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Micropaleontological record of Holocene estuarine stages in the Bahía Blanca estuary, Argentina

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ABSTRACT

Holocene paleoenvironmental changes have been interpreted on the basis of benthic foraminifera and calcareous nannofossils recovered in samples from Napostá Grande Stream, Bahía Blanca estuary, southern Buenos Aires Province. Samples are fine sands and clay sediments from a Holocene outcrop and were studied with quantitative techniques. The benthic foraminiferal assemblage is dominated by *Ammonia parkinsoniana*, *Ammonia tepida*, *Bolivina pseudoplicata*, *Bolivina striatula*, *Bolivina* sp., *Buccella peruviana*, and *Elphidium* spp. The calcareous nannofossil assemblage recovered is a typical cold-water association, dominated by *Calcidiscus leptoporus*, *Coccolithus pelagicus*, *Emiliana huxleyi* and *Gephyrocapsa oceanica*. A dendrogram classification by cluster analysis was made for each microfossil group. The results of these analyses were coincident, showing a liaison between changes in the assemblages of benthic foraminifera and calcareous nannofossils. Those results, jointly with the sedimentological information, lead to the identification of three different paleoenvironments along the Napostá N1 site. The lower part of the succession represents an estuarine environment with larger marine connection. The middle part represents a gradual passage to a more restricted estuarine environment, and the upper part represents the establishment of the modern continental fresh-water environment.

1. Introduction

Foraminifers are well known for their remarkable fossil record and for their variety and abundance in almost all modern marine environments. These minute organisms constitute the most diverse group of testate protists in modern oceans, and are one of the fossil groups capable of provide reliable analogs for the understanding of marine environmental changes in the past (Scott, 2006). The advantage of using benthic foraminifers in paleoecology lies in their substantial abundance in marine sediments and in the exceptional preservation of their tests. Because their distributions and ecological preferences are fairly well known from the studies conducted in modern habitats, these assemblages can be used as proxies, and as reliable tools for paleoenvironmental reconstructions and environmental characterization (Sen Gupta, 1999).

Calcareous nannofossils on their part, have proved to be very useful on paleoceanographic and paleoenvironmental reconstructions during the Quaternary (Houghton, 1993; Winter et al., 1994; Roth, 1994; Jordan, 2002). They show sensibility to different environmental parameters as water temperature, availability of macro and micronutrients, salinity, light penetration, turbulence, and water depth (Jordan, 2002). While some species show low-adaptation capability, others exhibit differential toleration or preference for diverse environmental conditions and are key-species for paleoenvironmental interpretation. A series of studies and experiments were carried out with selected cultured species (mainly *Emiliania huxleyi* and *Gephyrocapsa oceanica*) to test their response to different environmental factors (Watabe and Wilbur, 1966; Wilbur and Watabe, 1967; Okada and Honjo, 1975; Kleijne, 1990, 1991; Fisher and Honjo, 1991; Hagino et al., 2000; Takahashi and Okada, 2000, among others).

Since Quaternary species are almost the same as modern living species, recent biogeographic distribution and composition of the assemblages could be extrapolated for paleoenvironmental and paleoceanographic reconstruction (McIntyre, 1967; McIntyre and Bé, 1967; McIntyre et al., 1970; Bukry, 1974; Dudley et al., 1980; Giunta et al., 2003; Alday et al., 2006).

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A paleoenvironmental reconstruction is presented after combining benthic foraminifera and calcareous nannofossil data. This contribution provides alternative evidence using multiple proxy analysis (sedimentology, benthic foraminifera and calcareous nannofossils) of the paleoenvironmental conditions during the beginning of the last Holocene transgression within the Bahía Blanca estuary. The objective of this contribution is to increase the knowledge about the Holocene transgression and environmental responses of the coastal area of the Bahía Blanca estuary; in order to reconstruct regional Holocene sea-level changes and to adjust the chronology of these events.

2. Study area

The Bahía Blanca estuary is a mesotidal environment located in the south of Buenos Aires Province and occupies a wide coastal stripe (Fig. 1). Its regional setting is determined by the presence of a complex web of meandering channels of different dimensions. Lots of low islands, extensive tidal flats and salt marshes described the physiography of the area. While the estuary has no significant watershed, is home of one of the major deep-water port systems of Argentina (Cuadrado et al., 2007).

From the point of view of their morphology, the estuary has a funnel configuration, with the main channels, Bermejo, Bahía Falsa, Bahía Verde and Caleta Brightman oriented NW-SE. It also has two tributary channels located on the north coast, which are the main freshwater inputs to the system (Fig. 1). Towards the head of the estuary is located the Sauce Chico River and a 1.6 km southeast of Ingeniero White lays the Napostá Grande Stream. Both small tributaries are also incorporating water in local rainfall runoff (Cuadrado et al., 2007).

The total area is 2300 km^2, 410 km^2 correspond to regions permanently emerged as islands; 1150 km^2 are occupied by intertidal zones and 740 km^2 correspond to subtidal areas (Montesarchio and Lizasoain, 1981). The largest intertidal areas are located in the northern portion; while in the southern sector the proportion is much lower (Piccolo and Perillo, 1999). Mean depth is 10 m, although values of 22 m were registered at the mouth of the estuary (Aliotta and Perillo, 1990). Mean annual surface temperature is of 13 °C varying from 21.6 °C in summer to 8.5 °C in winter (Piccolo et al., 1988). The distribution of mean surface salinity shows an exponential growth from the head up to the middle reach of the estuary. In the middle portion, the average salinity has a local minimum influence by the Napostá Grande stream and the Bahía Blanca city sewage discharge.

As for the balance of sediment in the Bahía Blanca estuary, it can be said that it is negative, since the amount of sediment leaving the estuary is higher than the input. However, it is necessary to note that this does not mean that the entire estuary is under erosion, as there are intertidal areas where eroded mud is retained mainly caused by stabilization due intertidal vegetation (*Spartina alterniflora* Loiseleur-Deslongchamps, 1807); while the sand eroded from channel banks and exiting the estuary usually forms internal, sub and intertidal, sand banks (Codignotto et al., 1993). The size distribution of sediments in the estuary is a direct consequence of environmental dynamics (Borel and Gómez, 2006).

3. Previous work on the Bahía Blanca estuary

Holocene sea level fluctuations for Buenos Aires Province have been analyzed by numerous authors, suggesting several environmental schemes based on studies of regional geology, paleontology and radiocarbon dates (Fray and Ewing, 1963; Parker and Violante, 1982; Codignotto et al., 1992; Codignotto and Aguirre, 1993; Cavallotto, 1995; Violante et al., 2001; Gómez et al., 2005; Schnack et al., 2005). In general terms the Holocene environmental setting for this area would have developed as follows:

At about 17000 yr BP, the peak of the last glaciation occurred. Sea level would have been located at about 170 km east of the existing shoreline, with a depth of −115 m. During the Late Pleistocene-Early Holocene transition (11000 yr BP); there was a progressive rise in sea level (Aguirre, 1995). Towards 9500 and about 7500 yr BP sea-level continued to rise to altitudes between −12 and −18 m (Aliotta and Perillo, 1990).

At 7000 years BP the increasing sea level, would reached similar values to the current ones and then surpassed them as proposed by Cavallotto et al. (2004) for the La Plata River. At *ca.* 6000 yr BP the

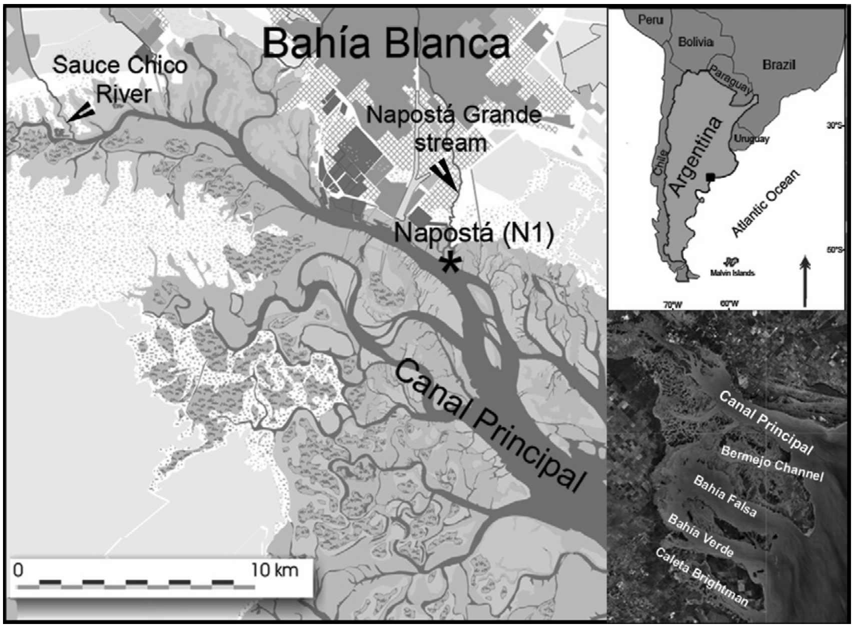

Fig. 1. Location map of Bahía Blanca estuary and Napostá N1 analyzed section.

sea level reached a high-stand with the maximum level located between +3.5 and 4.5 m above the present level, then a progressive and gradual drop at different rates would have occurred (Laprida et al., 2007). Gómez et al. (2005, 2006), after analyzing submarine sequences in the outer area of the Bahía Blanca estuary, proposed the development of negative pulses with a decrease in sea level, several meters below the present one (*ca.* 6350 and *ca.* 2500 years BP). As a consequence, this last transgressive–regressive cycle is still matter of controversy.

Concerning previous studies conducted in the Bahía Blanca estuary, they recently started on the basis of modern and Holocene samples (Guerstein et al., 1992; Cusminsky et al., 1995, 2006, 2009; Gómez et al., 1992, 2005, 2006; Calvo-Marcilese et al., 2007, 2009, 2011; Calvo-Marcilese, 2008, 2011; Calvo-Marcilese and Pérez Panera, 2008; Calvo-Marcilese and Cusminsky, 2009; Calvo-Marcilese and Pratolongo, 2009; Calvo-Marcilese and Langer, 2010; Calvo-Marcilese and Langer, 2012). These studies include, sedimentological and micropaleontological analysis (foraminifera, ostracods, palynomorphs and diatoms) of samples representing modern deposits of inner and external areas of the of Bahía Blanca estuary. Between these publications the first results combining data from benthic foraminifera and calcareous nannofossils have been obtained, presenting comparisons between fossil and recent material from the Arroyo Napostá area (Calvo-Marcilese and Pérez Panera, 2008). Several disciplines have contributed to the understanding of the current dynamics of the Bahía Blanca estuary, providing information on its coastal evolution during the Holocene. Piccolo and Perillo (1999) and Perillo et al. (1987, 2007) have studied the physical characteristics, geomorphology, hydrography and circulation within the estuary of Bahía Blanca. Gómez et al. (2005, 2006) analyzed variations in sea level during the Holocene in the study area determining the paleoenvironmental conditions and chronological significance of the features described in the PS2B2 core, as the most representative of submarine regional outcrops. Gómez and Perillo (1995) described at the external area of the estuary, the occurrence of fine-stratified layers with great quantities of mud that was determined by means of bathymetric and side scan sonar surveys. Borel and Gómez (2006) studied palynological samples from the Canal del Medio, at *ca.* 3500 ^{14}C yr BP, characterizing Holocene deposits in the middle area of the estuary, and determining that mean sea level was located at a similar position than the current one. Meanwhile Freije and Marcovecchio (2007) monitored chemical parameters such as temperature, salinity, oxygen and nutrients, conducting studies of environmental pollution. The analysis of ostracods in the vicinity of Bahía Blanca corresponds to the studies conducted by Bertels and Martínez (1990, 1997), Martínez (2002) and Cusminsky et al. (2006), on modern and fossil samples. Most of these results match perfectly with what has been proposed for foraminiferal assemblages on the same study area, reflecting the response of the microorganisms to sea level fluctuations.

