AMEGHINIANA
A GONDWANAN PALEONTOLOGICAL JOURNAL

Submitted: July 19th, 2017 – **Accepted**: November 28th, 2017 – **Published online**: December 19th, 2017

To link and cite this article:

doi: 10.5710/AMGH.28.11.2017.3139

COMPARATIVE TAPHONOMY OF MOLLUSK ASSEMBLAGES IN QUATERNARY FRESHWATER SEQUENCES FROM THE SALADO RIVER BASIN, BUENOS AIRES

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26 pages (text + references), 5 illustrations and 4 tables.

5. **Proposed header**: Pisano *et al.*: Surface alteration on *H. parchappii*

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ABSTRACT. From the analysis of taphonomic attributes of specimens of *Heleobia parchappii* found in fluvial and paleolacustrine sequences of the lower basin of the Salado River, the surface alteration of their shells was studied comparatively in order to assess differences between both environments. Main results obtained through NMDS and ANOSIM test (R=0.31, p<0.01), allowed recognition and statistical differentiation of both groups of samples. The taphonomic characteristics of those recovered from the paleolacustrine environment are more similar to each other while those from the fluvial environment showed greater dispersion. Through the SIMPER analysis we could determine that the discoloration and dissolution variables were the most important features to differentiate both groups, and the values of the indexes (Total Taphonomic Grades) were always higher in the paleolacustrine assemblages, showing greater decay. The differences of preservation could be explained by the residence time of the remains near the water-sediment interface, as well as by the differences in the sedimentation rate in both environments, which control the different exposure cycles of the shells. These differences would be related to changes in the hydrological regime (fluctuations in surface and groundwater levels) that, although affecting the entire study area, are more intense and frequent in shallow lakes favoring decay of the shells accumulated in this environment.

Keywords. *Heleobia parchappi*, alteration of the external surface, geomorphological changes, climate changes.

RESUMEN: TAFONOMÍA COMPARATIVA DE ENSAMBLES DE MOLUSCOS EN SECUENCIAS DULCEACUÍCOLAS HOLOCENAS DE LA CUENCA DEL RÍO SALADO, BUENOS AIRES**.** A partir del análisis de una serie de atributos tafonómicos sobre ejemplares de *Heleobia parchappii* provenientes de secuencias fluviales y paleolacustres holocenas acumuladas en la cuenca baja del rio Salado, se ha realizado un estudio comparativo de la alteración superficial de sus conchas para evaluar si existen diferencias entre ambos ambientes. Los resultados principales permiten, a partir de un NMDS y test ANOSIM (R=0,31, p<0,01), reconocer y diferenciar estadísticamente los dos grupos de muestras, presentando aquellas recuperadas del ambiente paleolacustre características tafonómicas más similares entre sí mientras las fluviales muestran mayor dispersión. El análisis SIMPER permitió determinar que las variables descoloración y disolución fueron las más importantes para diferenciar ambos grupos, y los valores de los índices obtenidos (Grados Tafonómicos Totales) siempre fueron más altos en los ensambles paleolacustres evidenciando un deterioro mayor en ellos. Las diferencias encontradas en la preservación podrían explicarse por el tiempo de permanencia de los restos cerca de la interfaz agua-sedimento y las diferencias en la tasa de sedimentación en ambos ambientes. Estas diferencias estarían relacionadas con cambios en el régimen hidrológico (fluctuaciones en los niveles de agua superficial y subterránea) que, si bien afectan toda el área de estudio, son más intensos y frecuentes en las lagunas favoreciendo la descomposición de las conchillas acumuladas en este ambiente.

Palabras Claves. *Heleobia parchappi*, alteración de la superficie externa, cambios geomorfológicos, cambios climáticos.

INTRODUCTION

Taphonomy aims to explain the processes and modifications which affect the fossil record. These changes may be related to intrinsic characteristics of individuals (Lockwood and Work, 2006), to those of the depositional environment (Powell *et al.*, 2011), to agents that modify after death (Kidwell and Bosence, 1991), to diagenetic conditions after burial, or a combination of them. Therefore, during their formation, fossil assemblages pass through a taphonomic filter that can cause the loss of original biological information, accompanied by the acquisition of new features (Parsons-Hubbard, 2005). In many cases, the way these preservational processes act and combine to generate the peculiar characteristics in the record is unclear (Powell *et al.*, 2011b), particularly in freshwater environments.

Specifically, comparative taphonomy studies the differential preservation among fossil groups, depositional environments, or periods of geologic time (Brett and Baird, 1986). Although the fossil record is rich in biological and ecological information, it is biased and controlled by the physical, chemical and biological processes that occur in the depositional environments (Parsons-Hubbard, 1989). Therefore, their contrast and recognition provide key information to strengthen and enrich paleoecological and paleoenvironmental interpretations.

Aquatic continental environments are more complex than marine ones, mainly because of fluctuations in water levels and currents, as well as of variations of the chemical composition of the environment (Pip, 1988; Dillon, 2004). The precipitation and dissolution of calcium carbonate are very important processes to take into account in freshwater environments, both fluvial (Canfield and Raiswell, 1991; Kotzian and Simões, 2006; Strayer and Malcom, 2007; Erthal *et al.*, 2011) and lacustrine (Cristini and De Francesco, 2012; De Francesco *et al.*, 2013), since waters undersaturated in calcium carbonate, whether from rain, river or subterranean, can quickly destroy the shells of mollusks and impact the quality of information in fluvial fossil record. Therefore, the fossil record in those settings is less diverse (in terms of richness of species), due to poorer preservation and the instability of waterbodies (Cummins, 1994; Kotzian and Simões, 2006).Therefore, it is believed that the taphonomic processes act on freshwater shells differently from what occurs in the marine environment (Erthal *et al.*, 2011; 2015), although this is a poorly developed subject, nowadays is receiving more attention of the researchers. Recently, studies on mollusks taphonomy have been carried out in shallow lake sediments of the SE sector of the Buenos Aires province (Cristini and De Francesco, 2012; De Francesco *et al.*, 2013; Tietze and De Francesco, 2017), as well as comparative analysis between diatoms and mollusks (Hassan *et al.*, 2014). And particularly in the Salado River basin, the preservation of assemblages of *H. parchappii* (d´Orbigny, 1835) and *H. australis* (d´Orbigny, 1835) in fluvial sediments has been comparatively analyzed (Pisano *et al.*, 2015).

