

MOLLUSCS, PALAEOENVIRONMENTAL VARIATIONS AND BIOTIC RESPONSES DURING PLEISTOCENE AND MID-HOLOCENE HIGHSTANDS ALONG BONAERENSAN AND PATAGONIAN LITTORAL AREAS (ARGENTINA)

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RESUMEN

Los moluscos bentónicos preservados en depósitos costeros cuaternarios (cordones, terrazas, facies estuáricas) de la Argentina son potencialmente útiles en reconstrucciones de paleoambientes y paleoclimas vinculados con cambios oceánicos y atmosféricos, historias evolutivas y biogeográficas, complementando estudios geológicos. Bivalvos y gastrópodos de estos depósitos sugieren: 1) desplazamientos de salinidad (Pleistoceno, Holoceno, Bonaerense), 2) fluctuaciones de temperatura (Pleistoceno, Holoceno), 3) respuestas bióticas al Hypsithermal (Holoceno). Taxones dominantes/característicos de las principales áreas son: 1) Bonaerense: *Conus*, *Thais*, *Crassostrea*, *Ostrea*, *Anomalocardia*, *Erodona*, *Macra*, *Pitar* (Pleistoceno); *Littoridina*, *Macra*, *Corbula*, *Tagelus*, *Raeta*, *Pitar* (Holoceno); 2) Patagonia: *Tegula*, *Buccinanops*, *Protothaca*, *Clausinella* (Pleistoceno), *Fissurella*, *Nacella*, *Pareuthria*, *Adelomelon*, *Brachidontes*, *Aulacomya*, *Protothaca*, *Eurhomalea*, *Mulinia* (Holoceno). El impacto inmigratorio de malacofaunas frías desde el extremo sur del Atlántico sudamericano, iniciado a través de la Corriente de Malvinas, habría definido el patrón biogeográfico actual con posterioridad a 4,5 ka A.P., como indican extinciones o retracciones de taxa (*Triphora*, *T. atra*, *U. rushi*, *A. avara*; *N. bisulcata*, *C. rhizophorae*, *A. brasiliana*). La excelente preservación y grandes cantidades de conchillas manifiestan variaciones morfológicas intraespecíficas muy probablemente asociadas con cambios ambientales (sustrato, energía, salinidad, temperatura).

ABSTRACT

Late Quaternary molluscs from coastal deposits (beach ridges, marine terraces, estuarine facies) of Argentina are potentially useful to reconstruct palaeoenvironments and palaeoclimates linked to oceanic and atmospheric changes, evolutive and palaeobiogeographic histories, which complement geological studies. Bivalves and gastropods from shell concentrations suggest differences with modern conditions: 1) salinity displacements (Pleistocene, Holocene; Bonaerensian); 2) temperature fluctuations (Pleistocene, Holocene); 3) biotic responses to the Hypsithermal (Holocene). Dominant/exclusive taxa characterize the main areas sampled: 1) Bonaerensian: *Conus*, *Thais*, *Crassostrea*, *Anomalocardia*, *Erodona*, *Macra*, *Pitar* (Pleistocene); *Littoridina*, *Diodora*, *Macra*, *Corbula*, *Tagelus*, *Raeta*, *Pitar* (Holocene); Patagonian: *Tegula*, *Buccinanops*, *Protothaca*, *Clausinella* (Pleistocene), *Fissurella*, *Nacella*, *Pareuthria*, *Adelomelon*, *Brachidontes*, *Aulacomya*, *Protothaca*, *Eurhomalea*, *Mulinia* (Holocene). Quantitative variations and latitudinal shifts are likely responses to climatic cycles and their effects on the marine biotas. The last impact of cold molluscan taxa from southernmost Atlantic Ocean, initiated through the Malvinas (Falkland) current, probably established the modern biogeographical pattern after ca. 4.5 ka B.P., shown by extinction or retraction of taxa from the Argentine Sea (*Triphora*, *U. rushi*, *A. avara*; *N. bisulcata*, *C. rhizophorae*, *A. brasiliana*). The excellent preservation and large amounts of shells reveal intraspecific morphological variability (i.e., *Macra*, *Littoridina*; *Brachidontes*, *Nacella*, *Tegula*) most probably associated with environmental changes (substrate, energy, salinity, temperature).

Key Words: molluscs, marine late quaternary, Argentina

1. INTRODUCTION

The Quaternary sea level history along the coastal area of Argentina has been explained by several factors (i.e., eustasy, sediment supply, wave action, current energy). Benthic marine molluscs, a major fossiliferous component and of the modern marine littoral record, especially those preserved in deposits formed during recent sea-level highstands, are useful indicators of palaeocoastlines and palaeoenvironments.