4. Material and methods

4.1. Napostá N1 site profile

The analyzed samples come from an outcrop located at 38° 46′16″ S and 62° 13′58″ W, 3 km from the mouth of the Napostá Grande stream and were taken in March 2006 (Figs. 1 and 2). This two meters thickness holocene succession overlies a hard rock layer attributed to a unit mostly composed of loessoid deposits of late Miocene to Mid-Pleistocene age (De Francesco, 1992; Borel et al., submitted for publication). At the base, it starts with a 10 cm of medium to coarse sand deposit with abundant marine shells such as *Tagelus plebeius* (Lightfoot), *Heleobia australis* (d'Orbigny), *Pitar rostratus* (Koch) and *Nucula semiornata* (d'Orbigny) interpreted as a shallow infralittoral to intertidal environment (Borel et al., submitted for publication).

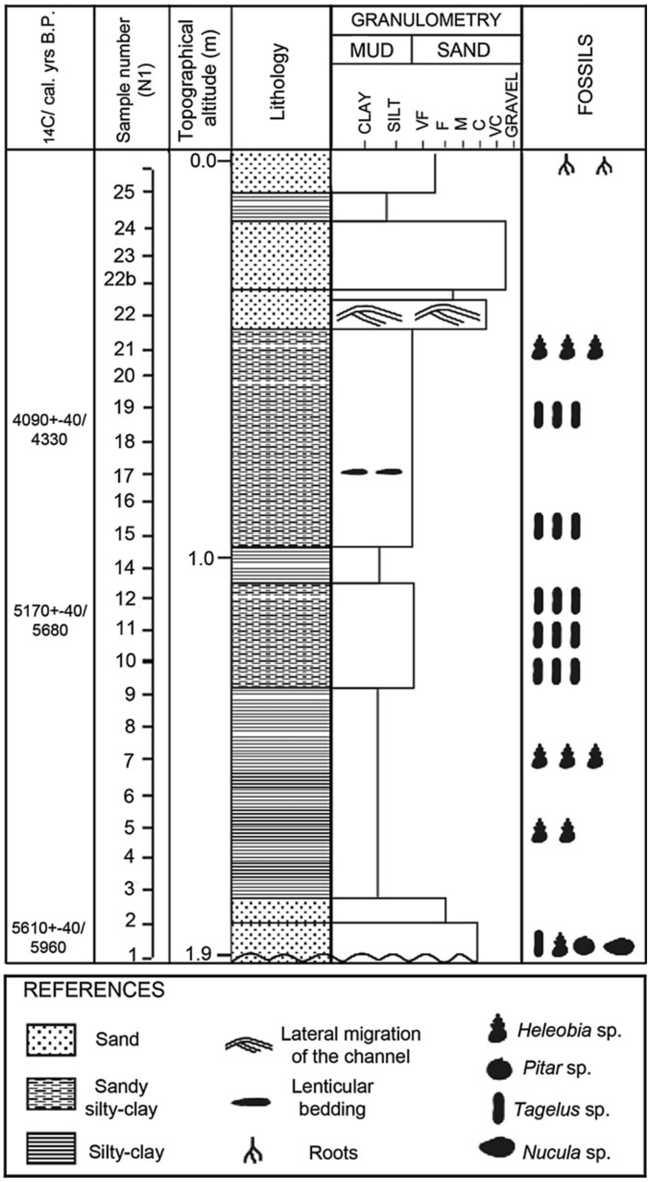

Fig. 2. Sedimentological column at Napostá N1 site.

Overlying the sand layer, there is a 145 cm deposit of sandy silty-clay and silty-clay sediments with sparse organic-rich layers. These sediments yield scarce *H. australis* and *T. plebeius*, and at 60 and 115 cm from the top of the profile, there are two local guide-horizons with *T. plebeius* in life position. One lenticular bedding was recognized at 70–80 cm, these deposits are typical of the tidal flats found along all Bahía Blanca estuary (Calvo-Marcilese et al., 2011; Borel et al., submitted for publication) (Fig. 2).

Towards the top of the succession, the sandy-silt layers are cut by a channel fill deposit of medium to coarse sand and gravel, with laminar trough cross-bedding sedimentary structure, grading upward to a silty-clay horizon (Fig. 2).

The topmost of the sequence is represented by surface soil and roots established over eolian deposits.

Table 1
Benthic foraminifera abundance chart at Napostá N1 site.

Sample	*Ammonia parkinsoniana*	*Ammonia tepida*	*Bolivina* sp.	*Bolivina pseudoplicata*	*Bolivina striatula*	*Buccella peruviana*	*Elphidium* aff. *E. clavatum*	*Elphidium gunteri*	*Elphidium* aff. *E. poeyanum* type I	*Elphidum* aff. *E. poeyanum* type II	*Amphycorina scalaris*	*Bolivina* aff. lomitensis	*Bolivina tortuosa*	*Bulimina* sp.	*Bulimina affinis*	*Bulimina marginata*
N1-m25																
N1-m24																
N1-m23																
N1-m22b							25			10						
N1-m22							0									
N1-m21	250		20			125	640			40						
N1-m20	25		5			30	315			60						
N1-m19	50					50	600			60						
N1-m18	250					100	215	115		580		5				
N1-m17	275					105	620	60		205						
N1-m16	750		5	5			455	380		265						
N1-m15	75		5			55	390	50		220		5				
N1-m14	150			20	5	185	550	95		955		5				
N1-m13	225	25			5	85	415	825	85	345						
N1-m12	150	5				100	325	385	40	265						
N1-m11	75	10		5	5	205	165		5	45						
N1-m10	200	5	10	20	10	510	110	15	65	145						
N1-m09	150	40	5		5	495	130	65	95	0						
N1-m08	350	20	10	15	5	880	10	70		365						
N1-m07	150	0	5			550	10	45		205				40		
N1-m06	150	30		5	5	645	50	65		200						
N1-m05	200	75				770	30	230	25	480						
N1-m04	525	90		20	10	1120	10	175	30	560		5				
N1-m03	1550	180	65	55	50	3335		440		1740		5			5	5
N1-m02	1150	35		35	15	1335		140		720				10		
N1-m01	225	5		10	20	425	65	20		0	5		20		5	

4.2. Methods and radiocarbon dates

Sampling was performed at regular intervals of ~10 cm equidistance, from the base water level up to the top, giving a total of 26 samples. In order to define the height of the outcrop in relation to the present sea level, the mean sea level (MSL) of the Ingeniero White tidal gauge (placed 2 km away) was transported to the study area by means of a double frequency geodesic RTK-GPS Sokkia Radian IS. Microfaunal collection and analyses were conducted following standard protocols of Boltovskoy (1965) for benthic foraminifera. Dry sediment was processed and disaggregated using tap water. Samples were then washed through a sieve of 63 μm mesh and dried at room temperature. From the residue, 1 g of material was extracted; the entire available tests were picked and

Table 2
Calcareous nannofossils abundance chart at Napostá N1 site.

Sample	Preservation	Abundance (Not reworked taxa)	Fields of view	*Calcidiscus leptoporus*	*Coccolithus pelagicus*	*Emiliania huxleyi*	*Gephyrocapsa caribbeanica*	*Gephyrocapsa oceanica*	*Gephyrocapsa sinuosa*
N1-m25	P	0.0103	390						
N1-m24	P	0.0103	390						
N1-m23	P	0.0026	390						
N1-m22b	P	0.0103	390			2			
N1-m22	–	Barren	390						
N1-m21	G	0.141	390	4	12	26		13	
N1-m20	G	0.0769	390	2	5	17		4	1
N1-m19	G	0.1949	390	1	12	45		11	6
N1-m18	G	0.1718	390	3	17	37		7	
N1-m17	G	0.3564	390	3	26	85		19	6
N1-m16	G	0.3282	390	19	58	33	2	11	4
N1-m15	G	0.3564	390	10	47	64	3	9	3
N1-m14	G	0.341	390	10	36	76	1	9	
N1-m13	G	0.5308	390	10	76	92	4	16	8
N1-m12	G	0.4359	390	16	47	74	1	24	8
N1-m11	G	0.3128	390	11	68	14		29	
N1-m10	G	0.541	390	23	92	51	4	30	11
N1-m09	G	0.3436	390	10	69	19	4	29	2
N1-m08	G	0.3718	390	6	111	9		18	
N1-m07	G	0.5897	390	7	108	2		106	1
N1-m06	G	0.6821	390	12	158	3		88	2
N1-m05	G	0.741	390	15	171	5		91	5
N1-m04	G	1.2077	260	14	154	5		129	9
N1-m03	G	0.6897	390	11	115	7		135	
N1-m02	G	0.9179	390	17	129	27		177	2
N1-m01	G	0.1641	390	10	27	13		7	

Bulimina patagonica	*Buliminella elegantissima*	*Cibicides lobatulus*	*Fissurina* sp.	*Fissurina laevigata*	*Glandulina* sp.	*Globulina australis*	*Guttulina* sp.	*Lagena* laevis *f. tenuis*	*Lagena striata*	*Lenticulina limbosa* chiriguanoi	*Nonionella auricula*	*Nonionella auris*	*Oolina melo*	*Pyrgo* sp.	*Quinqueloculina seminulum*	Species richness	Total specimens
																0	0
																0	0
																0	0
																2	35
																0	0
	10	5	10													7	1100
															5	6	440
															5	5	765
				5											5	8	1275
																5	1265
				5												7	1865
	15															8	815
	20											5				10	1990
								5								9	2015
																7	1270
																8	515
	5		10													12	1105
			5								5					10	995
	20	15	10				5			5						14	1780
	5															8	1010
																8	1150
	5				10											9	1825
													5		5	12	2555
20	50			25		5		10	5			15				18	7560
	20											10			10	11	3480
														5		13	805

studied under binocular microscope. Due to the small number of individuals recovered in some samples, and in order to have enough foraminifera for statistical calculations (>100) (Murray, 1991) the quantity recovered was weighted in 5 g of sediment. All foraminiferal species collected were plotted on a range-chart (including abundance and species diversity per sample), and are listed in Table 1. Systematic determinations were based mainly on Loeblich and Tappan (1988); Buzas-Stephens et al. (2002) and Ferrero (2006, 2009). For the *Elphidium* species Boltovskoy (1954a, 1954b, 1957) and Boltovskoy et al. (1980) were followed.