The main objectives of this paper are to 1) compare a set of taphonomic attributes related to the surface alteration of Quaternary mollusks shells and explore the existence of differences in preservation between assemblages deposited in fluvial and paleolacustrine environments of the Salado River basin, and 2) define, when possible, a series of taphonomic features of the assemblages that allow recognizing environmental characteristics through the preservation state of the recovered specimens.

STUDY AREA AND GEOLOGICAL SETTING

Most of the Salado River basin is located in the Buenos Aires Province (Fig 1.A), occupying nearly 17 million ha (186.000 km^2) in the geomorphological region of

“Pampásica deprimida or central” or “Pampa Deprimida” (depressed Pampa) (Frenguelli, 1950; Fidalgo, 1992), with the valley of the Salado River as its main axis. The regime of the Salado River is calm, with sinuous design and mostly meandering, NW-SE runoff, being subterranean water the main source (Soldano, 1947). Its hydrological regime is very variable with current flows that exceed 1,500 m^3s-1 in flood conditions and never exceeding 100 m^3s-1 in periods of drought (Gabellone *et al*., 2001).

The shallow lakes and paleolakes carved in the loess sediments of the Pampeano Formation are distributed throughout the Salado depression, with variable sizes and depths (0.5-2 m), associated or not with water courses. The main processes that gave rise to these forms are deflation and pelletizing (Tricart, 1973; Fucks *et al*., 2012), which are more efficient with high frequency of flooding and drying cycles (Gutiérrez Elorza *et al*., 2005). Therefore, those occurring in the region during the Quaternary (Iriondo, 1984; Fucks *et al*., 2012) were the ideal climatic scenario for the action of these processes.

At present, the Salado River basin is developed in a temperate-humid climate, with an mean annual precipitation of 900 mm and an average annual temperature varying from north to south between 13.8º and 15.9°C (Halcrow and Partners, 1999). These climatic conditions favor many of these basins to be occupied by water, forming permanent or semi-permanent shallow lakes, whereas in other cases the connection with the main course or its tributaries is active only in times of extreme flooding.

Because it is a plain basin with a poor hydrographical network, as a result of insufficient energy due to the low slope (0.1 and 0.01 %) and the inheritance of dry climates of the recent past (Tricart, 1973), it becomes a very fragile landscape not only in extreme hydrological events but also during the periodic episodes of intense rains, as it happens today.

During floods, the low slope prevents the evacuation of large volumes of water that accumulate in a short time and leads to the occurrence and persistence of flooding (Brandizi and Labraga, 2012; Fig 1.B). This causes an increase in the level of surface and subterranean water, decreasing the conductivity values due to the action of surface runoff. The salinity calculated during these periods was 900 uS/cm in the river (measured in conductivity units, Gabellone *et al*., 2003) and 744 mg/l in the lagoons (Dangavs *et al*., 1996). While in dry periods flow decreases significantly, even with interruption of the course and the total drying of the lentic bodies (Fig 1.C); inducing increases in salinity values up to 14000 uS/cm in the river (measured in conductivity units, Gabellone *et al*., 2003) and 2680 mg/l in the lagoons (Dangavs *et al*., 1996), due to the contribution of subterranean water (Gabellone *et al*., 2001).

Stratigraphically, the studied sediments are assigned to the fluvial Luján Formation, to the Gorch and Puente Las Gaviotas Members (Fucks *et al*., 2015). These sediments have a continuous record and high abundance of mollusk shells (Pisano and Fucks, 2016). Both members are Holocene in age, having the Gorch Member absolute ages between *ca* 11,000 and 5,600 years BP, and Puente Las Gaviotas Member between 3,040±70 and 680±60 years BP (Fucks *et al*., 2015).

MATERIALS AND METHODS

The study was conducted in three localities where geomorphological environments are clearly identifiable at present (Fig. 1), during a dry period (2010) that left the sequences exposed. “Estación Río Salado” (35°44'10"S/58°26'27"W) and “Puente Las Gaviotas”

(35°49'36"S/58°22'39"W) represents typical fluvial sequences while “Buena Vista de Guerrero” (35°56'34"S/57°46'46"W) corresponds to a paleolacustrine environment. Sedimentologically (Fig. 2) the fluvial sequences are dominated by the grayish brown fine silty sands, with homogeneous structure. While the paleolacustrine sequence is represented by an alternation of siltys and clays, of light to dark grey colors, with parallel lamination and stratification. At each locality a sedimentary core was extracted using a plastic PVC pipe that was sunk laterally into the outcrop and taken to the laboratory and then subsampled. Mollusks were recovered by sieving (0.5 mm), carefully washed and dried at room temperature. Shells were separated by picking under a stereomicroscope.

Examined materials

Preservation of shells of *Heleobia parchappii* (Caenogastropoda: Cochliopidae) was evaluated. This species was used as target taxon for the stated objectives due to its wide distribution and abundance in all the studied samples. When selecting specimens of a single taxon, the aim is to diminish factors of interspecific variability related to the features of the shell, such as: composition, internal microstructure, shape, size, thickness, and organic matter content, among others. However, this implies reducing the variability of taphonomic attributes (Powell *et al.*, 2011b).

H. parchappii is the dominant freshwater mollusk species in both modern (Tietze *et al.*, 2011) and Quaternary environments of the Pampean Region, with relative abundances that reach 90 – 100% (De Francesco *et al.*, 2013; Pisano and Fucks, 2016). It is an opportunist species, with a relatively short life cycle, with an estimated duration of 12 (De Francesco and Isla, 2004) to 20 months (Merlo *et al.*, 2016). The species has high reproductive rates and early reproduction (Tietze *et al.*, 2011) and direct development without a free-living larval stage (Cazzaniga, 2011).

The shell is thick, small (from 2 to 5 mm in length), with seven to eight anfracts separated by deep sutures, and has a typical elongated and narrow conic shape. The external surface is smooth or may bear axial growing lines; the original color is yellowish white or translucent brown, sometimes with brownish-reddish apex.

H. parchappii may live in creeks and shallow lakes, associated with submerged vegetation, stones or muddy bottoms (Tietze and De Francesco, 2010); juveniles and adults are able to disperse by flotation (Cazzaniga, 2011). This species was classically known as exclusive of freshwater, but it adapts to brackish waters as well, living in small water bodies with high concentration of salt due to evaporation (Bonadonna *et al.*, 1995; Tietze and De Francesco, 2010; 2017).