Bivalves and gastropods from Pleistocene and Holocene sediments between the Río de La Plata and

Santa Cruz Province (Fig. 1), are potentially useful to reassess palaeoenvironmental and palaeoclimatic interpretations linked to sea-level, palaeoceanographic and atmospheric changes, including palaeobiodiversity and palaeobiogeographic patterns which define their evolutive histories. Altogether providing data complementary of previous geological studies.

The aim of this study is to place the probable palaeoenvironments on record in suitable areas with modern chronological control and for which present-day data are available. On the basis of the molluscan

highstands (MOIS5e ?, MOIS11 ?). Warm taxa recovered within the Holocene (Las Escobas Fm.; *Noetia*, *Anomalocardia*, *Urosalpinx*, *Triphora*, *Anachis avara* among others; Fig. 1) suffered a northwards displacement after ca. 4.5 ky B.P., following the same shift of the Brazilian current, Subtropical Convergence and Anticyclonic centre after the Hypsithermal. A few taxa (*Urosalpinx*, *Thais*, *Conus*, *Crassostrea rhizophorae*, *Anomalocardia*, *Anadara*; *Ostrea cf. tehuelcha*) identified within the Pleistocene deposits (Pascua Fm. and Belgranense; Magdalena, Bahía Blanca, Belgrano) are also absent from the modern littoral at the same latitude. During the Pascua transgression the Bonaerensian littoral environment could probably be warm-temperate at Magdalena and Bahía Blanca, but not warmer than during the mid-Holocene. In the remaining Pleistocene deposits SST cannot be assumed to have been much warmer as there is no evidence of latitudinal displacements, like those documented for other sediments with similar minimum ¹⁴C ages (Nueva Palmira and La Coronilla, Uruguay) (Martínez *et al.*, 2001).

Curiously, the big and usually abraded shells of *Ostrea cf. tehuelcha* from the Belgranense are similar to those found at Camarones area (Patagonian MTIII). Although traditionally interpreted as the Last Interglacial highstand, the Belgranense was assigned to a pre-Last Interglacial highstand on magnetostratigraphic evidence (Nabel, 2002), in agreement with the faunal content and taphonomic signatures of the molluscan shells.

Substrate preferences of the fauna are similar for all transgressions. A difference can be established for the energetic conditions of the oceanic waters, probably higher during the Pleistocene. Soft substrates in a shallow littoral (upper infralittoral to intertidal) palaeoenvironment of moderate energy (Pleistocene) to low energy (mid-Holocene) were probably predominant along the area.

4- PATAGONIA

Fossiliferous coastal deposits along Patagonia were preserved in response to global sea-level highstands and minor neotectonic events, well known in the local literature as Feruglio's *Marine Terraces* (MT III, IV, V and VI). Selection of three sampling areas was based on the more precise geochronological framework available (Codignotto, 1988; Schellmann & Radtke, 2000). A total of 72 molluscan taxa (44 gastropods, 28 bivalves) were identified, all extant in the Southwestern Atlantic, and except for *Tegula atra* and *V. procera* they occur in the adjacent littoral.

4.1. Camarones area

Between Bahía Vera and Camarones (44.2° S-45° S) the rich biogenic composition consists mainly of molluscs and associated balanids, terebratulid brachiopods, polychaetes, bryozoans. The marine sedimentary deposits were originally described as MT III (+ 44m, Camarones), IV (+ 22-29m, Punta Pescadero and Camarones) and V (+ 16-18m, Bahía Vera, Punta Pescadero, Camarones) of Late Pleistocene age, and as MT VI (+ 8-14m, Punta

Lobería, Punta Pescadero, Camarones) of mid-Holocene age. Molluscs suggest variations of the nearshore conditions during marine episodes since at least the long warm highstand acknowledged for MOIS11 (MTIII).

Typical of MTIV (MOIS7?, ca. 225 ka BP) are *T. atra*, big *P. antiqua*, and *Veneroida* indet. (Fig. 1). The assemblage from MTV (MOIS5?, 125ka BP) (*T. atra*, *T. patagonica*, *C. dilatata*, *M. edulis*, *B. purpuratus*, *P. antiqua*, *P. rostratus*) is not indicative of a climatic optimum like the Last Interglacial maximum highstand (MOIS5e) (Muhs *et al.*, 2002; Kukla *et al.*, 2002). Exclusive for the MTIII (MOIS11?, ca. 350-400 ka BP) are *Pectinidae*, *Ostrea cf. tehuelcha* and *Macra cf. patagonica* which together with other taxa recorded by Feruglio (i.e., *Corbula patagonica*, *Diplodonta villardeboana*) suggest warmer SST than at present.