Calcareous nannofossils samples were prepared for its study under polarized light microscope according to the gravity settling technique of Bramlette and Sullivan (1961). A total of 390 fields of view were observed, and species identified were plotted on an abundance-chart along with preservation, abundance and total sum of specimens per sample (Table 2). The preservation criteria is

Helicosphaera carteri	*Oolithotus antillarum*	*Pontosphaera japonica*	*Reticulofenestra* sp.	*Thoracosphaera heimii*	*Thoracosphaera* sp.	*Umbilicosphaera sibogae*	Total (Not reworked taxa)	Reworked Cretaceous taxa
					4		4	0
					4		4	0
					1		1	0
					2		4	8
							0	1
							55	34
					1		30	21
					1		76	58
					3		67	47
							139	72
					1		128	58
					2	1	139	112
1							133	63
					1		207	108
							170	49
							122	37
							211	67
						1	134	37
						1	145	14
					2	4	230	19
					1	2	266	29
						2	289	20
1						2	314	36
			1				269	15
2						4	358	25
1	1	1		2		2	64	54

as follows: G: Good, most specimens exhibit little or no secondary alteration; M: Moderate, specimens exhibit the effects of secondary alteration from etching and/or overgrowth (identification of species not impaired); P: Poor, specimens exhibit intense effects of secondary alteration from etching and/or overgrowth (identification of species impaired but possible in some cases). Mean abundance was calculated dividing the total specimen count by the total fields of view.

Based on the assemblages determined, two dendrogram classifications by cluster analysis (one for each microfossil group) were created using CONISS program, included in the statistic package TILIA 2.0 (Grimm, 1991). Concerning foraminifera, these analysis considered only species registered with a relative abundance equal to, or greater than, 2% in at least two samples (Gómez et al., 2005; Calvo-Marcilese et al., 2011). For calcareous nannofossils all the available specimens were included. The coefficient used corresponded to the Standardized Euclidian distance, and data transformation by standardization to mean 0 and typical deviation 1, was applied (Grimm, 1991).

Radiocarbon dates consisting in organic matter and shells were dated at Beta Analytic Inc. (USA), using accelerated mass spectrometry techniques (AMS) (Borel et al., submitted for publication). The age of the sequence was 5610 ± 40 years BP (c.5960 cal yr BP) at the base (shells-197 cm); 5170 ± 40 years BP (5680 cal. BP) (organic matter-124 cm) and 4090 ± 40 yr BP (4330 cal yr BP) in the middle section (organic matter-76 cm) (Borel and Gómez, 2006; Borel et al., submitted for publication) (Fig. 2). For shell samples, the date was established on juvenile articulated valves of *Pitar rostratus* (Koch), calendar calibration followed the database and procedure given in Stuiver et al. (1986–2010) using CALIB 6.0.1 (Stuiver et al., 1986–2010) and Marine04 (Hughen et al., 2004). Concerning the regional difference in reservoir effect established for *P. rostratus* at the Bahía Blanca estuary (Gómez et al., 2008), it was subtracted from ^{14}C age previous calibration.

Gómez et al. (2008) showed that the shells from various sectors of the Buenos Aires cost presented very important and variable ΔR values. Those are mainly caused by the mixture of hard water of continental source (rivers and groundwater). However, for the inner areas of the Bahía Blanca estuary these authors obtained very low ΔR values, in the same order of magnitude than the corresponding standard deviation, which was attributed mainly to low local contribution waters of continental origin. This suggests that, with some restrictions, the marine calibration curve with standard parameters ($\Delta R = 0$) could be used at this location.

On sedimentary organic matter, calibration was made using the cited program and the South Hemisphere Curve (McCormac et al., 2004; see Gómez et al., 2008; Borel et al., submitted for publication, for detailed information). The rest of the samples age estimation was made by interpolation, assuming constant sedimentation rates between points (Borel and Gómez, 2006).

5. Results

5.1. Benthic foraminifera

Benthic foraminifera were well preserved and abundant in almost all samples. A total of 18 genera, represented by 32 species were recovered. Abundance values ranged from 35 to 7560 and species richness values (S) among 2–18 (Table 1).

Main foraminiferal species were *Ammonia parkinsoniana*, *Ammonia tepida*, *Bolivina pseudoplicata*, *Bolivina striatula*, *Bolivina* sp., *Buccella peruviana*, *Elphidium* sp. aff. *E. clavatum*, *Elphidium gunteri*, *Elphidium* sp. aff. *Elphidium poeyanum* type I and *Elphidium* sp. aff. *E. poeyanum* type II.

5.1.1. Benthic foraminiferal zones (N1-F)

From the information obtained by cluster analysis, the succession can be divided in two zones (Fig. 3). The first one includes samples from the base to sample m11, the second from sample m12 to sample m21. Samples m22 to m25 were considered sterile because of the lack or the scarce individuals registered. The relative abundance of each species (average) is indicated in parentheses.

5.1.1.1. Zone N1-F1 (Samples m1–m11). It is characterized by the dominance of *B. peruviana* (54%), seconded by *E.* sp. aff. *E. poeyanum* type II (19%). The remaining species were recorded with abundances lower than 10%: *E. gunteri* (7%), *E.* sp. aff. *E. clavatum* (7%), *E.* sp. aff. *E. poeyanum* type I (2%); *A. parkinsoniana* (4.1%); *Bolivina pseudoplicata* (1.2%); *B. striatula* (1%); *A. tepida* (2.6%) and *Bolivina* sp. (0.3%).

5.1.1.2. Zone N1-F2 (Samples m12–m21). It shows a gradual change in the dominance of the fauna, with increasing abundance of species like *E.* sp. aff. *E. clavatum* (47.5%); *E.* sp. aff. *E. poeyanum* type II (29%) and *E. gunteri* (13.8%), whereas *B. peruviana* (7.5%) decreases towards the top of the section. Relative abundances of the rest of the registered species were lower than 4%.

5.2. Calcareous nannofossils

Calcareous nannofossil assemblages were well preserved in moderate abundance and low species richness (among 4–9). A total of 13 taxa were recovered and *Calcidiscus leptoporus*, *Coccolithus pelagicus*, *Emiliania huxleyi* and *Gephyrocapsa oceanica* are the most abundant within the assemblages. The less abundant remaining taxa recovered were: *Gephyrocapsa sinuosa*, *G. caribbeanica*, *Helicosphaera carteri*, *Oolithotus antillarum*, *Pontosphaera japonica*, *Reticulofenestra* sp., *Thoracosphaera* sp., *Th. saxea* and *Umbilicosphaera sibogae* (Table 2).

5.2.1. Calcareous nannofossils zones (N1-CN)

For the cluster analysis, samples m22–m25 with abundance indexes lower than 0.05, were considered to be barren (Table 2). It is more likely that the scarce recovered specimens in those samples are due to reworking and furthermore, they lack of any statistical value. These “barren” samples produced a basal separation in the dendrogram between fertile samples (m1–m21) and the barren ones (m22–m25). Within the fertile samples, dendrogram shows a first separation in two major groups: Zone N1-CN1, samples m1-m8; and Zone N1-CN2, samples m9–m21 (Fig. 4). This grouping is mainly explained by an inversion in the relative abundance of *E. huxleyi* and *G. oceanica* and, secondarily, by a progressive increase in *C. leptoporus* abundance. In the following characterization of these zones, the relative abundance of each species (average) is indicated in parentheses.

5.2.1.1. Zone N1-CN1 (Samples m1–m8). This zone is dominated by *C. pelagicus* (51%), *G. oceanica* (34%), *E. huxleyi* (5%) and *C. leptoporus* (5%). It shows higher diversity due to the presence of open-shelf species such as *Helicosphaera carteri* and *U. sibogae.*

5.2.1.2. Zone N1-CN2 (Samples m9–m21). This zone is dominated by *E. huxleyi* (38%), *C. pelagicus* (33%) and *G. oceanica* (14%), and also shows a slight increase of *C. leptoporus* (7%) relative abundance. Species richness falls down due to the almost absence of open-shelf species.

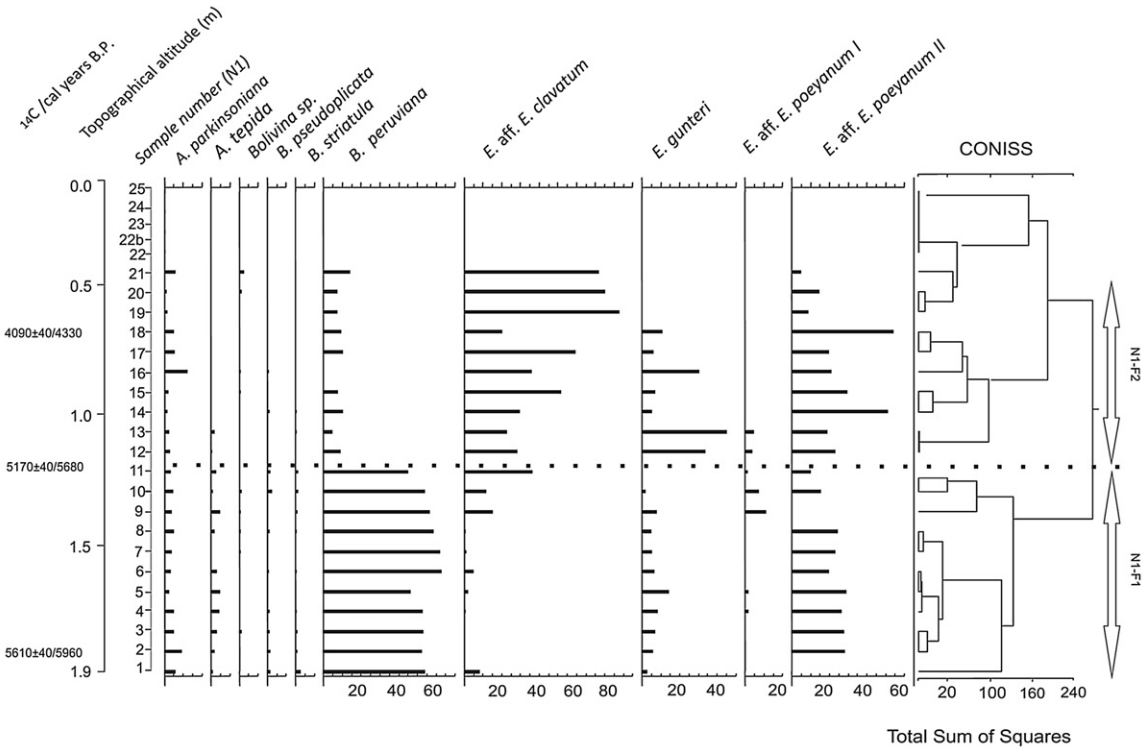

Fig. 3. Frequency diagrams of benthic foraminifera (in percentages) at Napostá N1 site. It includes radiocarbon dates (^{14}C yr BP) and the cluster analysis showing the recognized zonations.