Taphonomic characterization

A total of 65 samples were analyzed, 36 were taken of fluvial sequences and 29 of paleolacustrine environment. From each sample, between 100-150 specimens were used randomly selected from the total of the individuals present in each sample, both shells and fragments that could be reliably assigned to *H. parchappii*. Taphonomic attributes were characterized and quantified under a stereoscope microscope (10X) by a single operator to maintain the classification criterion (Rohtfus, 2004).

The attributes considered in this analysis were (1) discoloration, (2) luster, (3) dissolution and (4) ornamentation, which were described according to taphonomic degrees, i.e., arbitrary categories defined before starting the analysis (Kowalewski and Flessa, 1995; Kowalewski *et al.*, 1995). Therefore, for quantification, each shell was compared to a reference group of specimens assigned *a priori* for each degree of attribute (Fig. 3). Many authors use the concept of “fine-scale surface alteration” to gather all those processes such as dissolution, corrosion, bioerosion, corrasion, which individually or combined, alter the external surface of the remains (e.g. Kidwell and

Bosence, 1991; Best and Kidwell, 2000; Ritter *et al.*, 2013; Lockwood and Work, 2006; De Francesco *et al.*, 2013). In this paper, selected variables are considered as independent attributes, but they are intimately related and, in many cases, they are originated by the same processes (Tab. 1). The joint analysis will allow characterizing and comparing the stage of external preservation of the shells.

Discoloration and luster were considered as variables with two stages; Grade 0 gathers the shells that kept their primary characteristics (translucent / bright), as opposed to those with white and matte finish (Grade 1).

Dissolution is the degradation of the external surface of the shell, manifested by the presence of micro-perforations or pits and even holes in extreme cases. Three grades were defined: 0, without alteration; 1, shells with chalky surface less than 50 % and /or little pits present; and 2, chalky surface in more than 50 % of the shell, together with large pits or even holes of irregular margins.

Ornamentation refers to the loss or accentuation of the external ornamentation of the shell. It can be considered an important attribute to evaluate the abrasion undergone by the specimens (Hauser *et al.*, 2008) together with the loss of luster (Erthal, 2012). Grade 0, gathers the specimens that maintain the original ornamentation of the species; grade 1, those in which it is worn out or lost; grade 2, individuals with accentuated ornamentation.

Data analysis

In the general quantification, each sample was characterized according to the relative frequency of the different taphonomic degrees, from these the Total Taphonomic Grade (TTG) was calculated for each attribute. TTG was calculated as the arithmetic sum of the individual records of each sample, following the formula (N0*0)+(N1*1)+(N2*2)/ N_{total} (for variables with three grades) or (N0*0)+(N1*1)/ N_{total} for discoloration and luster (variables with two grades). Low TTG values are found in pristine samples with little modification.

A Non-Metric Multidimensional Scaling (NMDS) was performed to assess similarity of samples in environments, using Manhattan distance. NMDS is a multivariate ordination technique that represents a set of objects (samples in our study) in a geometrically two-dimensional space. Therefore, two near points are considered of greater similarity in their taphonomic profile. The value of STRESS (Standard Residual Sum of Squares) representing the degree of information lost when resizing the information for two ranked variables, is expressed following the classification proposed by Kruskal (1964), between, 1-0.05 are good, 0.05-0.025 are excellent and ≤0.01 perfect.

In addition, ANOSIM (Analysis of Similarities) was performed. This test of non-parametric multivariate permutations, detects differences between groups defined *a priori*, for this study the environments are used as clustering factors. ANOSIM has been used to test hypotheses of spatial and temporal changes or differences (Chapman and Underwood, 1999). It is based on the null hypothesis that the average range of similarity among objects within a group is the same as among objects among groups (Rees *et al.*, 2004). From the original matrix, another was made with Manhattan distance, which was analyzed as a dissimilarity matrix. The statistic test R acquires values between -1 and +1; those between 0 and 1 indicate some degree of difference between groups (Chapman and Underwood, 1999); the p-value was obtained by permutations (999), and values lower than 0.05 were considered significant.

The Mann-Whitney test was used to test whether there are differences among the TTG in both environments. The p value< 0.05 were considered statistically significant.

A similarity percentage analysis (SIMPER) was then performed to determine the percentage of contribution of each taphonomic variable to the difference between environments (Erthal, 2012).

Analysis and graphs were carried out with the "vegan" (Oksanen *et al.*, 2011), "graphics" and "stats" packages of the R (R Development Core Team, 2009) program.

RESULTS

A total of 9572 individuals were analyzed, which were distributed in 38 samples from fluvial (N=5331) and 29 (N=4241) from paleolacustrine environment. When analyzing each attribute individually (Tab. 2) most individuals showed modifications of their original coloration and were cataloged in grade 1 ($N_{fluvial}$= 3364, 63.10%; $N_{paleolacustrine}$= 3612, 85.17%). In luster and ornamentation, taphonomic grade 0 prevailed in samples from both environments. In the case of luster percentages reached 90.25% in fluvial (N=4811) and 83.64% (N=4811) in paleolacustrine environments. In ornamentation, these abundances reached 3502 individuals (65.69%) in fluvial and 2484 (58.57%) in paleolacustrine environments, as evidence that in both cases there is no loss or alteration.

Considering dissolution, most individuals showed grades 0 and 1. Most specimens of fluvial samples (N=2778, 52.11%) showed no signs of alteration (grade 0), whereas grade 1 prevailed in samples from paleolacustrine setting (N=2399, 56.51%).

Specimens with extreme dissolution (Grade 2) were scarce.

The calculated TTG was higher in samples of paleolacustrine environment (Tab.3 and Fig.4). Therefore, samples belonging to the fluvial environment, which presented lower TTG values, underwent less modification and retained the original characteristics to a greater extent. The comparisons made between both environments, using the Mann-Whitney test, were very significant for all the taphonomic attributes.

