

Taphonomic processes affecting late Quaternary molluscs along the coastal area of Buenos Aires Province (Argentina, Southwestern Atlantic)

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Abstract

Molluscan concentrations were abundantly deposited along the coastal area of Buenos Aires Province (Argentina, Southwestern Atlantic) by different sea-level episodes during the late Quaternary. Most of them represent Holocene ridges (highly energetic depositional environments) subparallel to the modern shore where the main associations preserved are parautochthonous, and others (mainly autochthonous associations) occurring in tidal flats seaward of the ridges or coastal lagoon deposits accumulated behind them (low-energetic). Analysis of three physical taphonomic signatures (disarticulation, fragmentation and abrasion) of the molluscan skeletons of four bivalve species (*Tagelus plebeius*, *Maetra isabelleana*, *Pitar rostratus*, *Brachidontes rodriguezii*), which exhibit different shell shape and thickness conditions, habitats and life habits and represent the most widely distributed and palaeoecologically significant taxa along the area of study, support the distinction of both palaeoenvironments, characterized by low and high taphonomic grades, respectively. The taphonomic alteration (breakage and abrasion) of most shells seems to have been a direct consequence of the amount of reworking of the material especially during periods of exposure along an extensive beach zone, more than a consequence of transport from a distant original habitat. Abrasion signatures are the only probably correlated with after death time span, shells showing a near modern aspect and original luster being most probably younger than those with chalky or polished appearance. The infaunal species analysed typically living on clays and silts or fine sandy bottoms of the infralittoral or intertidal (*T. plebeius*, *M. isabelleana*) are better preserved (less fragmented and abraded) than shells of the epibyssate *B. rodriguezii*, which lives on hard bottoms of the intertidal and supralittoral areas more exposed to highly unstable conditions with longer episodes of exposure. Although these nearshore concentrations may represent a time-averaging of 1000 yr B.P., taking into account the ecological requirements of the most constant and dominant taxa together with the taphonomic analysis of shells from parautochthonous and autochthonous associations, they still represent valid indicators of past marginal marine conditions in the area, but are only reliable to establish long-term palaeoenvironmental variations. © 1999 Elsevier Science B.V. All rights reserved.

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1. Introduction

As a consequence of late Quaternary sea-level fluctuations shell concentrations accumulated along the Atlantic coastal area of South America (i.e., Guiana to Argentina). In Argentina they extend from the Río de La Plata littoral down to Patagonia and Tierra del Fuego in the south. Between Punta Indio and Bahía Blanca along the coastal area of Buenos Aires Province (Fig. 1), they are especially abundant and well preserved reflecting palaeoenvironmental conditions and the effect of differential taphonomic processes on the molluscan shells occurred mainly during the Holocene (since ca. >7000 yr B.P.).

Available studies for this area relate to several aspects of Late Pleistocene and Holocene marine deposits (review by Aguirre and Whatley, 1995a), e.g., sedimentological (Spalletti et al., 1987; Farinati et al., 1992), stratigraphical (Fidalgo, 1979; Fasano et al., 1982; Violante, 1988; among others), geochronological (Fidalgo et al., 1981; Farinati, 1985b; González et al., 1988; Figini et al., 1990; Aguirre et al., 1995), geomorphological (Fidalgo et al., 1973; Aliotta and Farinati, 1990; Codignotto and

Aguirre, 1993; Cavalotto, 1995) and palaeontological work (Tonni et al., 1981; González et al., 1983; Tonni and Cione, 1984; Farinati, 1985a; Farinati and Aliotta, 1987; Aguirre, 1993a; among others). Many of these studies concentrate on isolated localities or restricted areas, but provide a basic framework to interpret the coastal evolution, sea level and environmental changes in the area.

Taphonomic studies based on these shelly concentrations (taphocoenoses) have recently been initiated by Farinati and Zavala (1995) and Farinati and Aliotta (1997) for Quequén Salado and Bahía Blanca areas (Fig. 1) and by Aguirre (1993a,b, 1994) for Berisso–Mar Chiquita, while outside the area of this study Gordillo (1994) analysed bioerosion signatures of recent and fossil bivalves from the Beagle Channel (Tierra Del Fuego).

We now attempt to emphasize the taphonomic attributes of these fossil concentrations combining localities from both areas. The littoral deposits sampled which were accumulated by transgressive–regressive episodes during the Holocene (since ca. 7700 ^{14}C yr B.P.) along a relatively extensive coastal area of Buenos Aires Province.

We analyse the behaviour of the main taphonomic attributes of the taxa selected as a consequence of different depositional conditions and particular characteristics of their shells, life habits and habitats. Provided a relatively thorough knowledge of the taxa is available (e.g. taxonomic composition, ecologic requirements of the species considered, species distribution along the area of study, adaptations to substrate types, among others) taphonomic signatures of death assemblages can be useful supplementary palaeoenvironmental indicators (Fürsich and Flessa, 1987).

This approach would allow us to evaluate the response of the most abundant and palaeoecologically significant bivalve species occurring in the late Quaternary littoral deposits from the study area to post-mortem processes and to check previous palaeoenvironmental interpretations referred to the Holocene deposits studied (ridges and tidal flats).

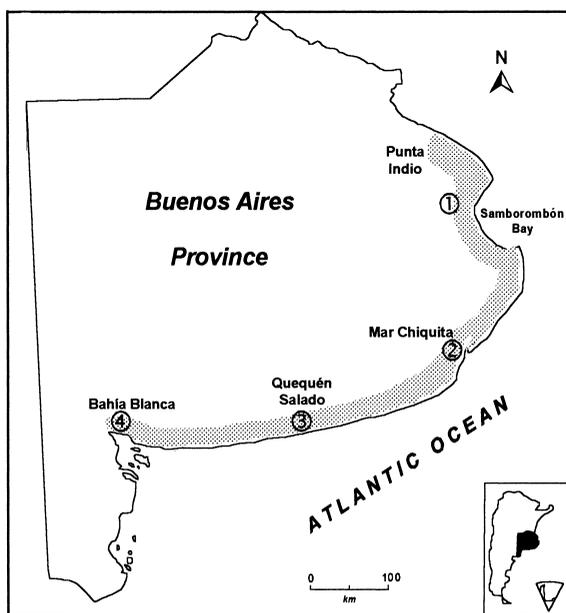


Fig. 1. Area of study and localities analysed. 1 = Punta Indio-Samborombón Bay; 2 = Mar Chiquita; 3 = Quequén Salado; 4 = Bahía Blanca.

2. Area descriptions

The Buenos Aires Province coastal area considered in this study is shown in Fig. 1. It extends for some 800 km from the Río de La Plata littoral (Punta Indio surroundings) down to Bahía Blanca surroundings (ca. 39°S). The Holocene deposits studied form part of the so-called marine 'Platense' Stage (Frenguelli, 1957) or Las Escobas Fm. (Fidalgo, 1979) and equivalents. They are important testimonies of the sea-level oscillations occurred during the last transgression since approximately 7500 ¹⁴C yr B.P. (Fasano et al., 1987).

They are especially abundant as littoral shell ridges and less frequently as tidal flat deposits which represent parautochthonous (ridges) and autochthonous (tidal flats) associations (Kidwell et al., 1986). Exposures occur from Buenos Aires city surroundings down to Mar Chiquita and again at Quequén Salado and around Bahía Blanca estuary. They continue southwards outside of the area of our study along Patagonia (Río Negro, Chubut and Santa Cruz provinces) and Tierra del Fuego and northwards along Uruguay, Brazil and Guiana (Gordillo, 1991; Gordillo et al., 1993; Pastorino, 1994; other references in Aguirre and Whatley, 1995b).

The Holocene deposits studied formed as a consequence of different sea-level episodes during the last transgression. Most of them represent high energy shelly deposits (littoral ridges) and less abundantly they can occur as low energy tidal flat and coastal lagoon deposits. Ridges from the whole area can be distinguished in terms of size, profile, shell fragmentation and lithology (Fig. 2) most probably reflecting different processes of ridge formation in the regions considered (see Meldahl, 1995), but detailed sedimentological and geomorphological studies for the whole area are still lacking. Their taxonomic composition includes mostly gastropods and bivalves, and an associated invertebrate macro and microfauna.

The selected areas for this study are located within four major regions (Fig. 1) which are representative of the whole marine Holocene of the Buenos Aires Province: (1) Punta Indio-Samborombon Bay; (2) Mar Chiquita; (3) Quequén Salado; and (4) Bahía Blanca. Observations are based on bulk samples (totalling 40) taken from different beds recognized within each locality.

2.1. Punta Indio-Samborombon Bay area (study region 1; Fig. 2)

Along this area Holocene coastal landforms developed over an erosional platform on pre-Holocene deposits. There have been recognized two geomorphologic features: well developed ridges subparallel to the modern coastline (Cerro de la Gloria Mb. of Las Escobas Fm. in Samborombon Bay area = marine facies of Mar Chiquita Fm. in the homonymous southern area) and coastal lagoon deposits accumulated behind the ridges (Canal 18 Mb. of Las Escobas Fm.). Previous studies (Codignotto and Aguirre, 1993) illustrated the occurrence of a progradational sequence of nearly parallel ridges and inter-ridge mudflats. This is a similar pattern to that described for Baja California (Kowalewski and Flessa, 1995).