5.2.2. *Reworked calcareous nannofossils*

Some Early and Late Cretaceous species were found along the samples, but they don't seem to show any pattern related to reworking or environmental conditions and were not considered in this study. Their relative abundance compared with the autochthonous taphocenosis randomly changes along the samples (Table 2) and they are though to be air-transported contaminants from Neuquén Basin Lower and Upper Cretaceous outcropping rocks.

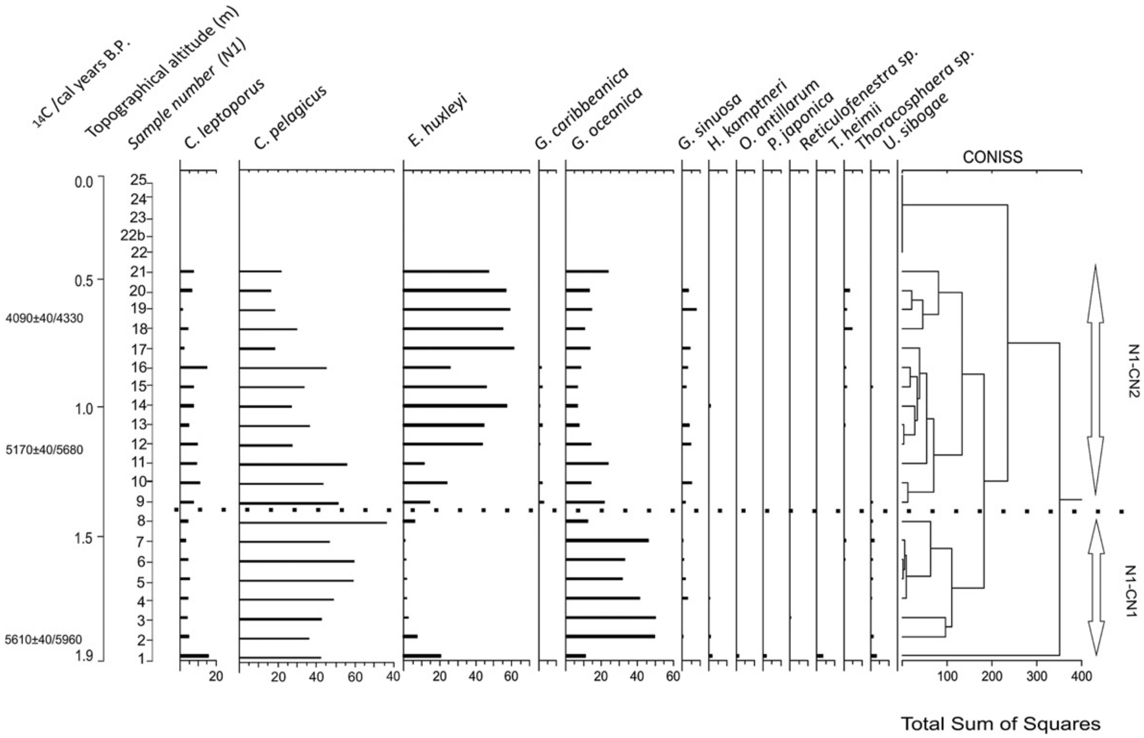

Fig. 4. Frequency diagrams of calcareous nannofossil (in percentages) at Napostá N1 site. It includes radiocarbon dates (^{14}C yr BP) and the cluster analysis showing the recognized zonations.

6. Discussion

6.1. Benthic foraminifera

For the foraminiferal analysis, this section is characterized by the dominance of *Buccella peruviana*; *Elphidium* aff. *E. poeyanum* type II; *Elphidium gunteri*; *Elphidium* sp. aff. *E. clavatum*, *Elphidium* aff. *E. poeyanum* type I, *A. parkinsoniana*, *Bolivina pseudoplicata*; *B. striatula*, *A. tepida* and *Bolivina* sp. Bolivinids were found with very low relative frequencies.

The genus *Buccella* has a wide distribution from 32° to 33°W to 57°–58°S occupying the Argentinian zoogeographic province (Boltovskoy et al., 1980). It is undoubtedly the most common species throughout the region under study and that is why the area has been called the "Kingdom of *Buccella*" (Theyer, 1966; Boltovskoy, 1970, 1976). Its morphology is highly variable, and consequently it has been named differently in Argentina and Brazil, being at the interface between brackish and marine environments, such as the mouths of estuaries and in the upper areas of bays (Hayward and Hollis, 1994). According to Murray (1991) this genus inhabits in inner shelf (0–100 m) and bathyal cold temperate waters. The predominance of *B. peruviana* suggests higher marine influence (Bernasconi and Cusminsky, 2005). Studies conducted by Cusminsky et al. (2006) in areas surrounding the modern Tres Brazas Channel, have recorded the presence of living specimens of *B. peruviana*, but only associated with channel facies or channel edge, in subtidal areas subjected to larger marine influence. Calvo-Marcilese and Pratolongo (2009) have been studying recent salt marshes and intertidal environments within the Bahía Blanca estuary; just a few empty shells of *B. peruviana* were recorded around the mouth of the estuary. It occurs both intertidally and subtidally at shallow depths. Within the genus *Elphidium*; *E. gunteri*, *E.* sp. aff. *E. clavatum*, *E.* sp. aff. *E. poeyanum* type I and type II, are the most abundant. According to Murray (1991), this genus is typical of coastal environments and has been found at depths ranging between 0 and 50 m in warm temperate environments. Boltovskoy (1976) indicates that this genus is widely distributed along the inner shelf of Argentina, and has been recognized worldwide (Murray, 2006). *E. gunteri* is characteristic of brackish environments in association with *Ammonia* and its forms as Lagoa Dos Patos, Brazil; in Río Quequén, Argentina (Boltovskoy et al., 1980; Cusminsky et al., 2006); and Florida Bay, USA (Ishman et al., 1996). Concerning the Bahía Blanca estuary, *E. gunteri* is common and abundant in the Holocene sections and it seems to be restricted to brackish environments (Cusminsky et al., 2006; Calvo-Marcilese et al., 2011). It has been recorded with variable abundance (total assemblages of 1–46 individuals) in modern samples from intertidal environments at the same areas. Living specimens seems to prefer intertidal locations in the lower reaches of the estuary (Calvo-Marcilese and Pratolongo, 2009). *E. clavatum* is characteristic of marginal-marine environments, estuaries and fjords and is dominant in coastal lagoons along the Atlantic coast from Canada to southern USA. It is present in cold temperate waters of the Baltic Sea (Murray, 2006) and is widely distributed in brackish and marginal marine environments throughout New Zealand (Hayward and Hollis, 1994). It is a common and abundant species and has been recorded in all the studied sections (Calvo-Marcilese et al., 2011). It also occurs in intertidal nearshore environments at the lower reaches of the Bahía Blanca estuary, and it is represented for a few living specimens (1–2) and some empty shells (1–22) (Calvo-Marcilese and Pratolongo, 2009).

Elphidium poeyanum is representative of coastal environments, bays and estuaries, and is less common in inner shelf areas (Poag, 1978). It occurs in brackish and normal marine waters worldwide, although it appears to be more common in mid to high latitudes than in warmer waters. Concerning the Argentinian coastal waters this species has been commonly assigned as *E. discoidale* but recently reassigned as *E. poeyanum* in marginal marine and restricted environments (Calvo-Marcilese, 2011; Calvo-Marcilese et al., 2011). It is noteworthy that Boltovskoy (1957) made this consideration, referring to specimens similar to those described herein as *E. poeyanum*, establishing and describing the differences with *E. discoidale*. The variability between characters leads to the distinction between these two forms, and suggests the need for further analysis. Within the Bahía Blanca estuary living specimens are very rare, although a few empty tests have been collected from modern samples along the lower reaches of the estuary (Calvo-Marcilese and Pratolongo, 2009).

The genus *Ammonia* also has a wide distribution and great morphological variety, bearing high salinity ranges. According to Walton and Sloan (1990) two varieties, *A. beccarii* f. *parkinsoniana*, *A. beccarii* f. *tepida* are present in brackish environments, bays, gulfs and estuaries. Boltovskoy (1957) defined for the Rio de la Plata estuary, different biofacies of *A. beccarii* f. *parkinsoniana*, which would correspond to a middle river area with salinities ranging from 0.5 to 25 depending on wind direction (Boltovskoy, 1957). In this paper, for the specific level determination of specimens included in the genus *Ammonia*, we decided to adopt the criterion proposed by Buzas-Stephens et al. (2002), which suggests that the name *A. beccarii* should be reserved exclusively to designate the ornamented form of *Ammonia*, corresponding to the original description. For its part, *A. beccarii* f. *parkinsoniana* and *A. beccarii* f. *tepida* should be named as *A. parkinsoniana* and *A. tepida* respectively, since evidence based on reproductive characteristics, genetic and geographical distribution, indicates that the three forms of *Ammonia* are different species (Calvo-Marcilese et al., 2011). In modern samples collected through the Bahía Blanca estuary, this species are very abundant and are well represented either in the upper and lower reaches of the main channel (Calvo-Marcilese and Pratolongo, 2009).

The *Ammonia-Elphidium* assemblage was mentioned by several authors in estuarine environments as in the English Channel, North Sea, in Puerto Deseado, in Nigeria, on the continental shelf in the Caribbean, Florida and in the Gulf of Mexico (Ishman et al., 1996; Sen Gupta, 2002). Most of *Elphidium* dominated assemblages, with or without dominance of *Ammonia*, are typical of cold water, temperate and tropical continental shelves with clastic substrate and normal salinity (Sen Gupta, 2002). Studies in cores extracted in the area of Florida, USA, suggest that the *Ammonia-Elphidium* assemblage would indicate oligohaline to mesohaline conditions with salinities of 5–18. A gradual increase in salinity would lead to an *Elphidium* increase and a decrease in the number of individuals of the genus *Ammonia* (Brewster-Wingard et al., 1996). It is a common assemblage in New Zealand and its surroundings, present in intertidal mud and sand, mostly on tidal flats and beaches (Hayward and Hollis, 1994). This assemblage occurs at shallow subtidal depths and in the lower half of the intertidal zone in the channels and tidal mud and sand flats at the seaward end of the Bahía Blanca estuary (Calvo-Marcilese and Pratolongo, 2009).

It is important to mention the complete absence of agglutinated specimens along the Holocene sections, which are very well represented in modern samples of the same estuary (Calvo-Marcilese and Pratolongo, 2009) and are typical in coastal environments worldwide (Boltovskoy et al., 1980; Hayward and Hollis, 1994; Gehrels and Van de Plassche, 1999; de Rijk and Troelstra, 1999).