NMDS (STRESS=0.09; Fig. 5) of the general analysis resulting from the combination of all TTG calculated, allowed the individualization of both groups of samples. Furthermore, results obtained from ANOSIM test indicated significant differences in preservation ($R=0.31$; $p<0.01$) of the shells between both environments, confirming the groups recognized through NMDS. Paleolacustrine samples showed taphonomic features more closely related, whereas fluvial ones showed larger dispersion, confirmed by the results obtained through Betadisper (Average distance to centroid in fluvial =0.12 vs lacustrine = 0.06 samples).

SIMPER analysis (Tab. 4) suggests that the discoloration and dissolution variables contribute more than 75% to the difference between both environments, the loss of luster in the samples turned out to be low and is the attribute that contributes less in the differentiation. Values in the paleolacustrine environment were always higher.

DISCUSSION

H. parchappii is the most abundant species in freshwater Quaternary deposits of the Pampean region. Although other taphonomic studies have dealt with its preservation stage (e.g. De Francesco *et al.*, 2013; Hassan *et al.*, 2014; Pisano *et al.*, 2015), the alteration in the outer surface of its shell is compared for the first time, in two sedimentary environments that can remain connected or isolated according to the climatic conditions in the region.

The alteration of the external surface, defined as the degree of degradation of a shell by the combined effect of different processes, is a very useful resource to assess the state of preservation of mollusk shells in different environments, either marine, fluvial, lacustrine or even terrestrial (e.g. Best and Kidwell, 2000; Lockwood and Work, 2006; Nielsen *et al.*, 2008; Bullard *et al.*, 2017; Tietze and De Francesco, 2017). In freshwater systems, as those studied here, the potential for preservation of fossils depends mainly on pH, carbonate saturation levels, rainwater and hardness of groundwater (including rivers, streams and lake) that strongly affect the preservation and disintegration of the calcareous shells (Strayer and Malcom, 2007; Nielsen *et al.*, 2008; De Francesco *et al.*, 2013).

A series of attributes (discoloration, luster, dissolution and ornamentation) have been selected in this paper, which together define the general state of the surface of shells in assemblages deposited in fluvial and paleolacustrine environments and provide important information about the taphonomic processes involved (Tab. 1). Among these processes, the following stand out: the lack of rapid burial favored periods of subaerial or subaquatic exposure, wetting and drying, etc. (eg Brett and Baird, 1986; Best and Kidwell, 2000), and cause the alteration of all the attributes here analyzed. The residence time in the Taphonomic Active Zone (TAZ) mainly produces color changes and dissolution (e.g. Brett and Baird, 1986; Powel *et al.*, 2011a; Erthal *et al.*, 2011, Erthal *et al.*, 2015). The TAZ is the sector of the sedimentary column that includes the water-sediment interface, in which the processes that cause gain or loss of skeletal material act more intensely. Finally, it is noteworthy the action of the chemical processes responsible for the dissolution of the shells (e.g. Brett and Baird, 1986; Farinati *et al.*, 2008; Nielsen *et al.*, 2008) and to increase the alterations in ornamentation (Parsons-Hubbard, 2005; Hauser *et al.*, 2008).

Both color changes and loss of luster are sensitive indicators of the early decay of the shells, since they usually occur quickly after death (Kowalewski, 1996; Parsons-Hubbard, 2005). In this study, both attributes were categorized with two states: natural and altered. The results were opposite, while most specimens suffered modifications in their color (63% of the fluvial shells and 85% paleolacustrine), only a minimum part lost the original luster (0.75% of the fluvial shells and 13.64% paleolacustrine).

When evaluating the dissolution, the TTG values were slightly higher in the paleolacustrine assemblages. While the evidences of extreme dissolution (Grade 2), represented by microperforations or pits that cross the entire shell, was uncommon (5.23% in fluvial environment vs. 3.05% in paleolacustrine); the greatest differences were found when quantifying the shells with chalky surface and/or small pits (Grade 1, 56% in paleolacustrine environment vs. 42% in fluvial environment). Powell *et al.* (2011a) showed that some taphonomic processes cannot advance rapidly without previous alteration; in the case of dissolution, the chalky texture is an intermediate situation that makes the shells softer and favors the appearance of more extreme dissolution conditions (e.g. the appearance of holes), and occurs shortly after the death (Kotzian and Simões, 2006).

Finally, when evaluating the modifications in ornamentation, although the average TTG were slightly higher in the paleolacustrine environment (0.55 vs. 0.45), the specimens that maintained the original ornamentation prevailed (66% in fluvial environment vs. 58% in the paleolacustrine), while the extreme condition of over relief was very low. The low values of TTG coincide with similar results obtained by Kotzian and Simões (2006), which these authors associate to the lack of mechanical abrasion. The *Heleobia* shells are usually transported by flotation (Cazzaniga, 2011), the permanence of them in suspension in the water column and the low values of fragmentation obtained in previous studies in the Salado basin, only 17% of the specimens showed evidence of severe breakage (Pisano *et al.*, 2015), could explain the lack of evidence of mechanical wear suffered by the specimens and the preservation of the original ornamentation in most of them.

Sedimentary factors affecting preservation

Given the obtained results and the inferences that can be made from the considered attributes, one of the plausible explanations for interpreting the differential decay of the shells in both environments would be considering the time of exposure and permanence in the TAZ. The fossils that remain in the TAZ are more likely to be modified or destroyed; however, a deep burial allows them to avoid the processes that operate there (Cherns *et al*., 2011; Erthal *et al*., 2015). In the environments studied in the Salado River Basin, the greatest accumulation of sediments occurs in the fluvial sequences, forming the levees and the floodplain adjacent to the course, causing the shells to be buried more rapidly.

Erthal *et al*. (2015) argue that a key process in fluvial systems is the transport and mixing of shells. A river can rework remains that were buried, incorporate them into their load, transport them and deposit them again. In the Salado River Basin during floods, fluvial and lacustrine environments are connected and an important part of the material can be transferred to the lakes where it accumulates. In addition, in these lakes, sedimentation rates are much lower (unless they are traversed by the Salado River) (Fucks *et al*., 2012) and therefore weathering is stronger. The shells are more likely to be exposed at the bottom of the lakes, where the action of weathering processes and in cases of an extreme event, wind erosion can favor their decay.