2.1.1. Ridges

The Holocene beach ridge facies is represented by nearly parallel domed deposits, subparallel to the modern shore, composed of coarse medium sand and abundant whole small shells, progressively younging towards the coast. They extend for some 120 km and occur 5 km inland in the area of P. Indio and 30 km inland in southern Samborombon Bay. They generally are 20–30 m wide, 5 m high and some 4–5 m above m.s.l. Cross-bedded facies have been commonly recognized in most beds (probably corresponding to subtidal–intertidal deposits) and are composed mainly of infaunal molluscan taxa typical of the infralittoral zone.

The age of the beach ridges range from ca. 2000 to 6890 yr B.P. along Samborombon Bay and from 3100 to 7600 ¹⁴C yr B.P. at Punta Indio (see Aguirre and Whatley, 1995a, for a synthesis of radiocarbon and amino-acid dating). But the chronological control of these landforms is not precise mainly due to the lack of AMS dating, different authors dated different species (sometimes bulk samples composed of several taxa) and studies on the reservoir effect are still lacking.

Most shells analysed from beach ridge beds are from loc. 10 of Aguirre (1993a), the type locality of Cerro de la Gloria Mb. of Las Escobas Fm. (regressive phase of the last transgression). This ridge is exposed over 5 m, reaches 5–6 m above m.s.l., and

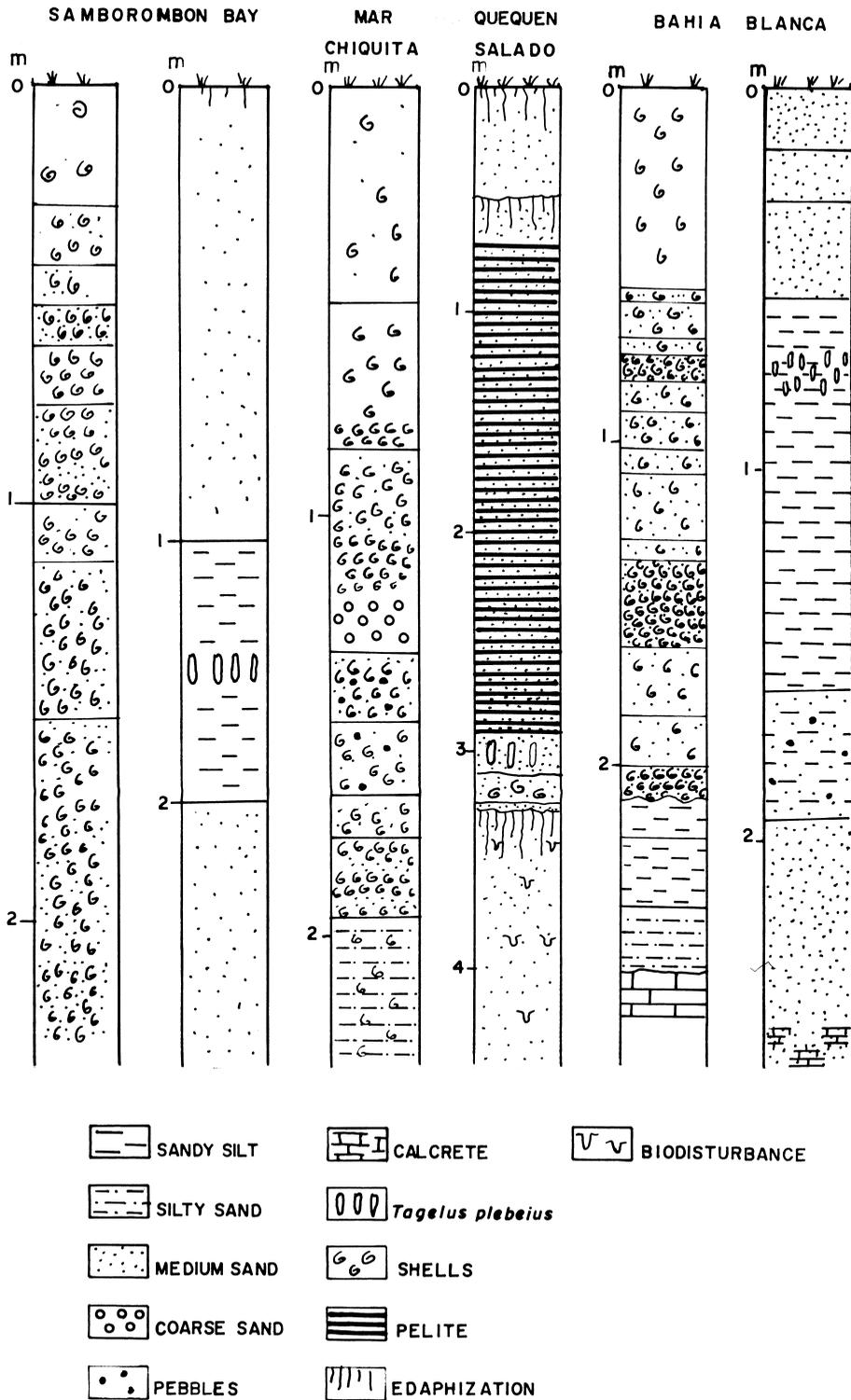


Fig. 2. Profiles analysed in the localities selected for this study. Modified from: Aguirre (1990), Farinati et al. (1992) and Farinati and Zavala (1995).

has an inclination of ca. 30°E. It is located inland at approximately 7 km from the modern coastline. Radiocarbon dates obtained on *M. isabelleana* shells gave an average age of 4500 yr B.P. (Figini et al., 1990, and references therein) whereas amino-acid dating on the same species gave a D/L ratio of 0.063 (Aguirre et al., 1995).

The beach ridges from Punta Indio seem to have formed during a period of different atmospheric circulation patterns which probably caused changes in the wind direction, reversals of the longshore sand transport, higher sea surface temperatures due to a southern shift of the Brazilian warm shallow water current and of the South Atlantic anticyclonic centre (Broecker and Denton, 1990; Iriondo and García, 1993; Aguirre, 1993b; Aguirre and Leng, 1996). Evidence for this assumption is based on the older radiocarbon dates (maximum of 7600) and higher amino-acid ratios (D/L = 0.103) on *M. isabelleana* from these ridges, their different geometry (truncation and different alignment) and their very different fauna (more diverse and with highest percentage of warm water elements) in comparison with the remaining Holocene ridges from Samborombon area. By contrast, the ridges along Samborombon Bay coastal area may have formed during a longshore drift similar to the present regime (Aguirre and Whatley, 1995b and references therein). The taphonomic features of shell concentrations from both areas may provide additional evidence to support the different (older) age of P. Indio ridges under different environmental conditions.

Molluscan samples for taphonomic analysis were taken mainly from ridges of three generations in the P. Indio–Samborombon area, according to their relative position perpendicular to the modern coast and their radiocarbon and amino-acid dates (Codignotto and Aguirre, 1993; synthesis of ¹⁴C ages in Aguirre and Whatley, 1995a; Aguirre et al., 1995) (they correspond to landforms I–III of the Punta Indio area and IV and V of Samborombon Bay, after Codignotto and Aguirre, 1993).

2.1.2. Coastal Lagoon deposits (Canal 18 Mb. of Las Escobas Fm.)

The deposits sampled are located at the left margin of Canal 15, approximately 12 km inland from the modern coastline, where they reach 2–3 m above

m.s.l. and are composed of a high proportion (87–90%) of clastic content (mostly clays and silts) and a scarce biogenic fraction characterized by very low faunal diversity.

Bivalve fossil shells preserved articulated (*Mac-tris isabelleana*, *Raeta plicatella*; Mactracea) or articulated and in living position (*Tagelus plebeius*) together with the associated molluscan fauna could be sampled only in one locality from central Samborombon Bay (Fig. 1) (loc. 11 = Canal de Las Escobas; Aguirre, 1993a) dated at ca. 6150 ± 190, 6459 ± 32 and 6764 ± 195 ¹⁴C yr B.P. (Fidalgo et al., 1981).

2.2. Mar Chiquita (study region 2; Fig. 2)

Most samples analysed in this area belong to the littoral ridges.

2.2.1. Ridges (marine facies of Mar Chiquita Fm.)

Smaller ridges (barrier spits) and estuarine sediments (estuarine facies of Mar Chiquita Fm.) occur along the coastal area surrounding Mar Chiquita Lagoon (Fig. 1). The ridges are similar to those sampled at Samborombon Bay area but are shorter and thinner, 2.5–4.3 m above m.s.l., and extend approximately 2.5 km inland.

Available radiocarbon ages for these ridges fluctuate between 3000 and a maximum of ca. 5000 ¹⁴C yr B.P. (Schnack et al., 1982; Violante, 1988) and amino acid ratios obtained on *M. isabelleana* are 0.053–0.06 (Aguirre et al., 1995).

2.2.2. Tidal flats and salt marsh deposits (estuarine facies of Mar Chiquita Fm.)

These sediments occur mainly between the ridges and the modern shore. The sampled tidal flats spread seaward of the ridges and their ages range from 1400 to 2500 ¹⁴C yr B.P. (Fasano et al., 1982). *T. plebeius* shells, articulated and in living position, were collected in this estuarine facies (loc. 17 and 25 of Aguirre, 1993a).