In modern environments from the Bahía Blanca estuary the *Trochammina inflata* assemblage has a low diversity (>5 species) and is dominated by *Trochammina inflata* and *Jadammina macrescens*. Other agglutinated species often present is *Miliammina fusca*, along with the calcareous forms *Haynesina germanica*, *A. tepida*, *A. parkinsoniana* and *Elphidium gunteri* (Calvo-Marcilese and Pratolongo, 2009). This assemblage appears to occur between mean high water (MHW) and mean high water spring (MHWS) in very sheltered, muddy environments with slightly lowered salinity. The lack of this group in the fossil sections could be related to selective preservation that leads to the disintegration of the tests, and their subsequent loss in the sedimentary record (Goldstein and Watkins, 1999). This absence could also be related to the fact that the sampled sections would not have been ideal for the settlement of agglutinated microfauna. Previous studies suggest that agglutinated foraminifera have been found inhabiting very specific vertical zones and occupying narrowly defined niches within the salt marshes or the middle and upper intertidal (Scott and Medioli, 1978; Gehrels, 1994; de Rijk and Troelstra, 1999; Haslett et al., 2001). It has been demonstrated as well that species as *T. inflata* and *J. macrescens* have robust and resistant tests and therefore are feasible preserved in the fossil record (de Rijk and Troelstra, 1999; Gehrels and Van de Plassche, 1999). Consequently, if the environments were suitable for the settlement and development of these species, the tests could have been preserved.

The low diversity (S) recorded in this section along the relatively low abundances, would indicate the development of a marginal marine environment subject to variations in environmental stability (Buzas and Gibson, 1969; Murray, 1991).

Variations in abundance of *A. parkinsoniana*, *Buccella peruviana*, and *Elphidium* species reflect oscillations in the degree of marine influence, as a result of environmental changes that occurred during the deposition of the sequence (Márquez and Ferrero, 2011). These considerations support the fact that the faunal assemblage recovered in this section, is typical of a restricted marine environment (Cusminsky et al., 2006; Calvo-Marcilese and Pratolongo, 2009; Calvo-Marcilese et al., 2011).

According to the zonations established from cluster analysis, qualitative and quantitative calculations, it was possible to recognize the development of shallow marginal marine environments with species characteristic of deeper waters, reflecting larger marine connection and significant flooding of the site (Zone N1-F1) (Fig. 3). Then, the gradual passage to low energy brackish environments (Zone N1-F2) was observed; with mixture of waters and variable salinity (Fig. 3). This section is characterized by the progressive decrease in foraminifera with more marine-affinity, and an increase in more restricted-estuarine species. Consequently it was possible to recognize the development of shallow marginal marine or estuarine environments, with predominantly mesohaline fauna, characterized by the dominance of a few foraminiferal species able to tolerate large salinity variations and environmental instability.

6.2. Calcareous nannofossils

Since there is no particular information about living calcareous nannoplankton in the Bahía Blanca estuary, we are not able to compare the fossil assemblages with their living counterparts. However, the assemblages found in all samples are coincident to the “cold-water association” that Mostajo (1985, 1986) defined for the southwestern Atlantic Ocean, which is characterized by *C. leptoporus*, *C. pelagicus*, *E. huxleyi*, *G. oceanica*, *H. carteri* and *U. sibogae*. Differences observed between Zones N1-CN1 and N1-CN2 were evaluated at the light of high-latitude Atlantic Ocean analogs and what is known about the response of selected species (*E. huxleyi* and *G. oceanica*) to environmental parameters. As it is evidenced by the cluster analysis, the main difference in these two zones is the inversion of relative abundance between *G. oceanica* and *E. huxleyi* (Fig. 4). Two other patterns could be deduced along Fig. 4 and these are: the slow but progressive decrease in *C. pelagicus* relative abundance, and the slightly increase of *C. leptoporus* relative abundance. We assume that these differences respond to changes in the paleoenvironmental conditions, and in estuarine environments one of the most variable parameters are salinity and water stratification; due to fresh-water and nutrient input, and tidal dynamics. Those parameters are probe to have a direct impact on the assemblage composition of calcareous nannoplankton (Bukry, 1974; Houghton, 1993; Jordan, 2002). Both *E. huxleyi* and *G. oceanica* share same ecological strategies and are found in high abundance in nutrient-rich waters as upwelling areas and along the outer continental shelves (Brand, 1994), but they also compete with each other. In modern seas, *G. oceanica* dominates eutrophic warm-water marginal seas, being more evident in the Pacific Ocean, and *E. huxleyi* dominates in middle to high-latitude marginal seas (McIntyre and Bé, 1967; Houghton, 1993; Winter et al., 1994). In the Atlantic Ocean, the dominance of *E. huxleyi* over *G. oceanica* is more manifest, but in some rich-nutrient seas as the upwelling regions off northwestern and southwestern Africa, and the continental slope off South America, *G. oceanica* can reach high relative abundances (Houghton, 1993; Mostajo, 1985, 1986; Baumann et al., 2004; Ziveri et al., 2004). Even when both are considered to be eurytopic opportunistic species, *E. huxleyi* can tolerate a wider range of salinity and temperature conditions than *G. oceanica* (Brand, 1994; Winter et al., 1994; Jordan, 2002). *Emiliania huxleyi* can build up to 100% of the assemblage in low salinity environments as the Norwegian fjords (Braarud, 1962; Berge, 1962), the Black Sea (Bukry, 1974) and the Sea of Azov (Pitsky, 1963).

Zone N1-CN1 shows high relative abundance of *C. pelagicus* and *G. oceanica*, and very low relative abundance of *E. huxleyi*. Zone N1-CN2 shows high relative abundance of *E. huxleyi* and *C. pelagicus* (Fig. 4). Zone N1-CN1 is thought to represent normal salinity eutrophic conditions in the middle and deeper parts of the estuary with similar composition and species richness as the cold-water association described by Mostajo (1985, 1986) for the Argentinean continental shelf. The sporadic occurrence of warm-water preferring species, like *Pontosphaera japonica* and *Oolithotus antillarum* in the oldest sample could be explained due to the proximity of the study area to the transitional zone (*sensu* Mostajo, 1985, 1986), where warm-water and cold-water coccolithophore assemblages are mixed. Zone N1-CN2 is interpreted as a restricted marine environment with high fresh-water input representing inland parts of the estuary dominated almost exclusively by *E. huxleyi*. Also, it is quite interesting the presence of *Gephyrocapsa caribbeanica* in some of the samples studied herein; a species with cold-water affinity. Its low abundance, mainly if compared to the *G. oceanica*, may be due to the better tolerance of the last one to coastal conditions. In North Atlantic assemblages, *G. caribbeanica* replace *G. oceanica* at high latitudes but it decreases towards near-shore environments (Geitzenauer et al., 1977; Houghton, 1993). Moderate to high relative abundance of *C. pelagicus* and *C. leptoporus* in Zone N1-CN2 seems to have no reason since those species need normal marine conditions to prosper (Ziveri et al., 2004). Our explanation is that those species in Zone N1-CN2 represent a taphonomic-selected fraction, transported from outer areas of the estuary by tidal flows. *Coccolithus pelagicus* and *C. leptoporus* have large and robust coccoliths that can better resist traction and dissolution than *G. oceanica*. Moreover, *C. leptoporus* is known to be one of the most dissolution resistant species (Schneidermann, 1977) and that could explain its increasing relative abundance compared to the decreasing relative abundance of *C. pelagicus* up to the top of the succession.

6.3. Integrated approach

As already demonstrate Alday et al. (2006), the combination of benthic foraminifera, calcareous nannofossils and sedimentological information serves as a robust proxy for the recognition and identification of different paleoenvironmental stages, from marine to estuarine. In this case, the benthic foraminifera and calcareous nannofossils recovered along the succession at Napostá N1 site show, together, a gradual passage from restricted marine conditions to an estuarine to continental environment, similar to the current Napostá Grande stream regime. On the basis of these two independent approaches, and with the control of the sedimentological data, it was possible to integrate the information and to identify three estuarine paleoenvironmental stages throughout the Napostá N1 site (Fig. 5).

The lower part of the succession (stage A) starts with marine sands and silty-clays that contain a marine restricted benthic foraminifera assemblage and a low diversity mesotrophic calcareous nannofossil assemblage (zones N1-F1 and N1-CN1). It is interpreted as an estuarine environment with higher marine influence.

The middle part (stage B) continues with massive silty-clays and sandy silty-clays with typical tidal flow lenticular bedding structures in the middle portion. It also shows a gradual change in the composition of microfossil assemblages. The increasing relative abundance of widely known opportunistic and marginal marine benthic foraminifera species such as *Buccella* sp., *Elphidium* spp. and *Ammonia* sp., and of the euryhaline and eurythermal opportunistic calcareous nannofossil *E. huxleyi* (zones N1-F2 and N1-CN2) suggests the establishment of more restricted estuarine conditions with higher fresh-water input. Regardless of the lenticular bedding structure, lithologic features through stages A and B are almost the same and it will be virtually impossible to delimitate the boundary between both stages on the basis of sedimentary analysis by its own. The boundary between stages A and B could be better identified on the basis of the microfossil assemblages. Even though benthic foraminifers and calcareous nannofossils zonations show some differences in their boundaries (N1-F1/N1-F2 limit between samples 11 and 12 and N1-CN1/N1-CN2 limit between samples 8 and 9, see Fig. 5), it is believed that this situation, rather than being an inconsistence, is a confirmation of the value of combining both proxies to improve paleoenvironmental interpretation. If the whole succession is considered, both benthic foraminifera and calcareous nannofossils are showing a gradual passage from an estuarine environment with higher marine influence to a more restricted one. The differences in the boundary location might be due to several aspects concerning the gradual passage from one stage to the other, the differential ecological tolerances of these microfossils groups, and their differential taphonomic responses linked to the differences in their size, lifestyle and habitat preferences. For practical purposes, the position of the stages A/B boundary in Fig. 5 has been selected according to the benthic foraminifera results because, since they display infaunal positions of life, they are less subject to transport and reworking, while calcareous nannofossil must have had some transportation until the final burial through the water column; and because there is plenty information on the living benthic foraminifers of Bahía Blanca estuary compared to that of living calcareous nannoplankton.

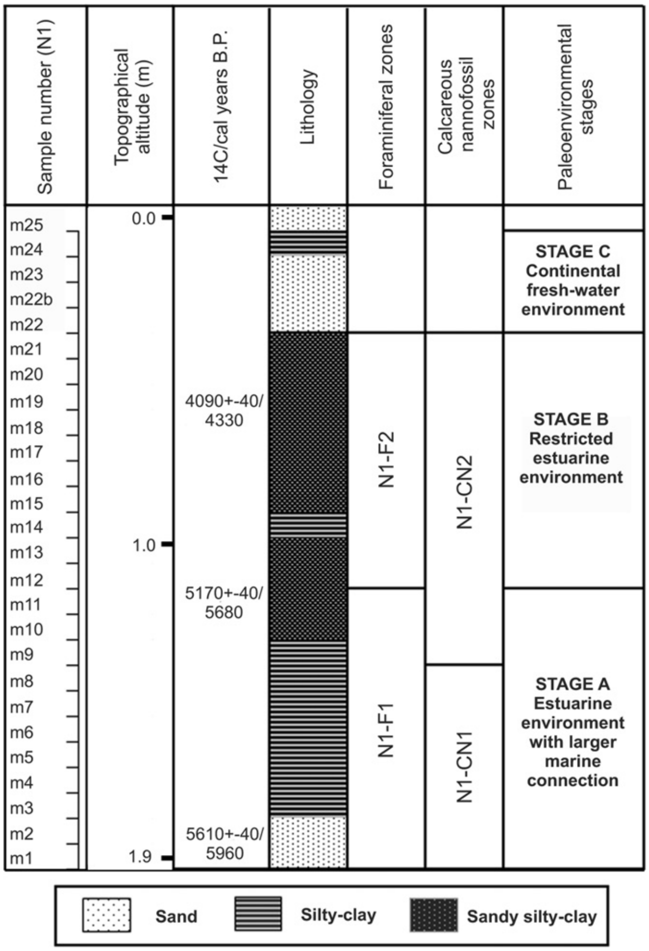

Fig. 5. Summary of sedimentology, micropaleontological zones and paleoenvironmental stages throughout Napostá N1 site.

