Frias Martins, A. M., Zazo, C., 2015. A review of the MIS 5e highstand deposits from Santa Maria Island (Azores, NE Atlantic): palaeobiodiversity, palaeoecology and palaeobiogeography. Quaternary Science Reviews 114: 126-148. https://doi.org/10.1016/j.quascirev.2015.02.012

Belanger, C.L., Jablonski, D., Roy, K., Berke, S.K., Krug, A.Z., Valentine, J.W., 2012. Global environmental predictors of benthic marine biogeographic structure. Proceedings of the Natural Academy of Science 109, 14046-14051.

Bettinelli, M., Dillenburg, S.R., Lopes, R.P., Caron, F., 2018. Pleistocene molluscan assemblage in the southern Coastal Plain of Rio Grande do Sul, Brazil: Implications in the evolution of a Barrier-Lagoon System. Journal of South American Earth Sciences 86, 200-215. https://doi.org/10.1016/j.jsames.2018.06.014

Bradley, R.S., 2015. Paleoclimatology. Reconstructing Climates of the Quaternary, 3rd Edition, Academic Press, Elsevier, Oxford.

Charó, M.P., Fucks, E.E., Gordillo, S., 2015. Late Pleistocene-Recent marine malacological assemblages of the Colorado River delta (south of Buenos Aires Province): Paleoecology and paleoclimatology. Quaternary International 377, 1-19. https://doi.org/10.1016/j.quaint.2015.05.025

Charó, M.P., Gordillo, S., Fucks, E.E., Giaconi, L.M., 2014. Late Quaternary molluscs from the northern San Matías Gulf (Northern Patagonia, Argentina), southwestern Atlantic: Faunistic changes and paleoenvironmental interpretation. Quaternary International 352, 26-47. https://doi.org/10.1016/j.quaint.2013.12.044

Charó, M.P., Fucks, E.E., Gordillo, S., 2013a. Moluscos marinos bentónicos del Cuaternario de Bahía Anegada (sur de Buenos Aires, Argentina): variaciones faunísticas en el Pleistoceno tardío y Holoceno. Revista Mexicana de Ciencias Geológicas 30 (2), 404-416.

Charó, M.P., Gordillo, S., Fucks, E.E., 2013b. Paleoecological significance of Late Quaternary molluscan faunas of the Bahia San Blas area, Argentina. Quaternary International 301, 135-149. https://doi.org/10.1016/j.quaint.2012.12.019

Clavijo, C., Scarabino, F., Rojas, A., Martínez, S., 2005. Lista sistemática de los moluscos marinos y estuarinos del Cuaternario del Uruguay. Comunicaciones de la Sociedad Malacológica del Uruguay 9 (88), 381-411.

Crowley, T.J., North, G.R., 1991. Paleoclimatology, Oxford University Press, Inc., New York.

Darwin, C., 1846. Geological observations on South America, being the third part of the geology of the voyage of the Beagle, under the command of capt. Fitzroy RN during the years 1832-1836, Smith, Elder and Co., London.

de Mata, O., 1947. La formación holocena en el Departamento de Montevideo (República Oriental del Uruguay), Imprenta Nacional, Montevideo.

Demicheli, M., Scarabino, F., 2006. Invertebrados bentónicos de La Paloma (Rocha, Uruguay). *In*: Menafra, R., Rodríguez, L., Scarabino, F. & Conde, D. (eds.), Bases para la conservacion y el manejo de la costa uruguaya, Vida Silvestre, Montevideo, pp. 523-534.

d´Orbigny, A., 1836-1843. Paléontologie. *In*: Voyage dans l'Amérique méridionale (le Brésil, la République orientale de l'Uruguay, la République Argentine, la Patagonie, la République du Chili, la République de Bolivia, la République du Pérou), exécuté pendant les années 1826-1833, t.3 (4), París/Estrasburgo.

Emiliani, C., 1955. Pleistocene temperatures. Journal of Geology 63, 538-578.

EPICA Community Members, 2006. One-to-one coupling of glacial climate variability in Greenland and Antarctica. Nature 444, 195-198.

Figueiras, A., Sicardi, O.E., 1980. Catálogo de los moluscos marinos del Uruguay. Parte X: Revisión actualizada de los Moluscos marinos del Uruguay con descripción de las especies agregadas. Sección II: Gastropoda – Cephalopoda y Bibliografía consultada. Comunicaciones de la Sociedad Malacológica del Uruguay 5 (38), 179-277.