2.3. Quequén Salado (study region 3; Fig. 1)

Near its mouth in the Southwestern Atlantic Ocean, the Quequén Salado River shows the sea influence which extends up to 8 km upstream. There

characteristics and facies analyses allowed a recognition of a transgressive–regressive event. The cycle begins with a beach palaeoenvironment which turns to a tidal flat, ending with of lacustrine brackish body. Holocene autochthonous and parautochthonous fossiliferous concentrations were analysed in order to evaluate the taphonomic history (Farinati and Zavala, 1995). Marine deposits of decreasing grain size and strata equivalent to las Escobas Fm. overlie fine silts with poor selection, bioturbated, without sedimentary structures (Late Pleistocene; Agua Blanca Fm.). The skeletal accumulations are composed of disarticulated valves, mostly concave down and stacked, within a medium to coarse sandy matrix.

The stratigraphical section considered includes 4.5 m of late Pleistocene and Holocene sediments (Fig. 2). Marine sediments (equivalent to Las Escobas Fm.) occur as skeletal accumulations formed by disarticulated valves generally convex up and stacked overlying fine badly sorted sands, bioturbated, and without sedimentary structures (Late Pleistocene, middle sandy Member of Agua Blanca Formation). These sediments are overlain by medium to fine sand levels with bad sorting which form a tabular body with a net base and ca. 20 cm thick. Abundant molluscan shells of *Tagelus plebeius* with both valves articulated and in life position have been recorded (Fig. 2). Radiocarbon dating carried out on these shells gave 7720 ± 100 yr B.P. No amino-acid dating is available for this area.

2.4. Bahía Blanca (study region 4; Fig. 1)

2.4.1. Ridges

Holocene sea-level fluctuations left important testimonies along the coastal area of the Bahía Blanca Estuary. Beds composed of abundant marine fossils are found in the subsurface in many places near the modern coastline (González et al., 1983; Aliotta et al., 1987; Farinati and Aliotta, 1987). At the surface, at heights of 8–10 m above mean sea level, the highest Holocene transgression produced a series of shell ridges. These ridges are found mainly in the inner part of the estuary and arranged in a narrow strip subparallel to the coastline (González, 1989; Aliotta and Farinati, 1990).

These landforms are of a hilly nature, about 70 m wide and reach 2 m in height. The general profile

of each ridge is remarkably asymmetric and the landward slope (9°) is greater than the seaward slope (about 3°). The Holocene transgressive sediments stand discordantly on a lithified sandy silt which is rich in calcium carbonate forming a calcrete.

The shell ridges are composed of a medium to fine sand with a high percentage of shells (whole and fragmented) and smaller proportions of pebbles of quartzite, calcrete, siltstone and pumice. The bedding is parallel and there is a slight inclination (about 3°) toward the sea. The beds can be differentiated on the basis of their varying concentrations of shells, which determine their different colours and degree of compaction. The orientation of the shells convex up usually coincides with the bedding (more stable; Emery, 1968; Salazar-Jimenez and Frey, 1982) and stacking, too. Like for the northern area mentioned above (study regions 1 and 2), the taxonomic composition of these deposits includes gastropods and bivalves. Detailed information on the whole molluscan fauna can be obtained from Farinati (1985a).

Radiocarbon dating (Farinati, 1985b; González, 1989) of these shells gave ages oscillating between 4615 and 6650 yr B.P. (similar to the age range obtained for Samborombon Bay ridges and coastal lagoon deposits; see above). No amino-acid dating is available for this area.

2.4.2. Tidal flats

Between the shell ridges and the modern tidal channel a wide Holocene tidal flat has developed as a consequence of a regressive sea level episode (Farinati and Aliotta, 1997). These sediments are composed of light brown sandy silt without visible sedimentary structures. A *Tagelus plebeius* horizon with articulated valves and still in life position (Fig. 2) is observed, suggesting that the habitat of the original benthic communities was typically estuarine. These sediments are overlying on silty fine sand which represents a transgressive event.

Radiocarbon dating carried out by González et al. (1983) and Farinati (1985b) established an age of approximately 3850 and 3373 yr B.P., respectively (younger than those from Canal de Las Escobas deposits in central Samborombon Bay, Fig. 1).

3. Material studied

Molluscan skeletons (gastropods and bivalves) represent 80–95% of the samples examined while the remaining 5% of the whole faunal content is composed of an associated invertebrate fauna (cnidarians, polychaetes, bryozoans, cirripedes, decapods). Of these, bivalve taxa were chosen because they can be found in living position making their radiocarbon dates more reliable (e.g. dates obtained on *Tagelus plebeius*), their ecological requirements are more thoroughly known and therefore they are more important palaeoecologically for the interpretation of the marine Holocene deposits along the area of this study.

Tagelus plebeius Lightfoot, *Macra isabelleana* d'Orbigny, *Pitar rostratus* (Koch) and *Brachidontes rodriguezii* (d'Orbigny) occur abundantly along the whole area, their ecological requirements and distributional ranges have been compiled and they represent different life type categories. Life habits may affect the potential and mode of preservation (epifaunal taxa being more exposed to processes leading to disarticulation, fragmentation and abrasion than infaunal molluscs). The species considered, arranged in decreasing order of preservational potential, are the following: (1) *Tagelus plebeius*, deep burrower; (2) *Macra isabelleana*, shallow burrower; (3) *Pitar rostratus*, shallow burrower; and (4) *Brachidontes rodriguezii*, epibyssate (Fig. 3).

4. Methods

Both Holocene littoral facies, ridges and tidal flats, were sampled for taphonomic studies. Additionally, modern material was collected along the adjacent littoral area or examined from museum collections (Museo Argentino de Ciencias Naturales Bernardino Rivadavia, Museo de La Plata and Bahía Blanca) to compare the living, fossil and subfossil taphonomic appearance of the shells analysed.

We collected samples (sedimentological and palaeontological) from profiles (Fig. 2) measured in all the localities. The taphonomic signatures were observed in the field and in the laboratory on abundant molluscan shells from bulk samples from each differentiated level. Codification refer to semi-quantitative observations based on presence–absence of

these attributes while quantitative, more detailed data are under current analysis. These features (Table 1) were measured on four bivalve genera (*Tagelus*, *Pitar*, *Macra* and *Brachidontes*) selected on the basis of their wide distribution along the marine late Quaternary deposits from the area of study and of their different habitats and life habits.

Three taphonomic signatures were compared (disarticulation, fragmentation and abrasion). Only physical processes were considered to attempt a distinction of time and differential taphonomic histories of the shells collected along the whole area. Shells accumulated in ridges have shown to be rarely affected by biological processes and are characterized by low rates of encrustation and bioerosion. On the contrary, they are affected by fragmentation, cracking, edge preservation, etc. (Kowalewski and Flessa, 1995). Additionally, luster signature of the shells have shown to be noteworthy for taphofacies analysis, being sometimes an important clue related to the age of the fossil assemblage.

Results of studies carried out by Meldahl (1994) and Kowalewski and Flessa (1995) have shown that taphonomic degradation represent generally a surface phenomenon (surficial shells exhibiting poorer preservation than subsurface ones). Therefore our observations are mainly based on the analysis of subsurface (more than 50 cm deep) samples taken both from the ridge and the tidal flats/coastal lagoon facies. Among others, we followed previous models proposed by Brett and Baird (1986), Kidwell (1986), Fürsich and Flessa (1987), Davies et al. (1989), Brandt (1989), Meldahl (1995) and Kowalewski and Flessa (1995) in recent taphonomic studies.

5. General characteristics of the bivalve species examined

5.1. *Tagelus plebeius* (Fig. 3, 1)

This species of the family Solecurtidae has a wide distribution, extending along the Caribbean, Brazilian and Argentine Malacological provinces, from North Carolina (USA), Surinam, Brazil, Uruguay and down to Golfo San Matías in Argentina. It is the so-called false razor clam which has been recorded living in Montevideo (Scarabino et al., 1975) and

Table 1

Taphonomic attributes of the bivalve species as preserved in the littoral deposits studied: ridges and tidal flat/coastal lagoon palaeoenvironments

Taphonomic attributes	Punta Indio	Samborombon Bay		Mar Chiquita		Quequen Salado	Bahia Blanca	
	ridges	ridges	coastal lagoon	ridges	tidal flats	tidal flats	tidal flats	ridges
<i>Tagelus plebeius</i>	absent	scarce	very abundant	scarce	very abundant	very abundant	very abundant	scarce
Disarticulation		high	none	high	none	none	none	high
Fragmentation		high	none–low	high	none–low	none	none	high
Abrasion		high	none–low	moderate	none–low	low	low	high
Age			6150 ± 190 6754 ± 195		2700 ± 90	7720 ± 100	3373 ± 205	4450 ± 95 3120 ± 70
<i>Macra isabelleana</i>	abundant	very abundant	scarce	abundant	scarce	absent	absent	scarce
Disarticulation	high	high (LV~RV)	low–none	high (LV~RV)	low			high
Fragmentation	high	moderate	low–none	low–none	none			high
Abrasion	high	moderate	none	low–none	none			high
Age	4490 7600	3490 ± 90 4460 ± 110		3110 3850 ± 60				
<i>Pitar rostratus</i>	abundant	abundant	absent	scarce	absent	scarce	abundant	very abundant
Disarticulation	high	high		high		high	low	high
Fragmentation	high	moderate–high		moderate		moderate	none	moderate
Abrasion	high	moderate–high		moderate		moderate–high	low	high
Age								4200 ± 190
<i>Brachydontes rodriguezii</i>	abundant	scarce	absent	abundant	scarce	abundant	scarce	very abundant
Disarticulation	high	high		high	high	high	high	high
Fragmentation	high	high		moderate	low	moderate	high	high
Abrasion	moderate	high		low	low	moderate–high	moderate	moderate
Age								6180 ± 90

RV = right valves; LV = left valves.