The upper part of the succession (stage C) is composed of coarse sands with sedimentary structures that show lateral migration of channels that are nearly barren of calcareous microfossils. The scarce foraminifers and calcareous nannofossils recovered within this section are considered to be reworked. This part represents the establishment of the modern continental freshwater conditions of the Napostá Grande stream.

Considering the inner location of the site in relation to the present day coastline and the geomorphologic constrain of the system, the paleoenvironments identified here represent different facies and estuarine stages of this area within the Bahía Blanca estuary. Causes of these environmental changes may be due to sea-level fluctuation as a forcing mechanism, but also shallowness of main channels, development of sand barriers and lateral migrations of fresh-water tributaries of the estuary could lead to limitations in the marine influence on a given position of the estuary. However, Isla (1989) and Cavallotto (2002), among others, proposed that at *ca.* 6000 yrs BP the maximum of the transgressive event occurred. Considering the radiocarbon dates, the transgression promoted a landward migration of the present-day shoreline generating a wide embayment. Between 5170 (5680 cal. BP) and 4090 (4330 cal. BP) yrs BP euryhaline conditions prevailed in a restricted environment. Afterwards, the marine influence kept dropping coincidently with the regressive event developed at regional level, besides that the lower reaches of the Napostá Grande stream were affected by fluvial flooding events (Borel et al., submitted for publication). Towards the top of the section, continental evidences were registered.

7. Conclusions

From the study of the sedimentary succession at Napostá N1 site, two foraminiferal and two calcareous nannofossil zones were defined. The information obtained after analyzing these microfossil zones, jointly with the sedimentological information, allowed the identification of three different paleoenvironments during the Holocene.

The lower part of the succession (stage A, samples m1–m11) represents an estuarine environment with larger marine connection. The middle part (stage B, samples m12–m21) represents a gradual passage to a more restricted estuarine environment, and the upper part (stage C, samples m22–m25) represents the establishment of the modern continental fresh-water environment of Napostá Grande stream.

This contribution represents the first paleoenvironmental reconstruction in the region, obtained after combining benthic foraminifera and calcareous nannofossil data. It provides alternative evidence of the environmental conditions during the Holocene in this part of the Bahía Blanca estuary and the accurate microfossils response to sea level fluctuations.

Acknowledgments

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Appendix A. Holocene microfossils found in this study

A1: Foraminifera

Ammonia tepida (Cushman) = *Rotalia beccarii* (Linné) var. *tepida* Cushman, 1926
Amphicoryna scalaris (Batsch) = Nautilus (Orthoceras) scalaris Batsch, 1791
Bolivina pseudoplicata Heron-Allen and Earland = *Bolivina pseudoplicata*
Heron-Allen and Earland, 1930
Bolivina striatula Cushman, 1922
Buccella peruviana d'Orbigny, 1839
Bulimina marginata d'Orbigny, 1826
Bulimina patagonica d'Orbigny, 1839
Buliminella elegantissima (d'Orbigny) = *Bulimina elegantissima* d'Orbigny, 1839
Elphidium excavatum (Terquem) = *Polystomella excavata* Terquem, 1876
Elphidium sp. aff. *E. clavatum* Cushman, 1930
Elphidium gunteri Cole = *Elphidium gunteri* Cole, 1931
Elphidium sp. aff. *E. poeyanum* (d'Orbigny, 1839) Tipo I
Elphidium sp. aff. *E. poeyanum* (d'Orbigny, 1839) Tipo II
Elphidium margaritaceum Cushman, 1930
Fissurina laevigata Reuss, 1850
Lagena aspera Reuss, 1861
Lagena laevis (Montagu) f. tenuis = *Ovulina tenuis* Bornemann, 1855
Lagena striata (d'Orbigny) = *Oolina striata* d'Orbigny, 1839
Lagena sp. aff. *sulcata* (Walker y Jacob) f. *lyelli* (Seguenza, 1862)
Miliolinella subrotunda (Montagu) = *Vermiculum subrotundum* Montagu, 1803
Miliolina subrotunda Brady, 1884
Nonion depressulum (Walker y Jacob) = *Nautilus depressulus* Walker and Jacob, 1798
Nonion pauperatum Balkwill y Wright = *Nonion pauperata* Balkwill and Wright, 1885
Nonionella auris (d'Orbigny) = *Valvulina auris* d'Orbigny, 1839
Oolina melo d'Orbigny, 1839
Pyrgo nasuta Cushman, 1935
Pyrgo patagonica (d'Orbigny) = *Biloculina patagonica* d'Orbigny, 1839
Pyrgo peruviana = *Biloculina peruviana* d'Orbigny, 1839
Quinqueloculina seminula (Linné) = *Serpula seminulum* Linné, 1758

A2: Calcareous nannofossils

Calcidiscus leptoporus (Murray and Blackman, 1898) Loeblich and Tappan, 1978
Coccolithus pelagicus (Wallich, 1817) Schiller, 1930
Emiliania huxleyi (Lohmann, 1902) Hay and Mohler in Hay et al., 1967
Gephyrocapsa caribbeanica Boudreaux and Hay, 1967
Gephyrocapsa oceanica Kamptner, 1943
Gephyrocapsa sinuosa Hay and Beaudry, 1973
Helicosphaera carteri (Hay and Mohler in Hay et al., 1967) Locker, 1972
Oolithotus antillarum (Cohen, 1964) Reinhardt in Cohen and Reinhardt, 1968
Pontosphaera japonica (Takayama, 1967) Nishida, 1971
Reticulofenestra sp. Hay et al., 1966
Thoracosphaera sp. Kamptner, 1927
Thoracosphaera heimii (Lohmann, 1919) Kamptner, 1941
Umbilicosphaera sibogae (Weber-van Bosse, 1901) Gaarder, 1970

References

Aguirre, M.L., 1995. Holocene Environmental and Climatic Change Record in the Molluscan Fauna from the Coastal Area of Buenos Aires Province. Institut français de recherche scientifique pour le développement en coopération, Argentina. Antofagasta, pp. 5–6. ORSTOM – IGCP Project 367.

Alday, M., Cearreta, A., Cachão, M., Freitas, M.C., Andrade, C., Gama, C., 2006. Micropaleontological record of Holocene estuarine and marine stages in the Corgo de Portorivulet (Mira River, SW Portugal). Estuarine Coastal and Shelf Science 66, 532–543.

Aliotta, S., Perillo, G.M.E., 1990. Línea de costa sumergida en el Estuario de Bahía Blanca, Provincia de Buenos Aires. Revista de la Asociación Geológica Argentina 45 (3–4), 300–305.

Baumann, K.-H., Böckel, B., Frenz, M., 2004. Coccolith contribution to South Atlantic carbonate sedimentation. In: Thierstein, H.R., Young, J.R. (Eds.), Coccolithophores, from Molecular Processes to Global Impact. Springer-Verlag, Berlín, pp. 367–402.

Berge, G., 1962. Discoloration of the sea due to *Coccolithus huxleyi* "bloom". Sarsia 6, 27–40.

Bernasconi, E., Cusminsky, G.C., 2005. Foraminíferos de un testigo de la plataforma continental argentina. In: Actas del XVI Congreso Geológico Argentino, La Plata, vol. 3, pp. 279–283.

Bertels, A., Martínez, D.E., 1990. Quaternary ostracodes of continental and transitional littoral-shallow marine environments. Courier Forschungsinstitut Senckenberg 123, 141–159.

Bertels, A., Martínez, D.E., 1997. Ostrácodos holocenos de la desembocadura del arroyo Napostá Grande, sur de la provincia de Buenos Aires, Argentina. Revista Española de Micropaleontología 29 (3), 29–69.

Boltovskoy, E., 1954a. Foraminíferos del golfo San Jorge. Revista del Instituto Nacional de Investigaciones y Museo Argentino de Ciencias Naturales Bernardino Rivadavia, Ciencias Geológicas 3, 85–246.

Boltovskoy, E., 1954b. Foraminíferos de la Bahía San Blas. Revista del Instituto Nacional de Investigaciones y Museo Argentino de Ciencias Naturales Bernardino Rivadavia, Ciencias Geológicas 3, 247–300.

Boltovskoy, E., 1957. Los foraminíferos del estuario del Río de La Plata y su zona de influencia. Revista del Instituto Nacional de Investigaciones y Museo Argentino de Ciencias Naturales Bernardino Rivadavia, Ciencias Geológicas 6, 1–77.

Boltovskoy, E., 1965. Los foraminíferos recientes. Eudeba, p. 510.

Boltovskoy, E., 1970. Distribution of the marine littoral Foraminifera in Argentina, Uruguay and Southern Brazil. Marine Biology 6, 335–344.

Boltovskoy, E., 1976. Distribution of recent foraminifera of the South American Region. Foraminifera 2, 171–236.

Boltovskoy, E., Giussani, G., Watanabe, S., Wright, R., 1980. Atlas of Benthic Shelf Foraminifera to the Southwest Atlantic. M. Junk Pub, The Hague, p. 174.

Borel, C.M., Gómez, E.A., 2006. Palinología del Holoceno del Canal del Medio estuario de Bahía Blanca, Buenos Aires, Argentina. Ameghiniana 43, 399–412.

Borel, C.M., Martínez, D.E., Gómez, E.A., Submitted for publication. Mid- to late-Holocene environmental evolution and sea-level fluctuations at the Bahía Blanca estuary, Argentina: evidence from palynology, micropaleontology and sedimentology. The Holocene.

Braarud, T., 1962. Species distribution in marine phytoplankton. Journal of Oceanographical Society of Japan 20, 628–649.

Bramlette, M.N., Sullivan, F.R., 1961. Coccolithophorids and related nannoplankton of the early Tertiary in California. Micropaleontology 2, 129–188.

Brand, L.E., 1994. Physiological ecology of marine coccolithophores. In: Winter, A., Siesser, W.G. (Eds.), Coccolithophores. Cambridge University Press, Cambridge, pp. 39–49.

Brewster-Wingard, G.L., Ishman, S.E., Edwards, L.E., Willard, D., 1996. A Preliminary Report on the Distribution of Modern Fauna and Flora at Selected Sites in North-central and North-eastern Florida Bay. Open-File Report USGS, pp. 96–732.

Bukry, D., 1974. Coccoliths as paleosalinity indicators – evidence from Black Sea. Memoirs of the American Association of Petroleum Geologists 20, 353–363.

Buzas, M.A., Gibson, T.G., 1969. Species diversity: Benthonic Foraminifera in Western North Atlantic. Science 163, 72–75.