Figueiras, A., Sicardi, O.E., 1972. Catálogo de los moluscos marinos del Uruguay. Parte VII. Comunicaciones de la Sociedad Malacológica del Uruguay 3 (22), 169-188.

Figueiras, A., Sicardi, O.E., 1968. Catálogo de los moluscos marinos del Uruguay. Parte II. Comunicaciones de la Sociedad Malacológica del Uruguay 2 (15), 255-275.

Figueiras, A., 1962. Sobre nuevos hallazgos de moluscos sufósiles de la Transgresión Querandina. Comunicaciones de la Sociedad Malacológica del Uruguay 1 (3), 53-68.

Figueiras, A., 1961. Contribución al conocimiento de la malacofauna holocena del Uruguay. Comunicaciones de la Sociedad Malacológica del Uruguay 1 (1), 15-21.

Figueira, R.M.A., Pimenta, A.D., 2008. Two new species of the genus *Cerithiopsis* Forbes and Hanley, 1850 (Gastropoda: Cerithiopsidae) from Brazil. Veliger 50: 72-80.

Forcelli, D., Narosky, T., 2015. Uruguayan seashells. Moluscos marinos Argentina, Uruguay, Brasil, Vázquez Manzini Editores, Buenos Aires.

Garilli, V., 2011. Mediterranean Quaternary interglacial molluscan assemblages: Palaeobiogeographical and palaeoceanographical responses to climate change. Palaeogeogeography Palaeoclimatology Palaeoecology 312, 98-114. https://doi.org/10.1016/j.palaeo.2011.09.012

Goñi, J.C., Hoffstetter, R., 1964. Uruguay. Lexique Stratigraphique. International, 5 Amerique Latine, 9ª. CNRS, Paris.

Gordillo, S., Cusminsky, G., Bernasconi, E., Ponce, J.F., Rabassa, J.O., Pino, M., 2010. Pleistocene marine calcareous macro-and-microfossils of Navarino Island (Chile) as environmental proxies during the last interglacial in southern South America. Quaternary International 221, 159-174. https://doi.org/10.1016/j.quaint.2009.10.025

Gordillo, S., Isla, F.I., 2011. Faunistic changes between the Middle/Late Pleistocene and the Holocene on the Atlantic coast of Tierra del Fuego: molluscan evidence. Quaternary International 233, 101-112. https://doi.org/10.1016/j.quaint.2010.06.006

Goso Aguilar, C., 2006. Aspectos sedimentológicos y estratigráficos de los depósitos cuaternarios de la costa platense del departamento de Canelones (Uruguay). Latin American Journal of Sedimentology and Basin Analysis 13 (1), 77-89.

Goso, H., 1972. Cuaternario, Programa de Estudio y Levantamiento de Suelos, Montevideo.

Hearty, P.J., Hollin, J.T., Neumann, A.C., O'Leary, M.J., McCulloch, M., 2007. Global sea-level fluctuations during the Last Interglaciation (MIS 5e). Quaternary Science Reviews 26, 2090-2112. https://doi.org/10.1016/j.quascirev.2007.06.019

Hsu, J.T., Leonardt, E.M., Wehmiller, J.F., 1989.Aminostratigraphy of Peruvian and Chilean Quaternary marine terraces. Quaternary Science Reviews 8, 255-262. https://doi.org/10.1016/0277-3791(89)90040-1

Huber, M., 2010. Compendium of bivalves. A full-color guide to 3,300 of the world's marine bivalves. A status on Bivalvia after 250 years of research, ConchBooks, Hackenheim.

Ihering, H. von., 1923. Transgression des Meeres während der Ablagerung der Pampas. Archiv. Für Mollskenkunde 55 (5), 183-193.

Ihering, H. von., 1907. Les mollusques fossiles du Tertiaire et du Crétacé Supérieur de l´Argentine. Anales del Museo Nacional de Buenos Aires 7 (3 Série), 1-611.

Journal of Sedimentary Environments
Published by Universidade do Estado do Rio de Janeiro
3 (4): 220-233. October-December, 2018
doi: 10.12957/jse.2018.39139

Isla, F.I., Rutter, N.W., Schnack, E.J., Zárate, M.A., 2000. La transgresión Belgranense en Buenos Aires. Una revisión a cien años de su definición. Revista Cuaternario y Ciencias Ambientales 4, 3-14.