Ages from Cortelezzi and Lerman (1971), Schnack et al. (1980), Fidalgo et al. (1981), Fasano et al. (1982), Figini et al. (1984) Violante (1988), Figini et al. (1990), and Codignotto and Aguirre (1993) for the area Punta Indio–Mar Chiquita (see references in Aguirre and Whatley, 1995a); ages from Farinati and Zavala (1995) and Farinati and Aliotta (1997) for the area Quequén Salado–Bahia Blanca.

Designation of ‘high’ means that the average of the shells in the samples from the ridges or tidal flats/coastal lagoon deposits was high for the attribute. Scarce, abundant or very abundant refer to the abundance of the shells of the corresponding species in each landform from each study region considered.

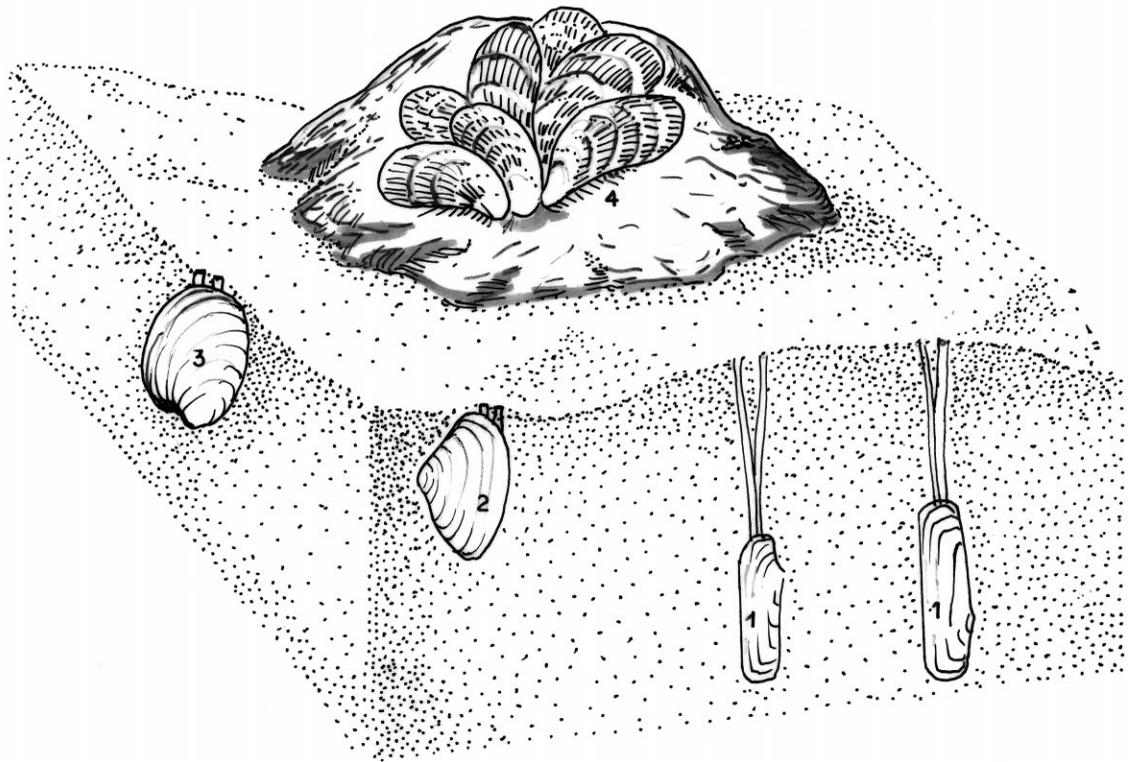


Fig. 3. Reconstruction of the original littoral communities and habitat of the bivalve species analysed. 1 = *Tagelus plebeius*; 2 = *Mactra isabelleana*; 3 = *Pitar rostratus*; 4 = *Brachidontes rodriguezii*.

during the summer in Bahía Blanca estuary (Elías, 1985). Available ecological studies for this species refer to other littoral areas, mostly from eastern North America (Stanley, 1970; Kranz, 1974; Holland and Dean, 1977), southeastern Brazil (Bembvenuti et al., 1978; Capitoli et al., 1978) and data supplied for the Uruguayan coast (Sprechmann, 1978). According to the information gathered (Table 2) this euryhaline species lives in estuaries, near river mouths or in open bays, on silty clays or cohesive sandy silts, along the intertidal (mostly) and upper infralittoral zones (see Aguirre and Whatley, 1995b, for more details and references).

The shell has an elongate outline with rounded ends, growth lines on its outer surface and a deep pallial sinus which can be observed interiorly. The valves can reach up to 90 mm long (Holland and Dean, 1977). It is found in the river mouth in a vertical position with its foot downwards and the long exhalant and inhalant siphons stretching upwards to the sediment/water interface. The siphons, which

can reach 30 cm in length (Carcelles, 1944), are extendable structures. The foot is perfectly adapted for excavation allowing a deep burrowing habit. It lives in tidal flat areas between the mean low tide level and 90 cm above this level where it inhabits sediments composed of more than 2% of silt and clay. As a deep burrower it exhibits a low burrowing index (BRI = 0.4) but is capable of making a relatively big Y-shaped burrow (the organism lives with the longitudinal axis vertical, perpendicular to the substrate plane, with the divergent siphons extended upwards posteriorly in contact with the surface and the foot emerging anteriorly, the upper part of the burrow being occupied by the living animal during low tide while the lower part is occupied when the tide is high). It is a suspension feeder (Stanley, 1970).

5.2. *Mactra isabelleana* (Fig. 3, 2)

It belongs to the family Mactridae and lives from southern Brazil down to Bahía Blanca in the Argentin-

Table 2

Ecological requirements of the species analysed. Modified from Aguirre (1993b) and Aguirre and Whatley (1995a)

ECOLOGICAL REQUIREMENTS	HABITAT						LIFE HABITS			TROPIC TYPE	SHALLOW WATER MASS				LIVING				
	SALINITY		ZONATION			SU	EPIFAUNA	INFAUNA			SUSPENSIVOROUS	DETRITIVOROUS	TR	ST	T	W	S. BAY AREA	OCEANIC AREA	
	BRACKISH	EUHALINE	SUPRATIDAL	INTERTIDAL	INFRA LITTORAL	CIRCALITTORAL	SOFT	HARD	EPIBYSSATE	SHALLOW BUR.									DEEP BUR.
<i>B. rodriguezii</i>		*	*	*				*				*		*	*		*		H
<i>M. isabelleana</i> <i>M. aff. isabelleana</i>	*	*			*		*			*	*		~	*	*			H	L/A
<i>Pitar rostratus</i>						*	*					*							
<i>T. plebeius</i>	*	*	*	*	*		*			*		-30	*	*	*	*	*	M	M/L

~ = occasionally; H = high; L = low; A = absent; M = moderate.

tine Malacological Province. This infaunal species (shallow or moderately deep burrower) (Fig. 3) is highly adapted at present to the poly-euhaline and polyhaline zones of the Rio de La Plata estuary. It is typical of sandy bottoms mostly from the infralittoral zone (collected alive most abundantly from 10 to 20 m deep).

Variations in the general shell shape have been recognized as ecomorphs, i.e. adaptations to different habitats (mainly substrate type) and depths of burial. On previous studies and on Table 2 they have been referred to as *Mactra isabelleana* (same general shape as the holotype) and *Mactra aff. isabelleana* (other morphs). Specimens (Plate I, 8, 9) which inhabit high-energy shallow neritic waters within coarse sandy substrates would probably burrow deeper and faster than those living in fine sandy bottoms of deeper and quieter habitats (Plate I, 7, 11). In accordance with this, the former exhibit a less convex shell shape and more elongate outline, the pallial sinus is longer and they generally present a more pronounced post-umbonal line or ridge (Aguirre, 1994).

5.3. *Pitar rostratus* (Fig. 3, 3)

P. rostratus (Veneridae) lives along the Argentine Malacological Province and probably along the Atlantic South African coasts. It is a typical marine shallow infaunal species, common in soft bottoms (mostly medium sand, sandy-clay, or sands and fragmented shells). It has been found at variable depths (4–6 down to 160 m) mostly in the infralittoral, although a few records are from the upper circalittoral zone (Olivier et al., 1972; Scarabino, 1977). It was recorded in waters of 14.58°C at 10 m deep. It has a shallow burrower life habit similar to that of *M. isabelleana* and is a suspension feeder (filter feeder).

5.4. *Brachidontes rodriguezii* (Fig. 3, 4)

This species of the family Mytilidae is a common element of the Argentine malacological Province, like *M. isabelleana* and *P. rostratus*. It is an epifaunal marine species but can also be found in areas of influence of estuarine waters, generally conforming large clusters composed of this and other species

(*Mytilus edulis*, *Siphonaria lessoni*, cirripeds, etc.). It lives byssally attached (Fig. 3) to hard bottoms of the supratidal and intertidal zones and less abundantly in the upper infralittoral (Table 2) and is a suspension feeder.