The MTVI (ca. 6.7 ka BP) is characterized by *B. cf. purpuratus*, *N. (Patinigera) magellanica*, *N.(P.) deaurata*, *Trophon geversianus*, *Brachidontes purpuratus*, *A. atra*. Exclusive for the modern littoral are *Chlamys* sp., *Panopea abbreviata*, *Lyonsia* sp. and *N. delicatissima*.

The MTIII at Camarones is the only terrace clearly showing extralittoral faunal elements (mainly *Ostrea cf. tehuelcha* d'Orb., *Macra cf. isabelleana* d'Orb.) of warmer waters than at present, in agreement with previous correlation with MOIS11 highstand (Schellmann & Radtke, 2000) and palaeoenvironmental conclusions by Feruglio (1950). The remaining terraces do not show typical warmer water elements or characteristic of climatic optima.

The mid-Holocene (MTVI, ca. 9-6 ka BP) shows a southwards latitudinal decrease of temperate taxa and increase of typical cold elements, an obvious consequence of the southwards stronger influence of the Malvinas (Falkland) current. Warm and warm-temperate taxa were more abundant during the Holocene (southwards shift of the Brazilian Current and Subtropical Convergence during a climatic optimum ?). The palaeobiogeographic response to sea-level and climatic changes is, however, less evident than at lower latitudes (Bonaerensian littoral areas).

4.2. Bustamante area

The most characteristic bivalves and gastropods recorded from MTIV, V and VI preserved along the coastal area of Bahía Bustamante and Caleta Malaspina surroundings (ca. 44.9° S and 45.3° S) (Fig. 1) practically coincide with the previous area. The molluscs and associated macrofauna (balanids, brachiopods, polychaetes, bryozoans) from 9 fossiliferous localities and 3 modern sites also provide palaeoenvironmental data with implications for palaeoclimate interpretations since at least MOIS7. *C. protea*, *B. paytensis* and *B. rodriguezi* are first recorded for the Late Pleistocene MTIV (MOIS5-7) and *N. (P.) deaurata*, *E. magallanicum*, *B. paytensis*, *A. tehuelchus*, and *Cl. gayi* for the Mid-Holocene MTVI (MOIS1) in the area.

V. procera represents a northwards migration and *T. atra* a faunal extinction from the Argentine sea probably in response to climate change. Overall the assemblages are indicative of hard substrates, shallow waters and truly

marine conditions, similar to the modern littoral. On a temperature basis, qualitative, quantitative, morphological and distributional variations suggest slightly higher SST during the Mid-Holocene (MTVI, MOIS1, Hypsithermal), slightly colder for MTV (MOIS5c ?, 5a?), and slightly warmer or similar for MTIV (MOIS5e, 7?).

Only one Pleistocene sample, previously dated and assigned to MOIS5e contains higher abundance of warm temperate fauna (i.e., *Macra* spp., *Corbula patagonica*, *Tegula patagonica*, with their southern boundary northwards of the beach systems studied) and higher diversity rate, probably accumulated during higher SST than at present. The remaining Pleistocene samples (MOIS5, MOIS7?) do not provide evidence for higher SST than at present. Conditions for MTIII (MOIS11 ?), with higher percentage of species either extinct or northwards displaced, could represent a scenario during highstands with higher SST.

4.3. Central and southern Golfo San Jorge area

The molluscan biodiversity of the Holocene successions at central and southern Golfo San Jorge, between Bahía Solano and Bahía Laárgara, is lower than for the Bonaerensian, Camarones and Bustamante areas. No anomalous molluscan assemblages have been identified and warm water taxa do not characterize any of the assemblages.

The Late Pleistocene raised beaches sampled belong to MTV, assigned to MOIS5e and with similar minimum radiocarbon ages as the Bonaerensian (Pascua Formation) and Uruguayan (Chuy Fm.) Late Pleistocene sediments. A major difference is the lower biodiversity and lack of warm taxa in addition to the occurrence of cold water brachiopods (*Magellania*, *Terebratella*) which need to be explained if these molluscs lived during a warmer and higher sea level high-stand.

The mid-Holocene molluscan assemblages (MTVI) differ from the Late Pleistocene counterparts by the dominance of *P. antiqua* and "patelliform" gastropods, by the absence of a few taxa (i.e. *T. atra*, *C. protea*) and occurrence of *S. tehuelchus*. Differences with the present are the scarcity of *E. exalbida* and the absence of cold water patelliform taxa (*F. picta*, *F. oriens*, *P. delicatissima*) (warmer SST during the mid-Holocene ?).

5- INTERPRETATION

Palaeoenvironmental interpretations were focused on the mid-Holocene assemblages due to the more abundant records and accurate dating, the more complete records, and better preservation of the shells. Based on a cluster analysis (Q-Mode; Dice similarity coefficient) of 27 localities and 134 taxa, two main groups of localities, represented by shell ridges and MT, are distinguished along the SW Atlantic: Group I, Surinam, Brazil, Uruguay and Bonaerensian areas; Group II; Patagonian area (Fig. 3). A third group (III) contains Bonaerensian samples from estuarine facies (*).