Jouzel, J., Masson-Delmotte, V., Cattani, O., Dreyfus, G., Falourd, S., Hoffmann, G., Minster, B., Nouet, J., Barnola, J.M., Chappellaz, J., Fischer, H., Gallet, J.C., Johnsen, S., Leuenberger, M., Loulergue, L., Luethi, D., Oerter, H., Parrenin, F., Raisbeck, G., Raynaud, D., Schilt, A., Schwander, J., Selmo, E., Souchez, R., Spahni, R., Stauffer, B., Steffensen, J.P., Stenni, B., Stocker, T.F., Tison, J.L., Werner, M., Wolff, E.W., 2007. Orbital and millennial Antarctic climate variability over the past 800,000 years. Science 317, 793-796. https://doi.org/10.1126/science.1141038

Kukla, G.J., Bender, M.L., de Beaulieu, J.-L., Bond, G., Broecker, W.S., Cleveringa, P., Gavin, J.E., Herbert, T.D., Imbrie, J., Jouzel, J., Keigwin, L.D., Knudsen, K.-L., McManus, J.F., Merkt, J., Muhs, D.R., Mueller, H., Poore, R.Z., Porter, S.C., Seret, G., Shackleton, N.J., Turner, C., Tzedakis, P.C., Winograd, I.J., 2002. Last interglacial climates. Quaternary Research 58, 2-13. https://doi.org/10.1006/qres.2001.2316

Lang, N., Wolff, E.W., 2011. Interglacial and glacial variability from the last 800 ka in marine, ice and terrestrial archives. Climates of the Past 7, 361-380.

Larrañaga, D.A., 1894. Memoria geológica sobre la formación del Río de la Plata, deducida de sus conchas fósiles, escrita por los años 1819. Anales del Museo Nacional de Montevideo 1 (2), 3-12.

Layerle, C., Scarabino. V., 1984. Moluscos del frente marítimo uruguayo entre los 9 y 78 m de profundidad: Análisis biocenológico. Contribuciones (Departamento de Oceanografía, Facultad de Humanidades y Ciencias) 1, 1-17.

Lisiecki, L.E., Raymo, M.E., 2005. A Pliocene-Pleistocene stack of 57 globally distributed benthic δ^{18}O records. Paleoceanography 20, PA1003.

Lopes, R.P., Dillenburg, S.R., Schultz, C.L., Ferigolo, J., Ribeiro, A.M., Pereira, J.C., Holanda, E.C., Pitana, V.G., Kerber, L., 2014. The sea-level highstand correlated to marine isotope stage (MIS) 7 in the coastal plain of the state of Rio Grande do Sul, Brazil. Annais da Academia Brasileira de Ciencias 86 (4), 1573-1595. http://dx.doi.org/10.1590/0001-37652014201302 74

Lopes, R.P., Simone, L.R.L., Dillenburg, S.R., Schultz, C.L., Pereira, J.C., 2013. A Middle Pleistocene marine molluscan assemblage from the southern coastal plain of Rio Grande do Sul State, Brazil. Revista Brasileira de Paleontologia 16 (3): 343-360. http://dx.doi.org/10.4072/rbp.2013.3.01

Lopes, R.P., Simone, L.R.L., 2012. New fossil records of Pleistocene marine mollusks in southern Brazil. Revista Brasileira de Paleontología 15 (1), 49-56. http://dx.doi.org/10.4072/rbp.2012.1.04

Lorenzo, N., Verde, M., 2004. Estructuras de bioerosión en moluscos marinos de la Formación Villa Soriano (Pleistoceno tardío – Holoceno) de Uruguay. Revista Brasilera de Paleontologia 7, 319-328.

Lowe, J.J., Walker, M., 2014. Reconstructing Quaternary Environments, 3rd Edition, Routeledge, Taylor and Francis Group, Abingdon.

Macsotay, O., Caceres Hernandez, R., 2005. Palaeoclimatology of the Pleistocene-Holocene using marine molluscs and hermatypic corals from northern Venezuela. Transactions of the 16th Caribbean Geological Conference, Barbados. Caribbean Journal of Earth Science 39, 93-104.