Taxonomic and palaeoecological information referring to other taxa occurring within the same marine late Quaternary deposits along the area of this study can be obtained from Farinati (1985a,b) and Aguirre (1990).

6. Taphonomic processes

Post-mortem modification is unavoidable fact of fossilization, but even among shelly taxa, species differ in their susceptibility to the potential preservation (Kidwell and Bosence, 1991). Abiotic factors like currents and wave sorting (deduced from shell fragment analyses), selective breakage and biologic controls like the action of predators and scavengers depend mainly on the taxa, shell shape and thickness, habitat and life habit and the final depositional environment (Trewin and Welsh, 1971; Salazar-Jimenez and Frey, 1982).

In order to document the differential preservation of shells from specific taxonomic groups we analyse the following taphonomic signatures on the bivalves chosen:

(1) *Disarticulation*: The process of disarticulation is especially frequent among bivalves, modern and fossil, after decay of soft parts and the organic ligament that join the valves together. But the original habitat of the taxa is an important factor which influence the degree of disarticulation, infaunal species showing greater chance of keeping the valves articulated.

(2) *Fragmentation*: Breakage of skeletons is usually an indication of high energy resulting from wave action, currents, tides or winds (Parsons and Brett, 1991). Bivalve shells tend to break along by weakness lines or areas of the external ornamentation such as ribs, ridges or costulae. There has also been seen a negative correlation between degree of fragmentation and shell thickness and size (i.e., thin shells of *Brachidontes rodriguezii* exhibit a high degree of breakage; Plate II, 23). However, even when found as fragments many bivalve shells (*Tagelus*, *Macra*,

Pitar and *Brachidontes* among many others) still have a good diagnostic value and allow classification up to generic or even specific levels (Plate II, 1, 10, 15, 22).

(3) *Abrasion*: Abrasion or polishing is a mechanical process during which the periostracum and the finer details of the shell surface and ornamentation are destroyed. Signals of abrasion are evident by rounding of edges, reduction of ornamentation on the exterior and interior surfaces and a typical chalky appearance of the whole or part of the shell (Plate I, 12; Plate II, 13).

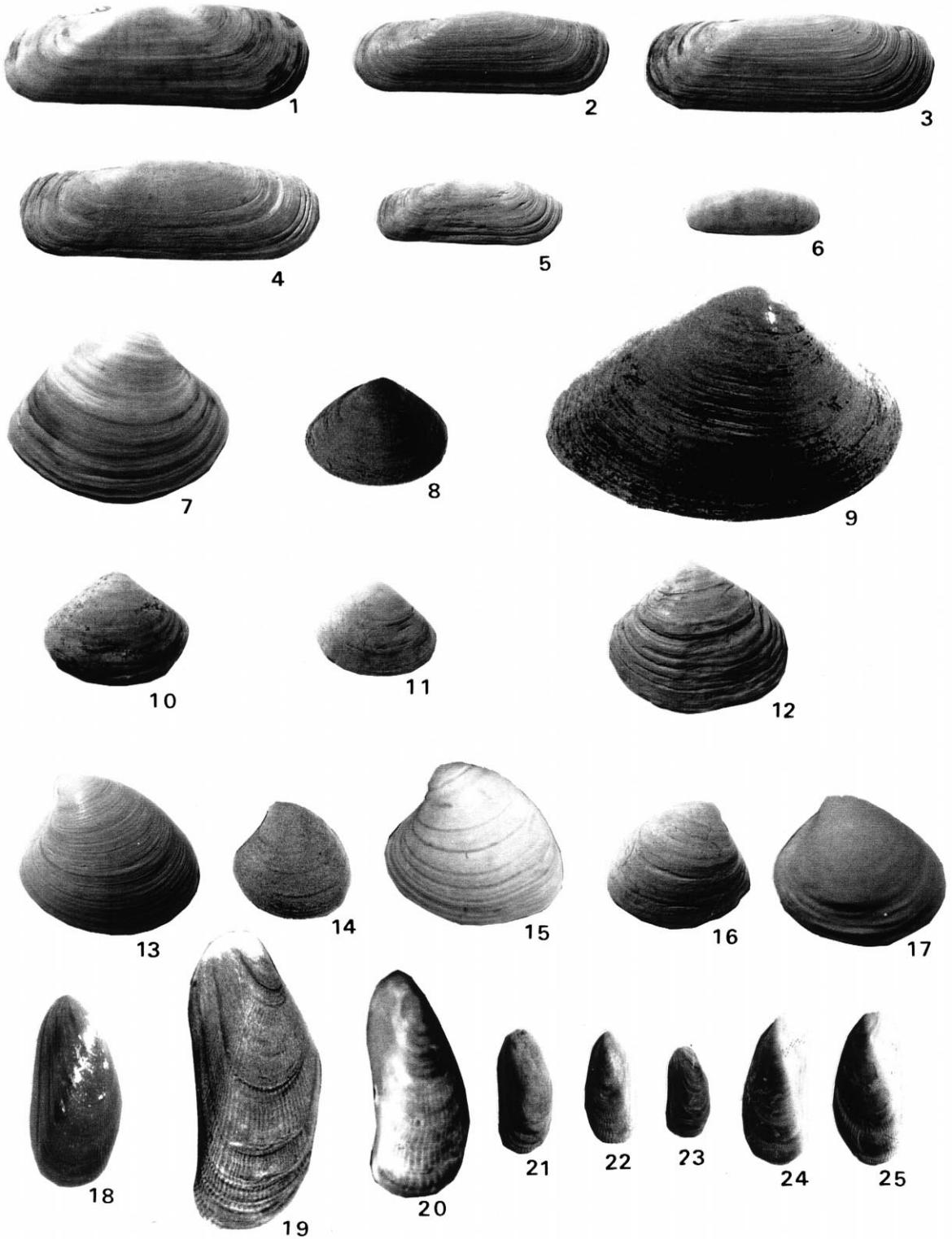
The degree of abrasion is related to environmental energy, time of subaerial exposure and particle size of the abrasive agent. It is most evident within the internal surface of bivalve shells and increases with increasing grain size: clay sized grains do not significantly abrade skeletons (shells of *T. plebeius* sampled at Canal de Las Escobas and Quequén Salado) (Plate I, 2), whereas sand and gravel sized material is probably the most effective agent which facilitates abrasion (Plate I, 6). The most common effect of strong abrasion is the loss of original luster and surface ornamentation, like seen on *P. rostratus*, *M. isabelleana*, and *B. rodriguezii* (Plate I, 17; Plate II, 7, 16, 21).

7. Results and analysis

7.1. Punta Indio–Samborombon Bay area

The shells from the ridges along Punta Indio–Samborombon Bay coastal area, showing larger dimensions, and containing a high proportion of fragmented large bivalve shells, may represent regressive beach ridges similar to those studied along the wave-dominated coast of Baja California by Meldahl (1995). The shell concentrations sampled along this area (Fig. 1) compose taphocoenosis where shells of taxa corresponding to different generations and habitats may be found together. Out of habitat transport, selective destruction, and time averaging are expected for these assemblages. The shells may have been transported different distances from their original habitat (although not far away) and reworked with differential intensities, depending on their size, shape and general characteristics (i.e., thickness,

PLATE I



size, ornamentation) as well as on the final depositional environment (Table 1; Plate II).

These ridges are composed mainly (>50–90%) of shells of *Macra isabelleana* which are thought to have dominated the original populations and been well adapted to their habitat: a large number of specimens are preserved, the different sizes of the shells accumulated represent all the ontogenetic stages and they exhibit considerable morphological variability (Aguirre, 1994).

Preservation is in general terms good as the shells show a close similarity to the living material collected from the adjacent littoral which was expectable due to their young age (less than 8000 yr B.P.) (Plate I). Evidence of continuous burial in sediment after death are the lack of periostracum on single valves which are often blackened and affected by solution, near absence of associated epifauna and

lack of signs of attack by boring organisms (Trewin and Welsh, 1971). The taphonomic grade (Brandt, 1989) may be defined as ‘poor’ in Punta Indio and ‘fair’ along Samborombon Bay on the basis of disarticulation, fragmentation and abrasion.

Nearly all shells sampled (80–90%) are disarticulated, and it is highly uncommon to observe remains of ligament on the odd valves. Nearly equal or identical numbers of left and right valves are preserved in all beds. Higher proportions of broken valves and degree of fragmentation of *M. isabelleana* shells are recorded for ridges of the Punta Indio area. Fragments can always be identified as to the specific level when having the hinge area preserved, but only to the generic level when retaining any other parts of the shell. Along Samborombon Bay the ridges show a moderate fragmentation degree and higher amounts of large *M. isabelleana* fragments can be found.

PLATE I

Taphonomic signatures of recent and fossil representatives of the species analysed from different environments of the coastal area of Buenos Aires Province.

1–6. *Tagelus plebeius*.

1. Recent. Mar Chiquita area. Exterior view of the right valve (RV). L = 7 cm.
2. Holocene. Canal de Las Escobas (coastal lagoon). Exterior view of the RV. L = 6.1 cm.
3. Holocene. Bahía Blanca area (ridges). Exterior view of the RV. L = 6 cm.
4. Holocene. Bahía Blanca area (tidal flats). Exterior view of the RV. L = 6 cm.
5. Holocene. Quequén Salado (tidal flats). Exterior view of the RV. L = 4.2 cm.
6. Holocene. Mar Chiquita (ridges). Exterior view of the RV. L = 4.5 cm.