Climate effect on preservation (droughts and flooding and related changes in the area)

Climate changes produce marked contrasts in geomorphological processes. During periods of great rainfall, the river and shallow lakes are connected and often, both environments cannot be differentiated. Floods produce increased transport, greater exchange, and accumulation of materials. On the other hand, when rainfall decreases, flow diminishes and isolated lagoons are formed, eventually drying completely if these conditions are maintained over time. This alternation also causes important chemical changes both in the Salado River and in the neighboring lakes (Maizels *et al*., 2003). Laprida and Valero-Garcés (2009) recreated for the Chascomús lagoon the prevailing conditions during a high water scenario where there is a greater contribution of meteoric waters and humic substances that cause the decrease of pH and salinity (Maizels *et al*., 2003), favoring the dissolution of carbonates and acidification of waters. Whereas, when the level of water decreases gradually, the evaporation processes and precipitation of carbonates dominate. The decay of the studied assemblages could be due to a combination of factors related to fluctuations in water levels, either periodic or extraordinary, which affect more drastically the lentic environments. In the lagoons, where there is a greater presence of chalky shells and modification of the original color, changes of the water volume are more abrupt, therefore the shells alternate submerged periods, with others in which they are exposed on the bottom, and are prone to be affected by subaerial exposure and winds in times of drought (Dangavs *et al*., 2006).

CONCLUSIONS

Dissolution and discoloration are among the most important attributes targeted to analyze the alteration of the external surface of shells of *H. parchappii*, especially in differentiating the assemblages of Holocene mollusks of fluvial and lacustrine environments of the Salado River basin.

Those assemblages deposited in fluvial environments were mainly characterized by retaining luster and ornamentation, and showed less evidence of shell dissolution. On the contrary, those samples recovered from the lacustrine environment showed more intense evidence of dissolution, being the chalky specimens the most frequent ones, along with loss of colour.

Differences of preservation between both environments could be related to the residence time of the remains near the water-sediment interface and the differences in the sedimentation rate in both environments that condition the different exposure cycles suffered by the shells. These processes are directly related to the changes of the hydrologic regime and fluctuations in water levels of the Salado River basin, which although affecting both the main course and the lagoons, it is in the latter that shells suffer most the abrupt changes, favoring a greater surface alteration in these assemblages.

ACKNOWLEDGEMENTS

Financial support for this study was provided by National University of La Plata (11/N800 project). We thank Claudio De Francesco for help in statistical analysis, and Carola Castiñeira Latorre and Marco Alvarez for allowing us to photograph the material in the Division of Mineralogy, Petrology and Sedimentology of the La Plata Museum (FCNYM-UNLP). We also acknowledge two anonymous reviewers and the editor for helpful and constructive reviews that greatly improved the manuscript. MFP, NNP and MSL thank the National Council of Scientific and Technical Research of Argentina (CONICET) for economic support.

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Captions

Figure 1: Location map with the studied localities (A). Comparative images of Buena Vista de Guerrero during a flood period (B) and drought (C), Digital Globe images from Google Earth.

Figure 2: Images of the upper section of two outcrops analyzed in Puente Las Gaviotas (A) and Buena Vista de Guerrero (B). Vertical bar =1 m

Figure 3: Reference specimens of *Heleobia parchappii* (d'Orbigny)*,* used for characterization and quantification of samples, showing different degrees of each attribute. Scale bar =1 mm.

Figure 4: Boxplots showing the difference in the degree of taphonomic alteration between environments. The number of asterisks denotes the *p* value for Mann-Whitney U test (*** = p value<0.001; ** = p value<0.01*)*

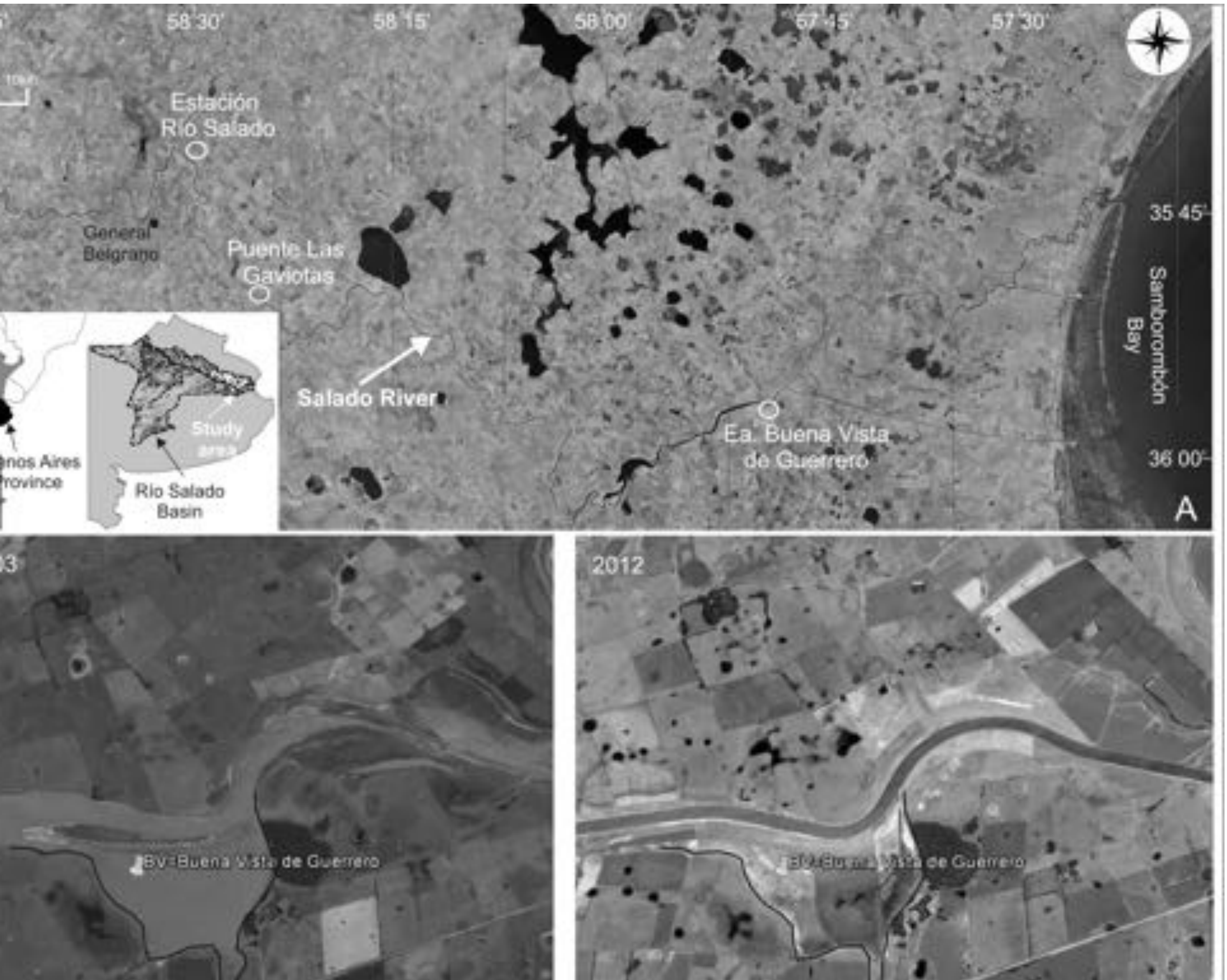
Figure 5: NMDS of the samples considering the TTG of four taphonomic variables combined.