Martínez, S., del Río, C., Rojas, A., 2016. A Pleistocene (MIS 5e) mollusk assemblage from Ezeiza (Buenos Aires Province, Argentina). Journal of South American Earth Sciences 70, 174-187. https://doi.org/10.1016/j.jsames.2016.05.008

Martínez, S., Rojas, A., 2013. Relative sea level during the Holocene in Uruguay. Palaeogeography Palaeoclimatology Palaeoecology 374, 123-131. https://doi.org/10.1016/j.palaeo.2013.01.010

Martínez, S., Rojas, A., Ubilla, M., Verde, M., Perea, D., Piñeiro, G., 2006. Molluscan assemblages from the marine Holocene of Uruguay: composition, geochronology, and paleoenvironmental signals. Ameghiniana 43 (2), 385-397.

Martínez, S., Ubilla, M., 2004. El Cuaternario de Uruguay. *In*: Veroslavsky, G., Ubilla, M., Martínez, S. (eds.), Cuencas sedimentarias de Uruguay: Geología, paleontología y recursos naturales. Cenozoico, DIRAC, Montevideo, pp. 195-228.

Martínez, S., Ubilla, M., Verde, M., Perea, D., Rojas, A., Guérèquiz, R., Piñeiro, G., 2001. Paleoecology and geochronology of Uruguayan coastal marine Pleistocene deposits. Quaternary Research 55, 246-254. https://doi.org/10.1006/qres.2000.2204

Martínez, S., 1990. Taphonomy and Paleoecology of Holocene mollusks from the western margin of the Merin Lagoon (Villa Soriano Fm., Uruguay). Quaternary of South America and Anctartic Peninsula 7, 121-135.

Martínez, S., 1988. Moluscos fósiles holocenos de la margen occidental de la Laguna Merín (Formación Villa Soriano, Uruguay). Comunicaciones de la Sociedad Malacológica del Uruguay 6, 409-418.

Masson-Delmotte, V., Dreyfus, G., Braconnot, P., Johnsen, S., Jouzel, J., Kageyama, M., Landais, A., Loutre, M.F., Nouet, J., Parrenin, F., Raynaud, D., Stenni, B., Tuenter, E., 2006. Past temperature reconstructions from deep ice cores: relevance for future climate change. Climate of the Past 2, 145-165.

de Mata, O., 1947. La formación holocena en el Departamento de Montevideo (República Oriental del Uruguay), Imprenta Nacional, Montevideo.

Meadows, M.E., 2012. Quaternary environments: Going forward, looking backwards? Progress in Physical Geography 36 (4), 539-547.

Meco, J., Guillou, H., Carracedo, J.L., Lomoschitz, A., Ramos, A.J.G., Rodríguez Yánez, J.J., 2002. The maximum warmings of the Pleistocene world climate recorded in the Canary Islands. Palaeogeography Palaeoclimatology Palaeoecology 185, 197-210. https://doi.org/10.1016/S0031-0182(02)00300-0

Medina-Elizalde, M., 2013. A global compilation of coral sea-level benchmarks: Implications and new challenges. Earth and Planetary Science Letters 362, 310-318. https://doi.org/10.1016/j.epsl.2012.12.001

Mikkelsen, P.M., Bieler, R., 2007. Seashells of Southern Florida: Living marine mollusks of the Florida Keys and adjacent regions. Bivalves, Princeton Univ. Press., New Jersey.

Miller, G.H., Brigham-Grette, J., Alley, R.B., Anderson, L., Bauch, H.A., Douglas, M.S.V., Edwards, M.E., Elias, S.A., Finney, B.P., Fitzpatrick, J.J., Funder, S.V., Geirsdóttir, A., Herbert, T.D., Hinzman, L.D., Kaufman, D.S., MacDonald, G.M., Polyak, L., Robock, A., Serreze, M.C., Smol, J.P., Spielhagen, R., White, J.W.C., Wolfe, A.P., Wolff, E.W., 2013. Paleoclimate, Paleoclimate history of the Arctic. *In*: Elías, S.A. (ed), *Encyclopedia of Quaternary Science,* Elsevier, Oxford, pp. 113-125.

Muhs, D.R., Groves, L.T., Schumann, R.R., 2014. Interpreting the paleozoogeography and sea level history of thermally anomalous marine terrace faunas: a case study from the Last Interglacial Complex of San Clemente Island, California. Monographs of the Western North American Naturalist 7, 82-108.

