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Bioerosion structures in *Crepidula* (Mollusca, Gastropoda) as indicators of latitudinal palaeoenvironmental changes: Example from the marine Quaternary of Argentina

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ABSTRACT

Late Quaternary marine skeletal concentrations from Argentina are rich in molluscs exhibiting a great variety of bioerosion structures. The shells of *Crepidula*, a characteristic gastropod occurring along more than 2000 km of coastline between the Río de La Plata margin and southern Patagonia, show traces of dwelling, predation and anchoring activities made by porifers, bryozoans, annelids, other gastropods and brachiopods. *Caulostrepsis, Entobia, Maeandropolydora, Iramena, Oichnus, Finichnus, Pennatichnus, Pinaceocladichnus, Podichnus* and *Renichnus* occur on the outer shell surface. *Finichnus* and *Oichnus* are the only traces present along the entire area and the full time span considered. The most characteristic structures are produced by bryozoans, polychaetes and predatory gastropods. Traces produced by annelids and predatory gastropods occur preferentially in the central shell sector, where predators gained access to the soft parts of the prey. By contrast, encrusting or branching bryozoan colonies are widely distributed as they can attach to any sector regardless of shell features available. No strict correlation is evident between ichnodiversity and either time or latitude, but ichnodiversity is linked to local oceanographical/biotic controls. For Patagonia, with a great majority of ichnotaxa made by bryozoans, the general trend of higher bioerosion degree and ichnodiversity at higher latitudes is controlled by sea surface temperature/productivity: for the modern and the Holocene, several ichnodiversity peaks match with well-constrained conditions (substrate, salinity, thermal fronts). By contrast, this does not hold for the Pleistocene: dissimilar conditions probably prevailed, especially during the Last Interglacial (colder waters richer in nutrients).

1. Introduction

Bioerosion structures can be the result of mechanical, chemical or a combination of both processes, and they represent several kinds of activities by different groups of organisms on hard substrates (rocks, wood, bones, shells, among others) (Boekschoten, 1970; Taylor and Wilson, 2003; Bromley, 2004; Lorenzo and Verde, 2004; Farinati et al., 2006; Kelley and Hansan, 2006; Seilacher, 2007; Santos and Mayoral, 2008; Lopes, 2012; Richiano et al., 2012; Árpád and Apród, 2013; Santos et al., 2014).

It is widely acknowledged that in a variety of marine environments, worldwide and through geological time, bioerosion is a taphonomic agent controlled essentially by the bioeroding organisms themselves (in their wide diversity through space and time), sedimentation rates, water depth, biological productivity, and the density and architecture of the substrate. Consequently, the different types and intensity of bioerosion can provide palaeoenvironmental evidence with important implications for palaeoecological interpretations (Bromley, 1994; Edinger, 2002; Edinger and Risk, 2007; Wilson, 2007). On the other hand, latitudinal changes in biodiversity (today and in the recent past) have been intensively used in palaeoenvironmental contexts and to analyse evolutionary patterns of different taxonomic groups, variations in their ecological requirements and responses to climate changes (among others, Radwanski, 1977; Edinger, 2002; Goldring et al., 2007; Chazottes et al., 2009; Buatois and Mangano, 2011; Brezina et al., 2014; Paul and Herbert, 2014). In contrast, few quantitative or biogeographical studies of bioerosion structures, have been carried out (but see Wisshak et al., 2011). This is especially true for the coast of the Southwestern Atlantic (SWA).

In Quaternary marine deposits from Argentina (South America, SWA) (Aguirre and Whatley, 1995; Aguirre et al., 2011a; Richiano et al., 2013), molluscs represent the dominant biogenic component of parautochthonous skeletal concentrations (*sensu* Kidwell, 1986).

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These are preserved between the Río de La Plata margin and southern Santa Cruz province (Patagonia), where they exhibit a wide range of bioerosive structures. Records of dwelling (Domichnia), anchoring (Fixichnia) and predation (Praedichnia) are the most common; they are abundantly preserved on gastropod and bivalve shells (Richiano et al., 2012). The most constant taxa were selected among bivalves and gastropods sampled along the Bonaerensian and Patagonian coastal areas in Argentina in order to objectively compare bioerosion traces identified on molluscan shells from a large number of fossiliferous localities and along the modern adjacent littoral (Fig. 1). Among these, *Crepidula* is a gastropod constantly present and commonly dominant in Pleistocene and Holocene littoral palaeoenvironments (mainly beach ridges and marine terraces, and sometimes in tidal flats and coastal lagoonal facies). These animals are outstanding due to the abundance and variety of bioerosion signatures preserved on their shells. Due to the nature of the substrate provided by the shells of this epifaunal gastropod and to the environments involved (mostly highly energetic in intertidal and shallow infralittoral habitats), bioerosion signatures are not preserved *in situ* but instead are transported– an infrequent condition for trace fossils. Also, a considerable residence time of the shells at the water-sediment interface enhances bioerosion intensity when reworking of sediments exposes the shells to frequent attacks or invasions by different organisms.

The localities selected for this study are based on the relative abundance of *Crepidula* as well as and on the availability of chronological controls for the sampled Quaternary coastal deposits preserved in Argentina. *Crepidula* is more abundant along Patagonia than in the Bonaerensian littoral, at present and since the Mid-Late Quaternary (Marine Isotope Stage, MIS11, ca. 400 ka B.P.; Zachos et al., 2001; Lisiecki and Raymo, 2005; Schellmann, 2007; Schellmann and Radtke, 2010). As a result, different numbers of localities and percentages of *Crepidula* shells are represented along the coast (Fig. 1).