Table 1: Summary of the taphonomic variables and main features that define the degrees.

Table2: Summary of general parameters (total and percentage abundances) calculated for the attributes in each environment.

Table 3: Summary of general TTG calculated for the attributes in each environment, and results of the Mann-Whitney test

Table 4: Summary of taphonomic degrees that define dissimilarity in each environment obtained through SIMPER analysis.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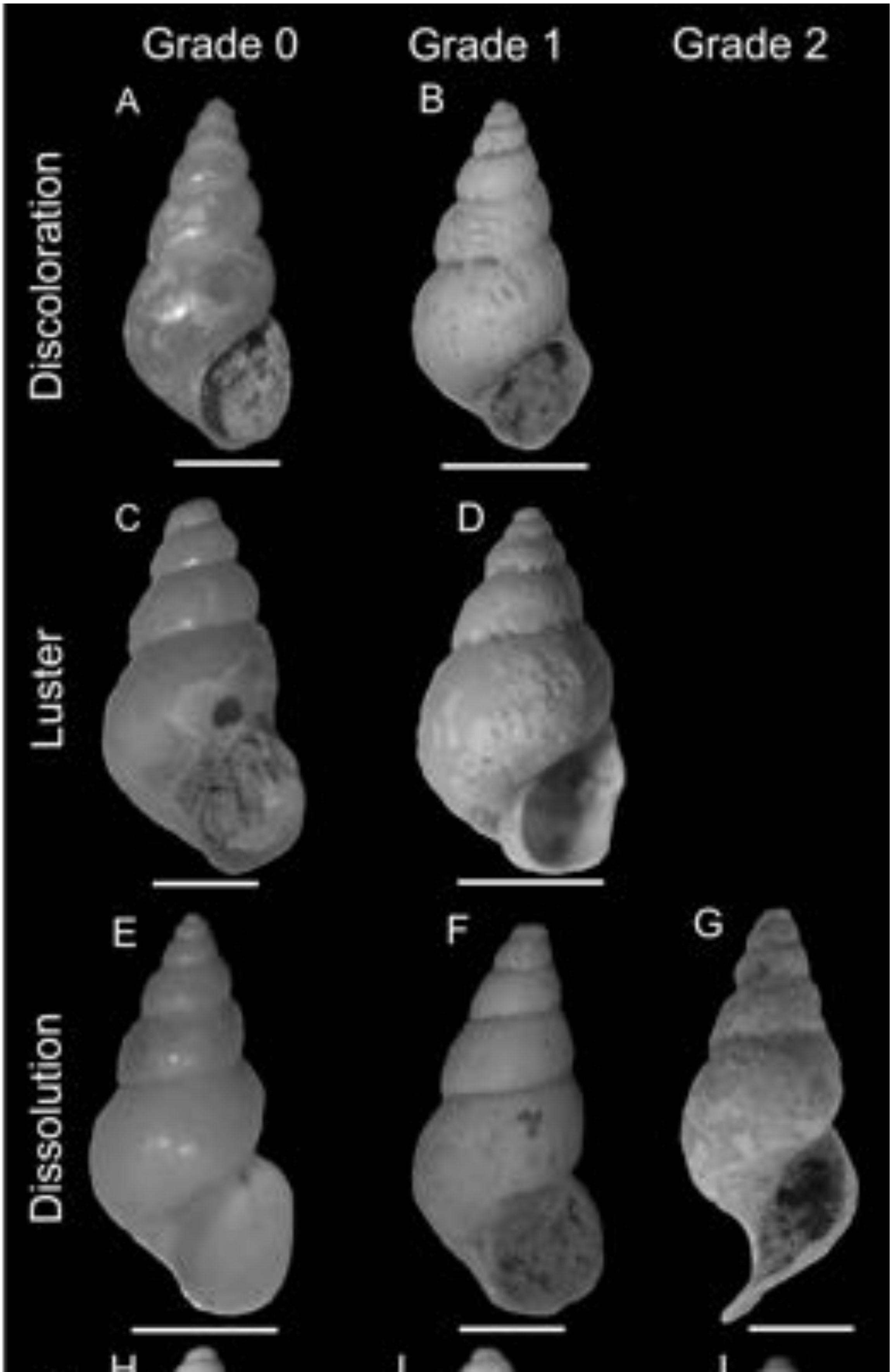
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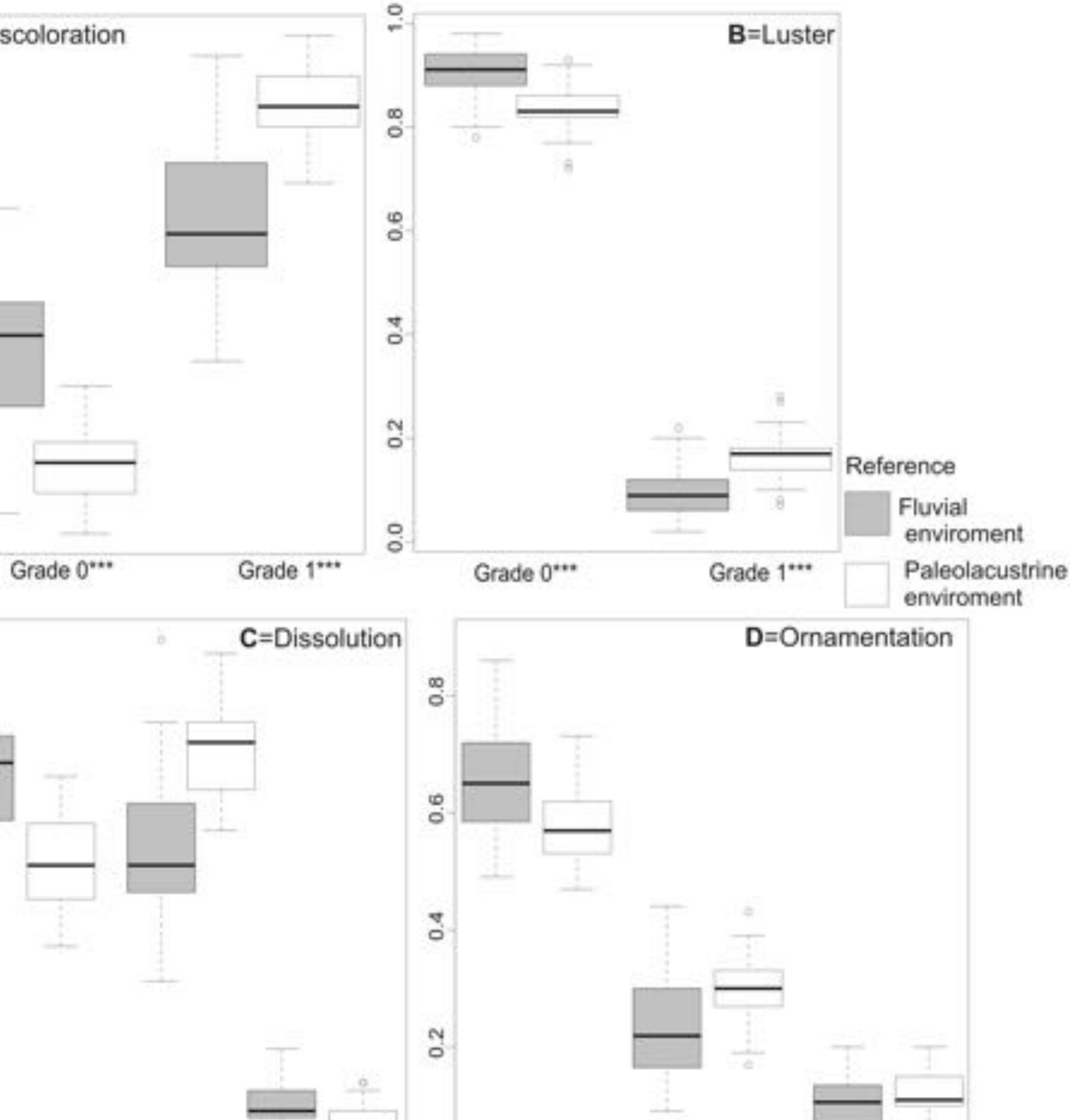
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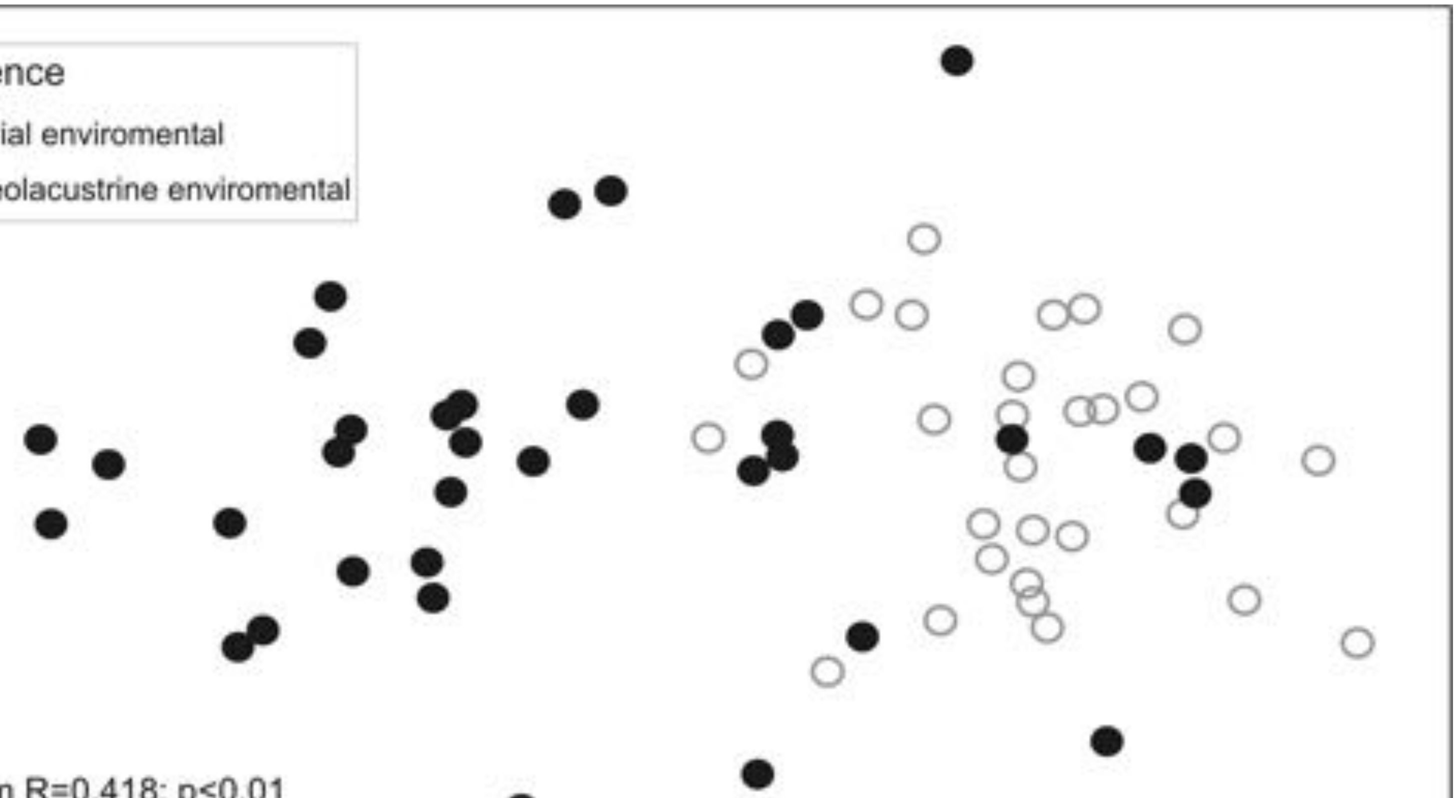
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Table 1 **– Summary of the taphonomic variables and main features that define the degrees**