Muhs, D.R., Simmons, K.R., Steinke, B., 2002. Timing and warmth of the Last Interglacial period: new U-series evidence from Hawaii and Bermuda and a new fossil compilation for North America. Quaternary Science Reviews 21, 1355-1383. https://doi.org/10.1016/S0277-3791(01)00114-7

Murray-Wallace, C.V., Woodroffe, C., 2014. Quaternary Sea-level changes, a global perspective. Cambridge University Press, Cambridge.

Oldfield, F., 2004. Some personal perspectives on the role of Quaternary science in global change studies. Global and Planetary Change 40, 3-9.

Ortlieb, L., Devries, T., Diaz, A., 1990. Ocurrencia de *Chione broggi* (Pilsbry and Olsson, 1943) (Pelecypoda) en depositos litorales cuaternarios del sur del Perú: implicaciones paleoceanográficas. Boletín de la Sociedad Geológica de Perú 81, 127-134.

Otto-Bliesner, B., Marshall, S., Overpeck, J., Miller, G., Hu, A., 2006. Simulating Arctic climate warmth and icefield retreat in the Last Interglaciation. Science 311, 1751-1753.

Pastorino, G., Bagur, M., 2011. The genus *Sphenia* Turton, 1822 (Bivalvia: Myidae) from shallow waters of Argentina. Malacología 54 (1-2), 431-435.

Petit, J.-R., Jouzel, J., Raynaud, D., Barkov, N.I., Barnola, J.M., Basile, I., Bender, M., Chappellaz, J., Davis, M., Delaygue, G., Delmotte, M., Kotlyakov, V.M., Legrand, M., Lipenkov, V.Y., Lorius, C., Pepin, L., Ritz, C., Saltzman, E., Stievenard, M., 1999. Climate and atmospheric history of the past 420000 years from the Vostok ice core, Antarctica. Nature 399, 429-436.

Pimenta, A.D., Absalão, R.S., 2002. On the taxonomy of *Turbonilla puncta* (C.B. Adams, 1850) (Gastropoda, Pyramidellidae), with the description of a new species from Brazil and remarks on other western Atlantic species. Zootaxa 78, 1-16.

Pimenta, A.D., Absalão, R.S., Miyaji, C., 2009. A taxonomic review of the genera *Boonea*, *Chrysallida*, *Parthenina*, *Ivara*, *Fargoa*, *Mumiola*, *Odostomella* and *Trabecula* (Gastropoda, Pyramidellidae, Odostomiinae) from Brazil. Zootaxa 2049, 39-66. https://doi.org/10.5281/zenodo.186507

Piñeiro, G., Scarabino, F., Verde, M., 1992. Una nueva localidad fosilífera del Holoceno marino de Uruguay (Punta Rasa, Departamento de Maldonado). Boletín de la Sociedad Zoológica del Uruguay 7, 61-62.

Pirazzoli, P.A., 1996. Sea-level changes: the last 20,000 years. John Wiley and Sons, Chichester.

Preciozzi, F., Spoturno, J., Heinzen, W., Rossi, P., 1988. Memoria explicativa de la Carta Geológica del Uruguay a la escala 1: 500.000. DINAMIGE, Montevideo.

Rabassa, J., Gordillo, S., Ocampo, C., Rivas Hurtado, P., 2009. The southernmost evidence for an interglacial transgression (Sangamon?) in South America. First record of upraised Pleistocene marine deposits in Isla Navarino (Beagle Channel, Southern Chile). Geologica Acta 6 (3): 251-258. http://dx.doi.org/10.1344/105.000000254

Ríos, E., 2009. Compendium of Brazilian sea shells, Evangraf, Rio Grande do Sul.

Ríos, E.C., 1994. Seashells of Brazil, Editora da FURG, Rio Grande.

Rivadeneira, M.M., Carmona, E.R., 2008. A Late Pleistocene macrobenthic assemblage in Caleta Patillos, northern Chile: paleoecological and paleobiogeographical interpretations. Revista Geológica de Chile 35 (1), 163-173.

Rojas, A., Demicheli, M., Martínez, S., 2018. Taphonomy of the Late Pleistocene marine molluscan assemblages from Uruguay. Neues Jahrbuch für Geologie und Paläontologie - Abhandlungen 289 (2), 217-235.