Bioerosion studies can reveal palaeobiodiversity patterns and evidence for the ecological structure of palaeocommunities through time (among others, Kelly and Bromley, 1984; Taylor et al., 1999; Martinell and Domènech, 2009; Buatois and Mangano, 2011; Paul and Herbert, 2014). In spite of this, studies from a macroscale perspective in space and time, which are useful to understand changes in ecological interactions between large communities of organisms regionally, are still missing for Argentina. This approach is also fundamental to assessing whether latitudinal ranges of ichnodiversity are in agreement with latitudinal biodiversity patterns based on benthic molluscan taxa. Like body fossils, bioerosion structures record the response of organisms to local and/or regional variations in physical and biotic parameters of the marine Argentine littoral (Aguirre et al., 2011a).

The aim of this study is to characterize bioerosion structures (and their trace makers) for one taxon, *Crepidula* which is constantly present along the coastal area of the Mar Argentino in the SWA. This will reduce the possible variables (taxonomic, ecological and environmental controls) and make a macro-scale comparative study possible. This approach will reveal latitudinal/temporal patterns since the Mid-Late Pleistocene, and allow palaeoenvironmental interpretations.

2. Geological settings

In Argentina, rich and thick marine skeletal accumulations of Late Quaternary age are abundant and exceptionally well preserved. They occur in beach ridges and marine terraces that reflect beach palaeoenvironmental parameters during sea-level fluctuations. The molluscan assemblages is dominated by gastropod and bivalve shells, which are mostly parautochthonous, and which accumulated during the last transgressive-regressive Mid-Late Pleistocene to Mid-Holocene marine cycles (Marine Isotope Stages, MIS, 11, 9, 7, 5, 1) (Haq et al., 1987; Burckle, 1993; Winograd et al., 1997; Zachos et al., 2001; Lisiecki and Raymo, 2005; Schellmann, 2007; O'Leary et al., 2013). These shell concentrations are extensively present along the entire Argentinean coastal area, from the modern supratidal zone up to a few kilometres inland (reaching up to ca. 30 km). Most of the fossiliferous deposits were accumulated during the Holocene (MIS1; mostly during the Mid-Holocene) and Mid-Late Pleistocene (MIS11 to 5), of which the most continuous and richest belong to MIS1, 5 and 7. Previous studies provided complete sources of information for morphostratigraphy, sedimentology, geochronological, taphonomical and palaeoecological aspects of these deposits (e.g., Feruglio, 1950; Farinati, 1985; Spalletti et al., 1987; Cionchi, 1988; Codignotto et al.,

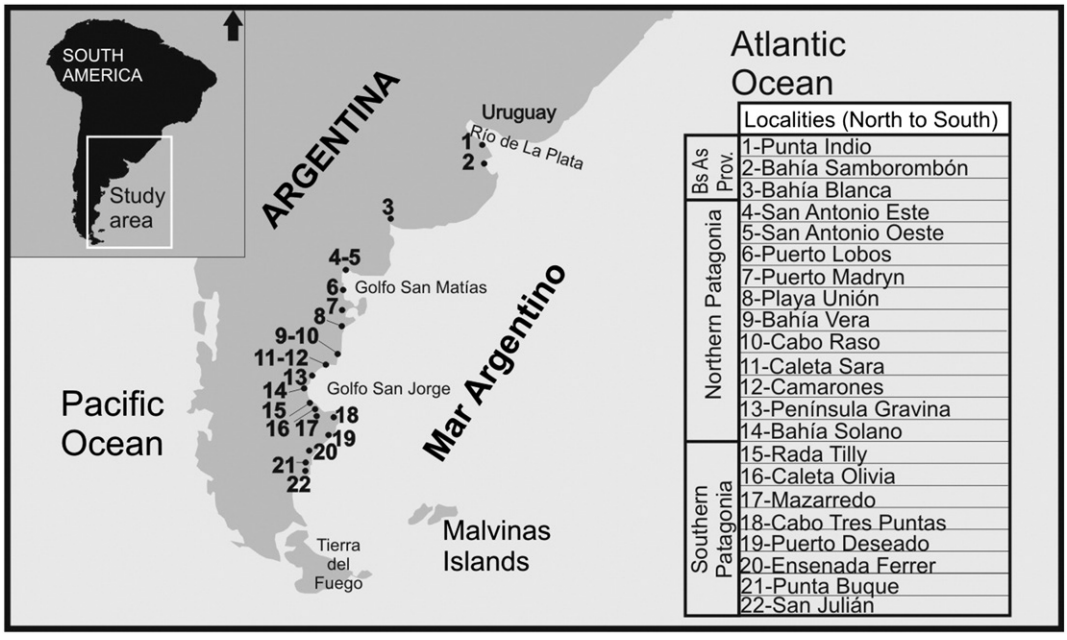

Fig. 1. Location of 22 sampled localities from the coastal area of Argentina, (Southwestern Atlantic, SWA) along Buenos Aires province (here called Bonaerensian area) and Río Negro, Chubut and Santa Cruz provinces (Patagonia).