Taphonomic attributes	*Taphonomic grade and general condition of the shells*	*Environmental information**
Discoloration	*Grade 0: translucent (Fig. 2 A)* *Grade 1: White (Fig. 2 B)*	*Subaerea or underwater exposure in the photic zone.Time of permanence in the TAZ.*
Luster	*Grade 0: Shiny (Fig. 2 C)* *Grade 1: opaque (Fig. 2 D)*	*Energy of the environment; transport, reworking.*
Dissolution	*Grade 0: Without alteration (Fig. 2 E)* *Grade 1: chalcky appearance and/or small pits (Fig. 2 F)* *Grade 2: chalcky appearance with large pits and/or holes (Fig. 2 G)*	*Chemical processes. Time of permanence in the TAZ.* *Burial and exhumation cycles.*
Ornamentation	*Grade 0: natural (Fig. 2 H)* *Grade 1: worn o loss (Fig. 2 I)* *Grade 2: accentuated (Fig. 2 J)*	*Energy of the environment; transport. Burial and exhumation cycles. Chemical dissolution*

**Reference used: Farinati and Aliotta(1995); Best and Kidwell (2000); Parsons-Hubbard (2005); Powell et al. (2011); Erthal (2012).*

Table 2 **– Summary of general parameters calculated for the attributes in each environment, and results of the Mann-Whitney test.**

Taphonomic attributes	*Fluvial environment*			*Paleolacustrine environment*			*Mann-Whitney U*	
	N	*%*	*mean*	*N*	*%*	*mean*	*U*	*p-value*
				Discoloration				
Grade 0	*1967*	*36.9*	*0.37*	*629*	*14.38*	*0.15*	*131.5*	*****
Grade 1	*3364*	*63.10*	*0.64*	*3612*	*85.17*	*0.85*	*128*	*****
				Luster				
Grade 0	*4811*	*90.25*	*0.90*	*3549*	*83.68*	*0.84*	*190*	*****
Grade 1	*520*	*0.75*	*0.10*	*692*	*13.63*	*0.16*	*190*	*****
				Disolution				
Grade 0	*2778*	*52.11*	*0.53*	*1711*	*40.44*	*0.40*	*197.5*	*****
Grade 1	*2274*	*42.66*	*0.43*	*2399*	*56.51*	*0.57*	*146*	****
Grade 2	*279*	*5.23*	*0.06*	*130*	*3.05*	*0.03*	*280.5*	*****
				Ornamentation				
Grade 0	*3502*	*65.69*	*0.66*	*2484*	*58.57*	*0.59*	*290*	****
Grade 1	*1278*	*23.97*	*0.24*	*1257*	*29.64*	*0.30*	*296,5*	****
Grade 2	*551*	*10.34*	*0.11*	*500*	*11.79*	*0.12*	*422*	

*N= Number of individuals in each grade, % = percentaje, Mean= mean calculated on the basis of relative abundancess, *** = p valor<0.001; ** = p valor<0.01*

Table 3 – Summary of taphonomic degrees that define similarity in each environment. Results obtained through SIMPER analysis, Bray Curtis similarity.

Taphonomic atributtes (Grade)	*AA*	*AS*	*Sim/SD*	*CTB%*	*ACM.%*
Ambiente Fluvial: Average similarity: 86.83					
Luster (Grade 0)	0.90	*21.52*	*16.66*	*24.78*	*24.78*
Ornamentation (0)	0.66	*14.82*	*8.43*	*17.07*	*41.85*
Discoloration (1)	0.63	*13.35*	*4.80*	*15.38*	*57.23*
Dissolution (0)	0.52	*11.24*	*4.39*	*12.94*	*70.18*
Dissolution (1)	0.43	*9.00*	*5.24*	*10.36*	*80.54*
Discoloration (0)	0.37	*6.79*	*2.00*	*7.82*	*88.36*
Ornamentation (1)	0.24	*4.69*	*3.24*	*5.40*	*93.76*
Ambiente Lacustre: Average similarity: 91.56					
Discoloration (1)	0.85	*19.74*	*13.78*	*21.56*	*21.56*
Luster (0)	0.84	*19.59*	*18.44*	*21.40*	*42.95*
Ornamentation (0)	0.58	*13.22*	*11.14*	*14.43*	*57.39*
Dissolution (1)	0.57	*12.84*	*10.59*	*14.02*	*71.41*
Dissolution (0)	0.40	*8.80*	*6.84*	*9.61*	*81.02*
Ornamentation (1)	0.30	*6.47*	*5.88*	*7.07*	*88.09*
Luster (1)	0.16	*3.25*	*3.47*	*3.55*	*91.64*

Abbreviations: AA = average abundance; AS = average similarity, Sim/SD = standard deviation, CTB% = percentage contribution; ACM% = accumulative percentage.

- ***TABLE 4 – Summary of taphonomic degrees that define dissimilarity in each environment obtained through SIMPER analysis, Bray Curtis similarity.***

Average dissimilarity: 15.94						
Taphonomic atributes (Grade)	AAf	AAl	AD	Diss/SD	CTB%	ACM.%
Discoloration (Grado 1)	0.63	0.85	2.92	1.67	18.31	18,31
Discoloration (0)	0.37	0.15	2.89	1.66	18.13	36.44
Dissolution (1)	0.43	0.57	1.98	1.72	12.45	48.89
Dissolution (0)	0.52	0.40	1.81	1.58	11.39	60.27
Ornamentation (0)	0.66	0.58	1.34	1.37	8.44	68.71
Ornamentation (1)	0.24	0.30	1.18	1.52	7.38	76.09
Luster (1)	0.10	0.16	0.99	1.48	6.23	82.32
Luster (0)	0.90	0.84	0.99	1.48	6.23	88.54
Ornamentation (2)	0.10	0.12	0.62	1.38	3.88	92.43

Abbreviations: AAf=average abundance fluvial; AAl= average abundance lacustre; AD=average dissimilarity; Diss/SD= standard deviation; CTB%: percentage contribution; ACM%=accumulative percentage.