7–12. *Macra isabelleana*.

7. Recent. Punta Rasa. Exterior view of the RV. L = 4.5 cm.
8. Holocene. Mar Chiquita. Exterior view of the RV. L = 1.9 cm.
9. Holocene. Mar Chiquita (ridges). Exterior view of the RV. L = 2.6 cm.
10. Holocene. Samborombon Bay (ridges). Exterior view of the RV. L = 2.3 cm.
11. Holocene. Punta Indio (ridges). Exterior view of the RV. L = 2 cm.
12. Holocene. Bahía Blanca (ridges). Exterior view of the RV. L = 5 cm.

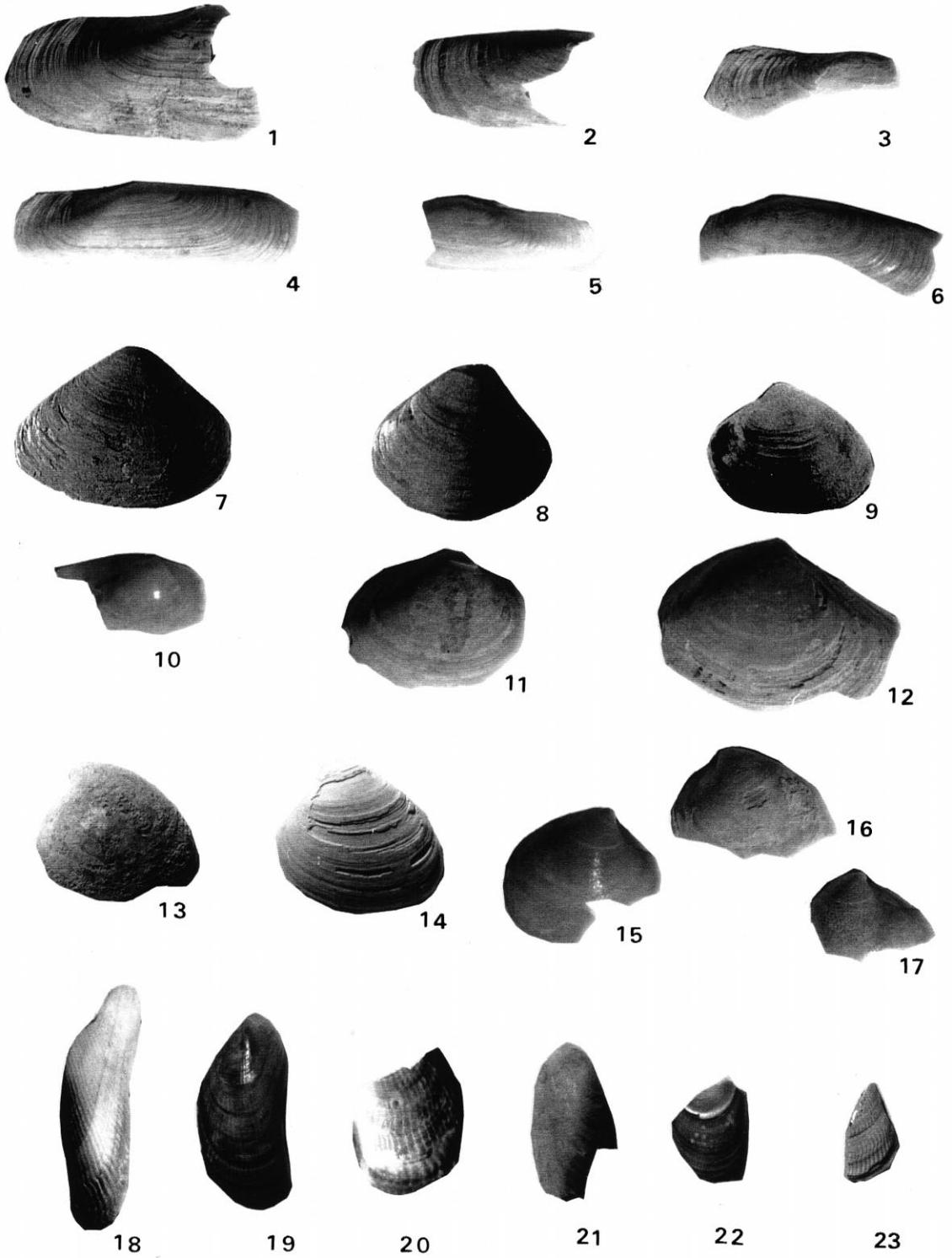
13–17. *Pitar rostratus*.

13. Recent. Monte Hermoso. Exterior view of the LV. L = 4.5 cm.
14. Holocene. Mar Chiquita area (ridges). Exterior view of the LV. L = 1.9 cm.
15. Holocene. Bahía Blanca (tidal flat). Exterior view of the LV. Natural size.
16. Holocene. Bahía Blanca (ridges). Exterior view of the RV. L = 3.8 cm.
17. Holocene. Bahía Blanca (ridges). Exterior view of the LV. L = 3.5 cm.

18–25. *Brachidontes rodriguezii*.

18. Recent. Monte Hermoso. Exterior view of the LV. L = 3.8 cm.
19. Holocene. Mar Chiquita (ridges). Exterior view of the LV. L = 3 cm.
20. Holocene. Bahía Blanca (ridges). Exterior view of the LV. L = 3.5 cm.
21. Holocene. Quequén Salado (tidal flat). Exterior view of the LV. L = 2.5 cm.
22. Holocene. Samborombon Bay (ridges). Exterior view of the RV. L = 2.2 cm.
23. Holocene. Bahía Blanca (ridges). Exterior view of the LV. L = 2 cm.
24. Holocene. Bahía Blanca (ridges). Exterior view of the RV. L = 2.5 cm.
25. Holocene. Bahía Blanca (ridges). Exterior view of the RV. L = 2.8 cm.

PLATE II



Higher abrasion is observed on shells of *M. isabelleana* from Punta Indio in agreement with their higher disarticulation and fragmentation degrees. Shell margins are more rounded (Plate I, 10) and the shell's original luster is less preserved both externally and internally. Along Samborombon Bay both fragmentation and abrasion are moderate (Table 1).

Disarticulation and fragmentation for *Pitar rostratus* are very similar to the signatures observed on *M. isabelleana* (Plate II). This may obviously be related with the infaunal habit and general characteristics (shape, thickness and size) of both species. However, abrasion is higher for *P. rostratus* shells which in most cases have lost their original colour and luster, which may be a consequence of more reworking and longer transport of these shells from a deeper (infralittoral–circalittoral) original habitat (Table 2). Therefore, we cannot consider these shells as autochthonous elements of the original littoral communities and palaeoenvironmental interpretations would

be less reliable when based on taphonomic signatures of this species.

Brachidontes rodriguezii is represented by small fragile shells generally very badly preserved in the beach ridges from the whole area (Plates I and II). Their physical alteration may be due mainly to the poor thickness of the shells and their epibyssate habit which makes them more easily exposed to transport along the beach after death. Similarly, fragile shells of *T. plebeius* are badly preserved and uncommon along these ridges.

The shelly associations recovered from the coastal lagoon facies can be defined as autochthonous (Kidwell et al., 1986) where the individuals have not suffered transport out of the original life habitat and therefore we can consider them reliable indicators of past environmental conditions in the area, especially if based on the dominant taxa recorded. These deposits are dominated (>90%) by shells of *Tagelus plebeius*. The general preservation of the shells is

PLATE II

Taphonomic signatures (fragmentation, abrasion) of the species analysed from low-energy (tidal flats and costal lagoons) and high-energy (ridges) from the area of study.

1–6. *Tagelus plebeius*.

1. Holocene. Canal de Las Escobas (coastal lagoon). Exterior view. Natural size.
2. Holocene. Canal de Las Escobas (coastal lagoon). Exterior view. Natural size.
3. Holocene. Mar Chiquita (ridges). Exterior view of RV. Natural size.
4. Holocene. Bahía Blanca. Exterior view of RV. Natural size.
5. Holocene. Bahía Blanca. Exterior view of LV. Natural size.
6. Holocene. Bahía Blanca. Exterior view of RV. Natural size.

7–12. *Mactra isabelleana*.

7. Holocene. Mar Chiquita (ridges). Exterior view of RV. L = 3.5 cm.
8. Holocene. Samborombon Bay. Exterior view of RV. L = 2.8 cm.
9. Holocene. Mar Chiquita (ridges). Exterior view of LV. L = 2.6 cm.
10. Holocene. Mar Chiquita (ridges). Exterior view of RV. L = 1.7 cm.
11. Holocene. Samborombon Bay (ridges). Exterior view of RV. L = 2.3 cm.
12. Holocene. Mar Chiquita (ridges). Exterior view of RV. L = 3 cm.

13–17. *Pitar rostratus*.

13. Holocene. Bahía Blanca (ridges). Exterior view of LV. L = 3.8 cm.
14. Holocene. Bahía Blanca (ridges). Exterior view of LV. L = 3.5 cm.
15. Holocene. Bahía Blanca (tidal flats). Exterior view of RV. L = 2 cm.
16. Holocene. Bahía Blanca (ridges). Exterior view of LV. L = 2 cm.
17. Holocene. Bahía Blanca (ridges). Exterior view of RV. L = 1.5 cm.