Rojas, A., Martínez, S., 2016. Marine Isotope Stage 3 (MIS 3) versus Marine Isotope Stage 5 (MIS 5) fossiliferous marine deposits from Uruguay. *In*: Gasparini, G.M., Rabassa, J., Deschamps, M. C., Tonni, E.P. (eds.), Marine Isotope Stage 3 in Southern South America 60 KA B.P.-30 KA B.P, Springer Earth System Sciences, Cham, pp. 249- 278.

Rojas, A., Verde, M., Urteaga, D., Scarabino, F., Martínez, S., 2014. The first predatory drillhole on a fossil chiton plate: an occasional prey item or an erroneous attack? Palaios 29, 414-419. https://doi.org/10.2110/palo.2014.030

Rojas, A., Urteaga, D., 2011. Late Pleistocene and Holocene chitons (Mollusca, Polyplacophora) from Uruguay: palaeobiogeography and palaeoenvironmental reconstruction in mid latitudes of the Southwestern Atlantic. Geobios 44: 377-386. https://doi.org/10.1016/j.geobios.2010.09.002

Rojas, A., 2007. Moluscos de aguas cálidas del Cuaternario Marino del Uruguay. MSc thesis, PEDECIBA, Universidad de la República, Montevideo.

Rojas, A., 2002. Tafonomía y cronología de nuevos depósitos fosilíferos del Holoceno marino de Uruguay. Actas de las II Jornadas Uruguayas del Cenozoico 1, 80-82.

Rosenberg, G., 2009. Malacolog 4.1.1: A Database of Western Atlantic Marine Mollusca. [WWW database (version 4.1.1)] URL http://www.malacolog.org/.

Rosenberg, G., Moretzsohn, F., García, E.F., 2009. Gastropoda (Mollusca) of the Gulf of Mexico. *In*: Felder, D.L., Camp, D.K. (eds.), Gulf of Mexico–Origins, Waters, and Biota. Biodiversity, Texas A&M University Press, College Station, Texas, pp. 579-699.

Roy, K., Jablonski, D., Valentine, J.W., 1995. Thermally anomalous assemblages revisited: patterns in the extraprovincial latitudinal range shifts of Pleistocene marine mollusks. Geolgy 23 (12): 1071-1074. https://doi.org/10.1130/0091-7613(1995)023<1071: TAARPI>2.3.CO;2

Scarabino, F., Zelaya, D.G., Orensanz, J.M., Ortega, L,, Defeo, O., Schwindt, E., Carranza, A., Zaffaroni, J.C., Martínez, G., Scarabino, V., García-Rodríguez, F., 2015. Cold, warm, temperate and brackish: Bivalve biodiversity in a complex oceanographic scenario (Uruguay, southwestern Atlantic). American Malacological Bulletin 33 (2), 1-18. https://doi.org/10.4003/006.033.0219

Scarabino, F., Zaffaroni, J.C., Carranza, A., Clavijo, C., Nin, M., 2006a. Gasterópodos marinos y estuarinos de la costa uruguaya: faunística, distribución, taxonomía y conservación. *In*: Menafra, R., Rodríguez, L., Scarabino, F., Conde, D. (eds.), Bases para la conservación y el manejo de la costa uruguaya, Vida Silvestre, Montevideo, pp. 143-155.

Scarabino, F., Zaffaroni, J.C., Clavijo, C., Carranza, A., Nin, M., 2006b. Bivalvos marinos y estuarinos de la costa uruguaya: faunística, distribución, taxonomía y conservación. *In*: Menafra, R., Rodríguez, L., Scarabino, F., Conde, D. (eds.), Bases para la conservacion y el manejo de la costa uruguaya, Vida Silvestre, Montevideo, pp. 157-169.

Journal of Sedimentary Environments
Published by Universidade do Estado do Rio de Janeiro
3 (4): 220-233. October-December, 2018
doi: 10.12957/jse.2018.39139

Scarabino, F., 2004. Lista sistemática de los Gastropoda marinos y estuarinos vivientes de Uruguay. Comunicaciones de la Sociedad Malacológica del Uruguay 8 (84-85/86-87). 305-346.

Scarabino, F., Zaffaroni, J.C., 2004. Estatus faunístico de veinte especies de moluscos citadas para aguas uruguayas. Comunicaciones Zoológicas, Museo Nacional de Historia Natural y Antropología 13 (202): 1-15.