Group I is explained by taxa typical of soft substrates, in shallow infralittoral and intertidal zones, warmer SST, and moderate energetic conditions. Warm-temperate or

temperate taxa are more abundant, some northwards displaced at present. Subgroups 1-3 (Surinam; Brazil and Uruguay; Bonaerensian) relate to SST conditions varying latitudinally.

Group II (Patagonia) contains species typical of more consolidated substrates, from supralittoral to shallow infralittoral zones, in colder and more energetic waters, with no apparent northwards displacements. Three subgroups (S.A.Oeste-Camarones, B.Bustamante-B. Lárgara, T del Fuego) show high correlation with the latitudinal position of the localities, relative abundance of warm temperate vs. cold taxa, and radiocarbon ages, confirming that temperature must have been the main controlling factor for the variations observed, at least during the 9-4.5 ky B.P. interval (Climatic Optimum = Hypsithermal). The post-Hypsithermal northwards shift of the Brazilian current, Subtropical Convergence and South Atlantic Anticyclonic Centre must have resulted in a stronger influence of the Malvinas (Falkland) cool Current, responsible for the more abundant cold taxa at present and for the modern biogeographical pattern of most taxa living along Patagonia.

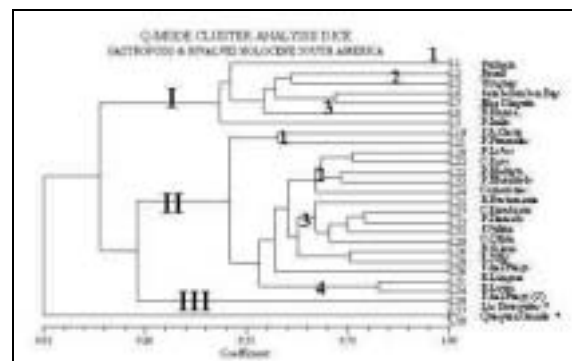


FIG.3

6- REMARKS

1- Molluscan taxa recovered from Quaternary coastal deposits along the Argentine littoral add data for palaeoenvironmental interpretations since MOIS11 (?) to present.

2- The Quaternary Bonaerensian assemblages show variations in faunal composition and biogeographical patterns. Displacements of salinity and temperature gradients are the most striking variations compared with the present, mostly for the mid-Holocene. Higher than present SST conditions during the three highstands preserved (MOIS11 ?, MOIS5e?, MOIS1) may account for the displacements during interglacial periods. Expansions of stenothermic warm taxa followed by retractions during subsequent colder cycles represent biotic responses of marine benthic communities to shifts of the warm Brazilian Current, the Subtropical Convergence and the South Atlantic Anticyclonic centre.

3- The Patagonian assemblages show minor compositional variations and no striking geographical displacements in comparison with the modern communities. Faunal differences, geographically and chronologically between the Late Pleistocene (MTIII, IV, V), mid-Holocene (MTVI) and present (Magellanean Province) suggest changes of substrate

nature, water energy, salinity, as the main controlling factors. The MTIII document warmer SST than at present, in agreement with previous geochronological data (correlation with MOIS11 highstand) and palaeoenvironmental interpretations (Feruglio,1950). The remaining terraces sampled do not show typical warmer water elements or characteristic of climatic optima. Higher than present SST are documented for the mid-Holocene.

The dominance and greatest size of *Tegula atra* and *P. antiqua* (Fig. 1) is outstanding within the Pleistocene (especially MTIV). *P. antiqua* in scarce quantities and lowest diversity rates characterize MTV (MOIS5c or 5a?). Dominance of *N(P.) deaurata*, *Trophon spp.* and of mitylid bivalves (*B. purpuratus*, *A. atra*) and highest diversity characterize MTVI (mid-Holocene, MOIS1).

4- During the mid-Holocene the zoogeographical provinces must have been southwards displaced, the Argentine probably down to 45°S, consequence of a southwards influence of warm water masses.

5- On the basis of the molluscan assemblages, a general comparison of the Late Pleistocene and Holocene highstands from the Argentine littoral urgently needs additional modern dating of selected, well preserved, palaeoecologically meaningful taxa (*Protothaca*, *Clausinella*, *Brachidontes*; *Nacella*, *Tegula*), as well as detailed ecological studies of dominant taxa or characteristic for the different areas sampled.

Based on the faunal content of the ridge systems, deciphering with more precision whether MOIS5 conditions in this area belong to substages 5e, 5c or 5a need to be improved by further isotopic studies of unaltered shells of selected taxa.

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