18–23. *Brachidontes rodriguezii*.

18. Holocene. Quequén Salado (tidal flat). Exterior view of LV. Natural size.
19. Holocene. Bahía Blanca (ridges). Exterior view of RV. Natural size.
20. Holocene. Bahía Blanca (ridges). Exterior view of RV. Natural size.
21. Holocene. Bahía Blanca (ridges). Exterior view of LV. L = 2.8 cm.
22. Holocene. Mar Chiquita (ridges). L = 1.3 cm.
23. Holocene. Bahía Blanca (ridges). L = 1.4 cm.

very good (Plate I, 2, 4), together with dominance of the clastic fraction (very fine sediments, mostly clays and silts) over the biogenic content, and the scarce faunal content is typical of estuarine low energy environments. The taphonomic signatures of these shells reveal a high taphonomic grade (equivalent to taphonomic grade A; Brandt, 1989): most of them correspond to joint valves in living position with large remains of ligament and are nearly identical to the living specimens compared (Plate I). They form a well preserved fossil assemblage which probably accumulated over short time spans.

The shells of *Maetra isabelleana* recorded from this facies are very fragile, subtriangular in outline, very thin, provided with a very thin posterior line (sometimes ridge) and a posterior inflation of the valve (Plate I, 9). These are the only beds where *M. isabelleana* shells of high taphonomic grade have been recorded. They are very well preserved, retaining their original colour and very often they are translucent, without evident signs of abrasion and fragmentation. Equal amounts of whole complete (joined valves) shells or odd valves have been recorded. Preservation of *M. isabelleana* shells support a low-energy, shallow original littoral environment, with very fine sediments. Minimum transport or reworking and rapid burial are assumed for this fossil assemblage.

Pitar rostratus and *Brachidontes rodriguezii* are absent in the coastal lagoon deposits sampled because they do not belong to the autochthonous or original molluscan communities: the first one belongs to a deeper (infralittoral–circalittoral) habitat and the latter to a higher energetic littoral environment on hard substrates.

7.2. Mar Chiquita area

According to their smaller dimensions, lower levels of fragmentation of large bivalve taxa (*Maetra isabelleana*, *Pitar rostratus*, *Tagelus plebeius*) within most beds and because they overlie marsh deposits, the ridges sampled at Mar Chiquita area could be similar to shoreline late Quaternary ridges from tide-dominated Baja California coastal area (Meldahl, 1995; Kowalewski and Flessa, 1995). Further work is necessary to give certain conclusions.

Tagelus plebeius is not commonly found within ridge beds from Mar Chiquita ridges as whole shells,

but generally as relatively small broken fragments of angulate margins (Plate II, 1, 3) or very small whole shells exhibiting a high degree of abrasion (Plate I, 6). It represents an allochthonous element in assemblages from this facies. On the contrary, within the tidal flats from the same area this species is very abundant and well preserved.

Similarly to our results for Punta Indio and Samborombon Bay, nearly all shells of *Maetra isabelleana* from Mar Chiquita ridges are disarticulated and there is an equal proportion of left and right valves preserved in all beds. Fragmentation and abrasion are lower, many shells retaining their original colour and luster, both externally and internally. Broken shells most commonly represent larger fragments than along Samborombon Bay ridges (Plate II, 12) and they generally exhibit angulated margins.

Brachidontes rodriguezii is a common species in the ridge facies of Mar Chiquita area where the disarticulation of the shells is high but fragmentation and abrasion are moderate and low, respectively (Plate II, 22). This may be a result of little to no transport, less reworking of the shells, and younger age of the accumulations in comparison with Samborombon Bay ridge deposits as proposed on the basis of amino acid dates by Aguirre et al. (1995). These subtriangular to subovate and fragile shells present optimal conditions for alteration. Especially in the varied, mostly hard bottoms of the intertidal or supralittoral, and within a narrow beach zone which constitute the original environment inferred for this area during the mid-Holocene (Aguirre, 1993a), where alternating periods of submergence and exposure of the shells may have often occurred. In addition, their epibyssate habit within a high energetic habitat makes them more exposed to breakage immediately after death when they lose the byssal attachment.

Pitar rostratus is absent in the tidal flats and scarce in the ridge facies from Mar Chiquita area where the shells show high disarticulation and moderate breakage and abrasion (Plate I, 14).

7.3. Quequén Salado

The taphonomic analysis allowed for the recognition of parautochthonous concentrations (Kidwell et al., 1986) in beach deposits, overlaid by au-

tochthonous concentrations of a tidal flat palaeoenvironment.

Many beds contain abundant shells (VL:VR rate = 1:1) of *Tagelus plebeius* with both valves articulated and in living position or slightly bent convex down. Low abrasion, high articulation rate and very low fragmentation are obviously related to the deep infaunal habit of this species. On the contrary, shells of *Pitar rostratus* exhibit highly disarticulation degree, the valves are strongly abraded with a typical chalky appearance which is in accordance with the over ca. 7500 ¹⁴C yr B.P. obtained for these sediments. Disarticulation of *Brachidontes rodriguezii* shells is very high. But most valves are whole, unbroken, and, like *Pitar rostratus*, they can be strongly abraded and even have lost their original ornamentation.

7.4. Bahía Blanca

Analysis of species richness within the different ridges from this area led to the distinction of a few levels of low diversity composed of highly monospecific skeletal concentrations suggesting different sources of biogenic and clastic material which formed the shell accumulations (Farinati and Aliotta, 1997). On the contrary, within the abundant densely fossiliferous levels the most frequent bivalve taxa are *Brachidontes rodriguezii* and *Pitar rostratus*.

The high disarticulation index of *Brachidontes rodriguezii* is probably due to its dysodont hinge type which is very weak and to the scarce thickness of the valves, making them extremely fragile. But different degrees of fragmentation can be observed within different levels or deposits (Plate II, 19–21, 23). Even small fragments can be useful to identify the shells to specific level (Plate II, 23). Because this epifaunal species lives typically on hard bottoms in highly energetic environments of the supralittoral down to the upper infralittoral (Table 2), strong erosive signatures of the shells are most common, like polished external surfaces and reduced ornamentation (Plate I, 25; Plate II, 20, 21).

Due to the stronger thickness of the valves, a more convex shape and its infaunal habit, disarticulation is high for *Pitar rostratus* but less marked than for *B. rodriguezii*. Abrasion, however, is very high, probably as a consequence of longer transport

from deeper original environments. This signature seems to be related to length of exposure time after death, older shells (Plate I, 16–17; Plate II, 13–14) generally more abraded than recent ones (Plate I, 13).

Like for the northern area (study regions 1 and 2; Fig. 1) *Tagelus plebeius* occurs in these ridges in scarce quantities and badly preserved, always disarticulated and highly abraded.

Mactra isabelleana is scarce both for the ridge and tidal flat facies from the area in comparison to the ridges from Punta Indio, Samborombon Bay and Mar Chiquita. This is probably due to different environmental conditions (coarser substrates and higher salinity gradient) in Bahía Blanca. The species shows similar fragmentation and abrasion signatures to *Pitar rostratus* with which it also shares most ecological requirements (Table 2) and life habit. Most commonly the shells are disarticulated and strongly abraded (Plate I, 12).

In contrast to the ridge facies, within the tidal flats sampled in this area species diversity is generally low. The shell concentrations are autochthonous (Kidwell et al., 1986) and have been slightly affected by minimum taphonomic processes. *Tagelus plebeius* is highly abundant with both valves articulated and in living position. When disarticulated, RV:LV ratio is 1. Fragmentation and abrasion are minimum (Plate I, 4) and bioerosion signatures are totally absent because they have not suffered any post-mortem transport.

Disarticulation and fragmentation of *Pitar rostratus* are very low, in opposition to these taphonomic signatures observed on shells from the ridge facies from the same area. Many shells have been found disarticulated but still associated and abrasion is nearly absent, most shells showing the original luster and ornamentation (Plate I, 15). *Brachidontes rodriguezii* is scarce in the tidal flat deposits because it belongs to a littoral original environment characterized by higher energy and harder substrates than those represented by the tidal flat facies.

8. Discussion

An actualistic approach of the Holocene shelly accumulations studied leads us to the comparison

of recent vs. fossil taphonomic differences (Plate I) and their relation to several environmental conditions, i.e., substrate type, energy, submergence periods (Fürsich and Flessa, 1987), salinity, surficial temperature. Most living molluscan communities are controlled by these factors. The sequence of increasing taphonomic changes (Plate I) of the shells analysed is, as obviously expected, recent beaches, low energy tidal flats or coastal lagoons, and beach ridges.

Time-averaging in nearshore marine settings has been shown to be over 100 to several 1000 years and the taphonomic condition of molluscan shells from these environments have been demonstrated to be a poor timekeeper (Flessa, 1993; Kidwell and Flessa, 1995). But still, some relatively useful information can be obtained in terms of palaeoenvironmental analysis for the area of our study.

Tagelus plebeius: Its best preservation is observed in tidal flats and coastal lagoon deposits along the whole coastal area of study, where these elongate, thin and very fragile shells have not been exposed to transport and physical alteration. Muddy substrates, low energy, considerable depth of burial have altogether provided a protected environment for them. While their worst preservation corresponds to ridges from Samborombon Bay, Mar Chiquita and Bahía Blanca ridges, where all the opposite conditions were observed.