Scarabino, F., 2003. Lista sistemática de los Bivalvia marinos y estuarinos vivientes de Uruguay. Comunicaciones de la Sociedad Malacológica del Uruguay 8 (80-81), 229-259.

Shilts, M.H., Pascual, M.S., Ó Foighil., D., 2007. Systematic, taxonomic and biogeographic relationships of Argentine flat oysters. Molecular Phylogenetics and Evolution 44, 467-473.

Sicardi, O.E., 1967. La influencia de las corrientes marinas sobre la malacofauna uruguaya. Comunicaciones de la Sociedad Malacológica del Uruguay 2 (12), 49-60.

Signorelli, J.H., Scarabino, F., 2010. *Mactra guidoi* n. sp. and *Mactra* patagonica (Bivalvia: Mactridae), two long misunderstood species from southwestern Atlantic Ocean. Malacologia 52 (1), 31-42. https://doi.org/10.4002/040.052.0103

Sime, L.C., Tindall, J.C., Wolff, E.W., Connolley, W.M., Valdes, P.J., 2008. Antarctic isotopic thermometer during a CO_2 forced warming event. Journal of Geophysical Research 113, D24119.

Sime, L.C., Wolff, E.W., Oliver, K.I.C., Tindall, J.C., 2009. Evidence for warmer interglacials in East Antarctic ice cores. Nature 462, 342-346.

Spalding, M.D., Fox, H.E., Allen, G.R., Davidson, N., Ferdaña, Z.A., Finlayson, M., Halpern, B.S., Jorge, M.A., Lombana, A., Lourie, S.A., Martin, K.D., McManus, E., Molnar, J., Recchia, C.A., Robertson, J., 2007. Marine ecoregions of the World: a bioregionalization of coastal and shelf areas. Bioscience 57, 573-583. https://doi.org/10.1641/B570707

Sprechmann, P., 1978. The paleoecology and paleogeography of the Uruguayan coastal area during the Neogene and Quaternary. Zitteliana 4, 3-72.

Teisseire, A., 1928. Contribución al estudio de la geología y la paleontología de la República Oriental del Uruguay. Región de Colonia. Anales de la Universidad 122 (series 37), 319-469.

Turgeon, D.D., Lyons, W.G., Mikkelsen, P., Rosenberg, G., Moretzsohn, F., 2009. Bivalvia (Mollusca) of the Gulf of Mexico. *In*: Felder, D.L., Camp D.K. (eds.), Gulf of Mexico–Origins, Waters, and Biota. Biodiversity, Texas A&M University Press, College Station, Texas, pp. 711-744.

Turney, C.S.M., Jones, R.T., 2010. Does the Agulhas Current amplify global temperatures during super-interglacials? Journal of Quaternary Science 25 (6), 839-843. https://doi.org/10.1002/jqs.1423

Ubilla, M., Martínez, S., 2016. Geology and Paleontology of the Quaternary of Uruguay. Springer Brief in Earth Sciences, South America and the Southern Hemisphere, Springer, Basel.

Valentine, J.W., Jablonski, D., 1993. Fossil communities: Compositional variation at many time scales. *In*: Ricklefs, R.E., Schluter, D. (eds.), Species diversity in ecological communities: Historical and geographical perspectives, University of Chicago Press, Chicago, pp. 341-349.

Van Meerbeeck, C.J., Renssen, H., Roche, D.M., 2009. How did Marine Isotope Stage 3 and Last Glacial Maximum climates differ? –Perspectives from equilibrium simulations. Climates of the Past 5, 33-51. https://doi.org/10.5194/cp-5-33-2009

Warwick, R.M., Turk, S.M., 2002. Predicting climate change effects on marine biodiversity: comparison of recent and fossil molluscan death assemblages. Journal of the Marine Biological Association of the United Kingdom 82 (5), 847-850.

Zazo, C., Goy, J.L., Dabrio, C.J., Lario, J., González-Delgado, J.A., Bardají, T., Hillaire-Marcel, C., Cabero, A., Ghaleb, B., Borja, F., Silva, P.G., Roquero, E., Soler, V., 2013. Retracing the Quaternary history of sea-level changes in the Spanish Mediterranean–Atlantic coasts: Geomorphological and sedimentological approach. Geomorphology 196, 36-49.