Buzas-Stephens, P., Pessagno, E.A., Bowen, C.J., 2002. A review of species names for *Ammonia* and *Elphidium*, common foraminifera along the Texas Gulf Coast. The Texas Journal of Science 54, 3–16.

Calvo-Marcilese, L., 2008. Registros holocenos de *Elphidium* spp. (Foraminifera, Protista) en el área interna del estuario de Bahía Blanca, Argentina. Reunión Anual de Comunicaciones de la Asociación Paleontológica Argentina, Plaza Huincul, pp. 22–23R.

Calvo-Marcilese, L., 2011. Sistemática y paleoecología de los foraminifera (Protista) del holoceno del área del estuario de Bahía Blanca, Argentina. Ph.D. thesis. Facultad de Ciencias Naturales y Museo, Universidad Nacional de La Plata, p. 253. http://sedici.unlp.edu.ar/handle/10915/21866.

Calvo-Marcilese, L., Cusminsky G.C., 2009. Foraminíferos de ambientes intermareales como indicadores de cambio ambiental, Estuario de Bahía Blanca, Buenos Aires, Argentina. IV Congreso Argentino de Cuaternario y Geomorfología. In: XII Congresso da Associação Brasileira de Estudos do Quaternário, II Reunión sobre el Cuaternario de América del Sur. La Plata, Buenos Aires, Argentina. Suplemento resúmenes, p. 80.

Calvo-Marcilese, L., Langer, M., 2010. Breaching biogeographic barriers: the invasion of *Haynesina germanica* (Foraminifera, Protista) in the Bahía Blanca estuary, Argentina. Biological Invasions. http://dx.doi.org/10.1007/s10530-010-9723-x.

Calvo-Marcilese, L., Langer, M., 2012. Ontogenetic morphogenesis and biogeographic patterns: resolving taxonomic incongruences within “species” of *Buccella* from South American coastal waters. Revista Brasileira de Paleontologia 15 (1), 23–32.

Calvo-Marcilese, L., Pérez Panera, J.P., 2008. Microfósiles calcáreos (Foraminíferos y Nanofósiles) del arroyo Napostá Grande, estuario de Bahía Blanca, Argentina. Reunión Anual de Comunicaciones de la Asociación Paleontológica Argentina, Plaza Huincul, p. 22R.

Calvo-Marcilese, L., Pratolongo, P., 2009. Foraminíferos de marismas y llanuras de marea del estuario de Bahía Blanca, Argentina: Distribución e implicaciones ambientales. Revista Española de Micropaleontología 41, 315–332.

Calvo-Marcilese, L., Cusminsky, G., Gómez, E.A., 2007. Foraminíferos bentónicos de un perfil holocénico del Arroyo Napostá Desembocadura. Bahía Blanca. Argentina. Reunión Anual de Comunicaciones de la Asociación Paleontológica Argentina. L Aniversario de Ameghiniana, Corrientes, Resúmenes. Ameghiniana 44, 23–24.

Calvo-Marcilese, L., Langer, M., Cusminsky, G., 2009. Revisión y actualización sistemática de los foraminíferos más conspicuos del Estuario de Bahía Blanca, Argentina. Reunión Anual de Comunicaciones de la Asociación Paleontológica Argentina. Buenos Aires. Ameghiniana, Suplemento Resúmenes 46, 66R.

Calvo-Marcilese, L., Cusminsky, G., Gómez, E.A., 2011. Asociaciones de foraminíferos bentónicos en secciones holocenas del estuario de Bahía Blanca (Buenos Aires, Argentina). Ameghiniana 48 (2), 210–225. http://dx.doi.org/10.5710/AMGH.v48i2(323).

Cavallotto, J.L., 1995. Evolución de la topografía del sustrato del Holoceno del “Río de la Plata”. 4 Jornadas Geológicas y Geofísicas Bonaerenses Junín 1, 223–230.

Cavallotto, J.L., 2002. Evolución holocena de la llanura costera del margen sur del Río de la Plata. Revista de la Asociación Geológica Argentina 57 (4), 376–388.

Cavallotto, J.L., Violante, R.A., Parker, G., 2004. Sea-level fluctuations during the last 8600 years in the de la Plata River (Argentina). Quaternary International 114, 155–165.

Codignotto, J.O., Aguirre, M.L., 1993. Coastal evolution, changes in sea level and molluscan fauna in northeastern Argentina during the late Quaternary. Marine Geology 110, 163–176.

Codignotto, J.O., Kokot, R.R., Marcomini, S.C., 1992. Neotectonism and sea-level changes in the coastal zone of Argentina. Journal of Coastal Research 8 (1), 125–133.

Codignotto, J.O., Kokot, R.R., Marcomini, S.C., 1993. Desplazamientos holocénicos verticales y horizontales de la costa argentina en el Holoceno. Asociación Geológica Argentina 48 (2), 125–132.

Cuadrado, D.G., Ginsberg, S.S., Gómez, E.A., 2007. In: Piccolo, M.C., Hoffmeyer, M.S. (Eds.), Ecosistema del Estuario de Bahía Blanca. Instituto Argentino de Oceanografía, Bahía Blanca, pp. 29–38.

Cusminsky, G.C., Gómez, E.A., Grill, S., Guerstein, R.G., Tumini, L., 1995. Estudio sedimentológico y micropaleontológico de sedimentos superficiales del estuario de Bahía Blanca, provincia de Buenos Aires. Primeros resultados. In: VI Congreso Argentino de Paleontología y Bioestratigrafía, Trelew, Actas, pp. 107–115.

Cusminsky, G.C., Martínez, D.E., Bernasconi, E., 2006. Foraminíferos y ostrácodos de sedimentos recientes del estuario de Bahía Blanca, Argentina. Revista Española de Micropaleontología 38, 395–410.

Cusminsky, G.C., Bernasconi, E., Calvo-Marcilese, L., 2009. Holocene benthic foraminifera from Bahía Blanca estuary: a review and update of systematic and palaeoenvironmental aspects. The Holocene 19, 1–11.

De Francesco, F.O., 1992. Estratigrafía del cenozoico en el flanco occidental de las sierras de Curamalal. Sierras Australes Bonaerenses. In: III Jorn. Geológicas Bonaerenses, pp. 3–12.

de Rijk, S., Troelstra, S.R., 1999. The application of a foraminiferal actuo-facies model to salt marsh cores. Palaeogeography, Palaeoclimatology, Palaeoecology 149, 59–66.

Dudley, W.C., Duplessy, J.C., Blackwelder, P.L., Brand, L.E., Guillard, R.R.L., 1980. Coccoliths in Pleistocene-Holocene nannofossil assemblages. Nature 285, 222–223.

Ferrero, L., 2006. Micropaleontología y Paleoecología del Cuaternario del sudeste de la provincia de Buenos Aires. Ph.D. thesis. Facultad de Ciencias Exactas y Naturales, Universidad Nacional de Mar del Plata, p. 373.

Ferrero, L., 2009. Foraminíferos y ostrácodos del Pleistoceno tardío (Mar Chiquita, provincia de Buenos Aires, Argentina). Ameghiniana 46, 637–656.

Fisher, N.S., Honjo, S., 1991. Intraspecific differences in temperature and salinity responses in the coccolithophore *Emiliania huxleyi*. Biological Oceanography 6, 355–361.

Fray, C., Ewing, M., 1963. Wisconsin sea level as indicated in Argentina continental shelf sediments. Proceedings of the Academy of Natural Sciences of Philadelphia 115, 113–126.

Freije, R.H., Marcovecchio, J., 2007. Oceanografía química. In: Piccolo, M.C., Hoffmeyer, M.S. (Eds.), Ecosistema del Estuario de Bahía Blanca. Instituto Argentino de Oceanografía, Bahía Blanca, pp. 69–78.

Gehrels, W.R., 1994. Determining sea-level change from salt-marsh foraminifera and plant zones on the coast of Maine, U.S.A. Journal of Coastal Research 10, 990–1009.

Gehrels, W.R., Van de Plassche, O., 1999. The use of *Jadammina macrescens* (Brady) and *Balticammina pseudomacrescens* Brönnimann, Lutze and Whittaker (Protozoa: Foraminiferida) as sea-level indicators. Palaeogeography, Palaeoclimatology, Palaeoecology 149, 59–66.

Geitzenauer, K.R., Roache, M.B., McIntyre, A., 1977. Coccolith biogeography from North Atlantic and Pacific surface sediments. In: Ramsay, A.T.S. (Ed.), 1977. Oceanic Micropaleontology, vol. 2. Academic Press, London, pp. 973–1008.

Giunta, S., Negri, A., Morigi, C., Capotondi, L., Combourieu-Nebout, N., Emeis, K.C., Sangiorgi, F., Vigliotti, L., 2003. Coccolithophorid ecostratigraphy and multi-proxy paleoceanographic reconstruction in the Southern Adriatic Sea during the last deglacial time (Core AD91-17). Palaeogeography, Palaeoclimatology, Palaeoecology 190, 39–59.

Goldstein, S.T., Watkins, G.D., 1999. Taphonomy of salt marsh foraminifera: an example from coastal Georgia. Palaeogeography, Palaeoclimatology, Palaeoecology 149, 103–114.

Gómez, E., Perillo, G.M.E., 1995. Sediment outcrops underneath shoreface-connected sand ridges, outer Bahía Blanca Estuary, Argentina. Quaternary of South America and Antarctica Peninsula 9, 27–42.

Gómez, E.A., Martínez, D.E., Cusminsky, G.C., Suárez, M.I., Vilanova, R.F., Guerstein, G.R., 1992. Estudio del testigo PS2, Cuaternario del estuario de Bahía Blanca, provincia de Buenos Aires. In: Parte I: Sedimentología y micropaleontología. III Jornadas Geológicas Bonaerenses, Actas, pp. 38–46.

Gómez, E.A., Martínez, D.E., Borel, C.M., Guerstein, G.R., Cusminsky, G.C., 2005. Submarine evidences of Holocene sea-level fluctuations in the Bahia Blanca estuary, Argentina. Journal of South American Earth Sciences 20, 139–155.

Gómez, E.A., Martínez, D.E., Borel, C.M., Guerstein, G.R., Cusminsky, G.C., 2006. Negative sea-level oscillation at the Bahía Blanca estuary related to a ca. 2650 yr BP global climatic chang. Journal of Coastal Research 39, 181–185. Special issue.

Gómez, E.A., Borel, C.M., Aguirre, M.L., Martínez, D.E., 2008. Radiocarbon reservoir ages and hardwater effect for the NE coastal waters of Argentina. Radiocarbon 50, 1–11.

Grimm, E.C., 1991. Tilia Software. Illinois State Museum. Research and Collection Center, Springfield, Illinois.

Guerstein, G.R., Vilanova, R.F., Suárez, M.I., Cusminsky, G.C., Martínez, D.E., Gómez, E.A., 1992. Estudio del testigo PS2, cuaternario del estuario de Bahía Blanca, provincia de Buenos Aires. In: Part II: evaluación paleoambiental. III Jornadas Geológicas Bonaerenses, Actas, pp. 47–52.