The taphonomic attributes of *T. plebeius* within Canal de Las Escobas (Samborombon Bay) are very similar to those observed for the same species in Holocene tidal flat deposits (ca. 3300–3800 ¹⁴C yr B.P.) from Napostá Grande Creek in Bahía Blanca area as described by Farinati et al. (1992) who concluded that the original population suffered a mass mortality phenomenon as a consequence of the catastrophic burial after a sudden influx of sandy fluvial sediments from the nearby river. Therefore they were very well preserved and in most cases can be found in life position.

Because similar depositional histories may be assumed for beds which show similar taphonomic grades (Brandt, 1989), the same kind of event may have taken place in Canal de Las Escobas, of which setting, sedimentology and faunal content and preservation is in general agreement with the description of Napostá Grande locality (Bahía Blanca)

and of the Quequén Salado area, where abundant *Tagelus plebeius* with articulated valves and in life position within autochthonous concentrations suggest that disarticulation and fragmentation processes have been minimum in their taphonomic history.

Mactra isabelleana: Its best preservation was observed in Mar Chiquita area and Canal de Las Escobas, while their worst preservation was found along the ridges from Samborombon Bay. The high degree of fragmentation of *M. isabelleana* shells may lead to the conclusion that in the Punta Indio area the depositional environment was highly energetic and more transport of the shells may have occurred in comparison to calmer waters along Samborombon Bay area where the high levels of abrasion observed on some shells may be indicative of more or longer reworking, not transport (probably affected by longer exposure on the sea floor before final burial).

A lower taphonomic grade (equivalent to C of Brandt, 1989) for shells of Punta Indio may be assumed in comparison to Samborombon Bay (grade B). An older time scale of deposition and different history of accumulation may be inferred if, together with the above mentioned evidence, we take into account the older radiocarbon (maximum ca. 7600 yr B.P.) (Table 1) and amino-acid dates (0.103 D/L ratios) obtained for these ridges as mentioned above. This supports a previous hypothesis relating the ridges from Punta Indio with changes in the wind direction and different longshore sand transport (see area descriptions above).

Variations in their general shape represent adaptations to different environments, especially as a response to substrate type and depth of burial. These ecomorphs (*M. isabelleana* and *M. aff. isabelleana*) (Aguirre, 1994), also exhibit differential taphonomic features:

(a) Shells of specimens living within high-energy shallower waters on coarser sandy bottoms (i.e. Mar Chiquita) seem to burrow more rapidly and deeply. Their shell shape is less convex and the general outline is more elongate, a thin but more evident post-umbonal ridge is generally present and the palial sinus is longer (*M. aff. isabelleana*).

These shells are generally larger, more complete, less fragmented and abraded and can retain the original colour. It is assumed that in spite of a high energetic original environment, transport and reworking

have not been considerable due to a smaller extension of the beach zone along this coastal area.

(b) Shells of specimens living in deeper littoral environments within calmer waters (i.e. Samborombon Bay, Rio de La Plata) in fine sandy substrates seem to belong to shallower burrowers.

These shells have generally a less elongate outline, rarely provided of a posterior line or ridge and the pallial sinus is smaller (*M. isabelleana*). Both modern (washed ashore) and fossil shells of this kind are most often disarticulated, more abraded, with considerable loss of the original luster and colour and less sharp edges, whole or fragmented (relatively large size fragments).

In spite of the less energetic original habitat, the depositional environment may have been characterized by a more extensive beach zone, when periods of submergence of the shells may have been interrupted with longer periods of exposure and where reworking was probably stronger. However, the infaunal habit prevented these shells from being highly eroded. In general terms, evidence of continuous burial in sediment after death are the lack of periostracum on single valves which are often blackened and affected by solution, near absence of associated epifauna and lack of signs of attack by boring organisms (Trewin and Welsh, 1971).

P. rostratus: It is in general considerably altered along the northern area (where it is scarce), but its worst preservation was observed within the ridges from Punta Indio, with strong loss of luster (chalky appearance) of the shell surface most likely caused by meteoric waters (Kowalewski and Flessa, 1995). This may be another evidence of increasing age of these deposits, supporting the older ^{14}C and D/L ages obtained for these deposits.

The taphonomic alteration is even more evident in the ridges from the Bahía Blanca area, where the valves are strongly abraded (Plate II, 13–14) which can be explained by a long exposure time prior to final deposition.

B. rodriguezii: It exhibits its best preservation along the Mar Chiquita area, being more altered along Samborombon Bay. This is the only one of the four species analysed where bioerosion signatures were frequently observed (Plate II, 20), probably as a result of longer exposure of the shells during low tides in the shallow littoral zone, commonly in-

habited by Naticid gastropods, Clionid sponges and boring Polychaetes.

In the Quequén Salado area, *Brachidontes rodriguezii* shows very bad preservation but occurs as whole specimens with maximum sizes reaching 4 cm in length (Plate II, 18). In the ridges from the Bahía Blanca area the species is especially abundant and exhibits good preservation in spite of the thin valves. Both convex up and convex down stackings are associated with storm reworked concentrations (Farinati and Aliotta, 1997) and are probably a result of interference among shells during transport (Kidwell et al., 1986).

9. Conclusions

The taphonomic attributes of shells (subfossil and fossil) of four bivalve species, well represented in the Holocene littoral deposits (beach ridges and tidal flats) from the coastal area of Buenos Aires Province (Argentina, Southwestern Atlantic), represent useful indicators of past environmental conditions mainly during the last ca. 7500 ^{14}C yr B.P.

On the basis of three physical attributes (disarticulation, fragmentation, abrasion) the results obtained on three infaunal species (*Tagelus plebeius*, *Macra isabelleana*, *Pitar rostratus*) and one epibyssate species (*Brachidontes rodriguezii*) support the occurrence of two kinds of palaeoenvironments represented by: (1) low energy (tidal flats and coastal lagoon facies) in Canal de Las Escobas (Samborombon Bay), Mar Chiquita and Quequén Salado and Bahía Blanca; and (2) high energy deposits (beach ridges) in Punta Indio, Samborombon Bay, Mar Chiquita and Bahía Blanca. Whereas biological attributes (i.e., bioerosion) seem to have been less significant at least for the species here considered during the time span of the Holocene.

The shell material analysed have two kinds of origins: (1) untransported (in situ) as autochthonous associations represented by dominance of *T. plebeius* mostly in life position (coastal lagoon facies from Samborombon Bay, tidal flats from Quequén Salado and Bahía Blanca; Fig. 2); and (2) transported (at different scales) shells represented by parautochthonous associations (ridges). The best attribute which clearly differentiates both associations is disarticulation, fol-

lowed by abrasion which were obviously lowest within in situ assemblages.

High fragmentation and abrasion of the shells suggest that they remained exposed during a considerable time span before their final burial. Most breakage and abrasion attributes seem to be more a consequence of reworking of the shells than of transport. This is most evident in those accumulations where shells come from an original environment characterized by an extensive beach zone (although with soft bottoms and comparatively calmer waters) (e.g., Samborombon Bay and Bahía Blanca ridges) and not necessarily in hard bottoms, shallower or highly energetic littoral environments where higher transport would be more expected (e.g., ridges from Mar Chiquita area). For Bahía Blanca Farinati and Aliotta (1997) proposed that the ridges were originated by extraordinary stormy conditions. They probably formed during several episodic events.

We support conclusions by other authors (Brandt, 1989; Kowalewski and Flessa, 1995) regarding changes in preservation following one direction: good to poor. Lower taphonomic attributes being good indicators of younger shells and/or less energetic habitat. Abrasion is the only attribute which seems to vary or correlate more or less directly with age (e.g., *Maetra isabelleana*, Table 1; Plate II, 2), the loss of luster of the shell surface (chalky appearance or more polished surfaces) corresponding to older shells and in general terms increasing with the age of the deposits.

As expected, the infaunal bivalve species analysed (*T. plebeius*, *M. isabelleana*, *P. rostratus*) are better preserved than the pibyssate *B. rodriguezii*. Infaunal species typically living on silty sand substrates of the intertidal and infralittoral zones (*T. plebeius*, *M. isabelleana*) are less fragmented and abraded than shells of infaunal species living in coarser bottoms in the infralittoral (*P. rostratus*). *B. rodriguezii* is very seldom abundantly preserved unfragmented, with original sculpture and luster and in abundant quantities.

Shells recorded from autochthonous deposits (high taphonomic grade; Brandt, 1989) (Canal de Las Escobas in Samborombon Bay, estuarine facies of Mar Chiquita area, Quequén Salado river and Bahía Blanca tidal flats) are more reliable in terms of palaeoenvironmental conditions. These shells have

been affected by low energy depositional conditions. The low taphonomic attributes support the minimum influence of the postmortem processes on shells from these autochthonous skeletal concentrations.

Due to time-averaging of shell remains, dominant taxa from parautochthonous assemblages (ridges from both areas) are relatively reliable only to detect long-term palaeoenvironmental variability (not less than ca. 1000 yr time span). This needs to be taken into account when analysing radiocarbon and amino-acid dates from these deposits and palaeoecological information based on the molluscan fauna.

Infaunal species from fine sediments may prove to represent more reliable dating material and palaeoecological indicators for future palaeoenvironmental studies carried out along this coastal area.

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