Hagino, K., Okada, H., Matsuoka, H., 2000. Spatial dynamics of coccolithophore assemblages in the Equatorial Western-Central Pacific Ocean. Marine Micropaleontology 39, 53–72.

Haslett, S.K., Strawbridge, F., Martin, N.A., Davies, C.F.C., 2001. Vertical Saltmarsh accretion and its relationship to sea-level in the Severn estuary, U.K.: an investigation using foraminifera as tidal indicators. Estuarine, Coastal and Shelf Science 52, 143–153.

Hayward, B.W., Hollis, C.J., 1994. Brackish foraminifera in New Zealand: a taxonomic and ecologic review. Micropaleontology 40, 185–221.

Houghton, S.M., 1993. Recent coccolith sedimentation patterns and transport in the North Sea: implications for palaeoceanographic studies of marginal and continental shelf seas. In: Jenkins, D.G. (Ed.), Applied Micropaleontology. Kluwer Academic Publishers, Dordrecht, pp. 1–39.

Hughen, K.A., Baillie, M.G.L., Bard, E., Beck, J.W., Bertrand, C.J.H., Blackwell, P.G., Buck, C.E., Burr, G.S., Cutler, K.B., Damon, P.E., Edwards, R.L., Fairbanks, R.G., Friedrich, M., Guilderson, T.P., Kromer, B., McCormac, F.G., Manning, S., Bronk Ramsey, C., Reimer, P.J., Reimer, R.W., Remmele, S., Southon, J.R., Stuiver, M., Talamo, S., Taylo, R.F.W., van der Plicht, J., Weyhenmeyer, C.E., 2004. Marine04 marine radiocarbon age calibration, 0–26 cal kyr BP. Radiocarbon 46, 1059–1086.

Ishman, S.E., Brewster-Wingard, G.L., Willard, D., Cronin, T.M., Edwards, L.E., Holmes, C.W., 1996. Preliminary Paleontologic Report on Core T-24, Little Madeira Bay, Florida. Open-File Report USGS, pp. 96–543.

Isla, F.I., 1989. Holocene sea-level fluctuation in the southern hemisphere. Quaternary Science Reviews 8, 359–368.

Jordan, R.W., 2002. Environmental applications of calcareous nannofossils. In: Haslett, S.K. (Ed.), Quaternary Environmental Micropaleontology. Oxford University Press, New York, pp. 185–206.

Kleijne, A., 1990. Distribution and malformation of extant calcareous nannoplankton in the Indonesian Seas. Marine Micropaleontology 16, 293–316.

Kleijne, A., 1991. Holococcolithophorids from the Indian Ocean, Red Sea, Mediterranean Sea and North Atlantic Ocean. Marine Micropaleontology 17, 1–76.

Laprida, C., García Chapori, N., Violante, R.A., Compagnucci, R.H., 2007. Mid-Holocene evolution and paleoenvironments of the shoreface–offshore transition, north-eastern Argentina: New evidence based on benthic microfauna. Marine Geology 240, 43–56.

Loeblich, A., Tappan, H., 1988. Foraminiferal Genera and Their Classifications, vol. 1–2. Van Nostrand Reinhold, New York, p. 1182.

Loiseleur-Deslongchamps, J.L.A., 1807. Flora Gallica, seu enumeratio plantarum in gallia sponte nascentium, p. 742.

Márquez, M., Ferrero, L., 2011. Paleoecología de foraminíferos de un testigo holoceno en la planicie costera de la laguna Mar Chiquita, Buenos aires, Argentina. Ameghiniana 48, 289–304.

Martínez, D.E., 2002. Microfauna (Ostracoda, Crustacea) del Cuaternario de las Cercanías de Bahía Blanca, República Argentina. Ph. D. thesis. Universidad Nacional del Sur, Bahía Blanca, p. 378.

McCormac, F.G., Hogg, A.G., Blackwell, P.G., Buck, C.E., Higham, T.F.G., Reimer, P.J., 2004. SHCal04 southern hemisphere calibration 0–11.0 cal kyr BP. Radiocarbon 46, 1087–1092.

McIntyre, A., 1967. Coccoliths as paleoclimatic indicators of Pleistocene glaciation. Science 158, 1314–1317.

McIntyre, A., Bé, A.W.H., 1967. Modern coccolithophorida of the Atlantic Ocean-1. Placoliths and Cyrtoliths. Deep Sea Research and Oceanographic Abstracts 14, 561–597.

McIntyre, A., Bé, A.W.H., Roche, M.B., 1970. Modern Pacific coccolithophorida: a paleontological thermometer. Transactions of the New York Academy of Sciences 32, 720–731.

Montesarchio, L.A., Lizasoain, W.O., 1981. Dinámica sedimentaria en la denominada ría de Bahía Blanca. In: Contribución científica, vol. 58. Instituto Argentino de Oceanografía, Bahía Blanca, Argentina, p. 31, 208.

Mostajo, E.L., 1985. Nanoplankton calcáreo del Océano Atlántico Sur. Revista Española de Micropaleontología 17, 261–280.

Mostajo, E.L., 1986. La tanatocenosis de cocolitofóridos como indicadores biológicos de masas de agua superficiales. Neotrópica 32, 167–170.

Murray, J.W., 1991. Ecology and Paleoecology of Benthic Foraminifera. Longman, Wiley, New York, p. 397.

Murray, J.W., 2006. Ecology and Applications of Benthic Foraminifera. Cambridge University Press, Cambridge, p. 426.

Okada, H., Honjo, S., 1975. Distribution of coccolithophores in marginal seas along the western Pacific Ocean and in the Red Sea. Marine Biology 31, 271–285.

Parker, G., Violante, R.A., 1982. Geología del frente de costa y plataforma interior entre Pinamar y Mar de Ajó, Provincia de Buenos Aires. Acta Oceanographica Argentina 3, 57–91.

Perillo, G.M.E., Piccolo, M.C., Arango, J.M., Sequeira, M.E., 1987. Hidrografía y circulación del estuario de Bahía Blanca, Argentina, en condiciones de baja descarga. In: Proceedings of 2° Congreso Latinoamericano de Ciencias del Mar, Perú, II; pp. 95–104.

Perillo, G.M.E., Piccolo, M.C., Palma, E.D., Pérez, D.E., Pierini, J.O., 2007. Oceanografía física. In: Piccolo, M.C., Hoffmeyer, M.S. (Eds.), Ecosistema del Estuario de Bahía Blanca. Instituto Argentino de Oceanografía, Bahía Blanca, pp. 61–67.

Piccolo, M.C., Perillo, G.M.E., 1999. Geomorphologic and physical characteristics of the Bahía Blanca estuary. In: Perillo, G.M.E., Piccolo, M.C., Pino Quivira, M. (Eds.), Estuaries of South America: their Geomorphology and Dynamics. Environmental Science Series. Springer-Verlag, Berlin, pp. 195–216.

Piccolo, M.C., Perillo, G.M.E., Arango, J.M., 1988. Hidrografía del Estuario de Bahía Blanca, Argentina. Revista Geofísica 26, 75–89.

Pitsky, G.K., 1963. O kachestvennom sostave fytoplanktona Azovskogo morya (On the qualitative composition of Phytoplankton in the Sea of Azov). Trudy Sevastopol Biological Station 16, 71–89.

Poag, C.W., 1978. Paired foraminiferal ecophenotypes in gulf coast estuaries: ecological and paleoecological implications. Transactions of the Gulf Coast Association of Geological Societies 28, 395–420.

Roth, P.H., 1994. Distribution of coccoliths in oceanic sediments. In: Winter, A., Siesser, W.G. (Eds.), Coccolithophores. Cambridge University Press, Cambridge, pp. 199–218.

Schnack, E., Isla, F., De Francesco, F., Fucks, E., 2005. Estratigrafía del Cuaternario Marino Tardío en la Provincia de Buenos Aires. In: De Barrio, R., Etcheverry, R., Caballé, M., Llambías, E. (Eds.), Geología y Recursos Minerales de la provincia de Buenos Aires, 16° Congreso Geológico Argentino, Relatorio, pp. 159–182. La Plata.

Schneidermann, N., 1977. Selective dissolution of recent coccoliths in the Atlantic Ocean. In: Ramsay, A.T.S. (Ed.), 1977. Ocean Micropaleontology, vol. 2. Academic Press, London, pp. 1009–1053.

Scott, D.B., 2006. Testate rhizopods as reliable, cost-effective indicators of environmental change. Anuário do Instituto de Geociências - UFRJ 29, 129–140.

Scott, D.B., Medioli, F.S., 1978. Vertical zonations of marsh foraminifera as accurate indicators of former sea levels. Nature 272, 528–531.

Sen Gupta, B.K., 1999. In: Gupta, Sen (Ed.), Introduction to Modern Foraminifera. Modern Foraminifera. Kluwer Academic Publ, p. 371.

Sen Gupta, B.K., 2002. Foraminifera in marginal marine environments. In: Sen Gupta, B.K. (Ed.), Modern Foraminifera. Kluwer Academic Publ, pp. 151–159.

Stuiver, M., Reimer, P.J., Reimer, R.W., 1986–2010. CALIB 6.0.1. Available at: http://calib.qub.ac.uk/calib/.

Takahashi, K., Okada, H., 2000. The paleoceanography for the last 30,000 years in the southeastern Indian Ocean by means of calcareous nannofossils. Marine Micropaleontology 40, 83–103.

Theyer, F., 1966. Variationstatische Untersuchungen zur Verbreitung der Gattung Buccella Andersen im Südlichen Teil Südamerikas (Protozoa, Foraminifera). Zoologische Jahrbücher Abteilung für Systematik 8, 203–222.

Violante, R.A., Parker, G., Cavallotto, J.L., 2001. Evolución de las llanuras costeras del este bonaerense entre la Bahía Samborombón y la laguna Mar Chiquita durante el Holoceno. Revista de la Asociación Geológica Argentina 56, 51–66.

Walton, W.R., Sloan, B.J., 1990. The genus *Ammonia* Brünnich, 1772: Its geographic distribution and morphologic variability. Journal of Foraminiferal Research 20, 128–156.

Watabe, N., Wilbur, K.M., 1966. Effects of temperature on growth, calcification, and coccolith form in *Coccolithus huxleyi* (Coccolithinae). Limnology and Oceanography 11, 567–575.

Wilbur, K.M., Watabe, N., 1967. Mechanisms of calcium carbonate deposition in coccolithophorids and molluscs. Studies in Tropical Oceanography 5, 133–154.

Winter, A., Jordan, R.W., Roth, P., 1994. Biogeography of living coccolithophores in ocean waters. In: Winter, A., Siesser, W.G. (Eds.), Coccolithophores. Cambridge University Press, Cambridge, pp. 161–177.

Ziveri, P., Baumann, K.-H., Böckel, B., Bollmann, J., Young, J.R., 2004. Biogeography of selected Holocene coccoliths in the Atlantic Ocean. In: Thierstein, H.R., Young, J.R. (Eds.), Coccolithophores, from Molecular Processes to Global Impact. Springer-Verlag, Berlín, pp. 403–428.