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Tomographic Analysis for Bioerosion Signatures in Shallow-Water Rhodoliths from the Abrolhos Bank, Brazil

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ABSTRACT

Bioerosion at all scales is now recognized as playing a major role in facies interpretation. Macroscopic and microscopic borings can provide an indication of water depth, if they can be attributed to the action of specific borers. Tomographic analysis is a new method for assessing bioerosion, for identifying boring taxa, as well as for calculating the volume and porosity in present-day rhodoliths. The tomographic system provides also a quantification of the calcium carbonate produced by bioerosion. Recent rhodoliths collected at 20-m water depth on the Abrolhos Bank, Brazil, have been multisann analyzed. The study shows that rhodoliths from this site are characterized by a highly diversified assemblage of boring bivalves and sponges associated producing the ichnogenera Gastrochaenolithes and Entobia. The fauna from this boring assemblage can remove up to 10% of the rhodolith volume. The method can be expected to yield similar results as applied to both modern and fossil rhodoliths from other localities and time frames.

ADDITIONAL INDEX WORDS: Rhodoliths, tomography, borers, Abrolhos Bank, Brazil.

INTRODUCTION

Rhodolith pavements are constituted of benthic communities dominated by coralline red algae and often also contain corals and other invertebrates (e.g., bryozoans, hydroids, sponges, bivalves). These invertebrates normally grow attached on (epifauna) or in (infauna) the rhodoliths. Therefore, rhodoliths may exert a large effect on associated organisms, causing an increase in diversity over communities of purely soft benthic habitats at similar water depths (Foster et al., 2007; Hinojosa-Arango and Riosmena-Rodriguez, 2004; McArthur et al., 2010; Riel et al., 2009; Steller and Foster, 1995). The rhodoliths play the role of “bioengineers” (Foster, 2001) by providing relatively stable microhabitats for other organisms that live within the coralline branches, and for borers inside the rhodolith itself (e.g., Steller et al., 2003; Steneck, 1986).

Biological erosion (or bioerosion; Neumann, 1966) is associated with both the grazing activities of a range of fish and echinoid groups, as well as the activities of endolithic borers. These borers include specific groups of sponges, bivalves, and worms (termed macroborers), as well as cyanobacteria, chlorophytes, rhodophytes, and fungi (termed microborers) (Hutchings, 1986). Macroscopic and microscopic borings can provide an indication of water depth if they can be attributed to the action of specific borers (Bromley and Asgaard, 1993). Macroboring is typically dominated by sponges (Bosence, 1984; Hepburn, Perry, and Blanchon, 2005; Pandolfi and Greenstein, 1997; Perry, 1998) living in high-energy intertidal and reef-crest/shallow reef-front settings (0–10 m). Boring molluscs are important secondary components of the endolithic boring communities in these settings (Hepburn, Perry, and Blanchon, 2005; Peyrot-Clausade and Brunel, 1990). The first records and descriptions of such ichnocoenoses have been carried out from the shallowest settings of the reef depositional system and have been considered as ancient sea-level indicators (e.g., Bromley et al., 2009; de Gibert, Martinell, and Domènech, 1998; Santos et al., 2010).

Computerized transverse axial scanning (X-ray computed tomography) is a radiographic technique designed to recover precise cross-sectional images (tomograms) of three-dimensional objects. This highly sensitive process permits carbonate shells of similar density to be separated and displayed unambiguously. These special features are, therefore, ideal for analyzing the cross-sectional geometry of carbonate nodules, even when they are highly mineralized and their constructional cavities are occluded by sedimentary matrix.

Here we report on a case of shallow-water rhodoliths and related ichnocoenoses (boring biota) from the Abrolhos Bank, Brazil. The studied rhodoliths, collected from 20-m water depth, were first subjected to tomography, and then sectioned to assess their coralline inner arrangement and the ichnooco-
nosis. We illustrate for the first time the application of a tomographic system to the rhodolith analysis.

**MATERIALS AND METHODS**

The rhodoliths in this study were collected on current-exposed parts of the bank at 20-m water depth, at the Abrolhos Bank, Brazil (17°54.235′ S, 38°18.568′ W; Figure 1). To study the size, shape, and composition of living organisms on rhodolith surfaces, a large amount of living rhodoliths was collected. For this purpose, rhodoliths were taken from one site on the Abrolhos Bank (R.N. Leal, unpublished data) by scuba diving. The sampled rhodoliths were dried onboard soon after collecting to preserve the colours of the living organisms. The inner arrangement, degree of bioerosion, and biotic composition were observed using thin sections and polished slabs of rhodoliths.

The scan was done using a model Philips Brilliance 64 multislice tomography (medical scanner). Settings used were: 120 kV, 83 mA, no filter, slice thickness 0.8 mm, width 3000, dual field of view 250 mm at 512 × 512 pixels. Two-dimensional images were analyzed using the MxLiteView DICON Viewer version 1.25.0.0.


Studied rhodolith specimens are deposited in the Instituto de Pesquisas Jardim Botânico, Rio de Janeiro, Brazil.

**RESULTS**

The studied rhodoliths, spheroidal in shape, are constituted mainly by encrusting coralline red algae with a massive inner arrangement in competition with the larger encrusting foraminifer Acervulina inhaerens, bryozoans, serpulids, and subordinate smaller encrusting foraminifera such as Homotrema and Miniacina. The outer rhodolith growth stage shows dominant encrusting growth forms (Figure 2). The coralline taxonomic assemblage is characterized by Hydrolithon rupetris (Foslie) Penrose, Lithophyllum stictaeformis (Areschoug) Hauck, Lithothamnion superpositum Foslie, and Mesophyllum engelhartii (Foslie) Adey.

Tomographic analyses and polished slab surfaces revealed that the rhodoliths are inhabited by Spengleria rostrata (Spengler), Lithophaga nigra (D’Orbigny), Botula fusca (Gmelin), and Gastrochaena hians (Gmelin) (Figures 2 and 3). These boring bivalves produce the ichnogenus Gastrochaenolites, which occurs in habitats from shallow-marine rock grounds and hard grounds and in firm, compacted, but un lithified substrates (e.g., Kelly and Bromley, 1984), down to ca. 100-m water depth in macroid beds (Bassi, Humblet, and Iryu, 2011). Gastrochaenolites is a flask-shaped boring with a narrow aperture and a larger, round, ovoid chamber. This ichnogenus is produced by boring bivalves (Kelly and Bromley, 1984). Several members of recent bivalve families (e.g., Pholadidae, Gastrochaenidae, Mytilidae) are active borers (Fischer, 1990).

Entobia, the work of the sponge Cliona, the worm boring Trypanites, and microendolithic traces are also present. Entobia is a complex, multiapertured, multichambered sponge boring. Tens of ichnospecies have been described on the basis of the peculiarity of their three-dimensional configurations (Bromley and Asgaard, 1993; Bromley and D’Alessandro, 1990).

These boring organisms can remove up to the 10% of the rhodolith volume (Figure 1). All the bioerosion structures correspond to the boring activity of endolithic organisms and, from an ethological point of view, only dwelling structures (domichnia) are present. Spengleria rostrata is a chemical borer adapted to live inside fragile and rapidly eroded hard substrates because of the capability to repair the burrow by means of an aragonitic lining. This species secretes Y-shaped bifurcating tubes that separate inhalant and exhalant siphons. This strategy is absent in L. nigra, which produces cylindrical burrows with a single siphonal aperture.

**CONCLUDING REMARKS**

This first application of a tomographic analysis on rhodoliths from coral-reef-related biotopes allowed Gastrochaenolites associated with its boring bivalves to be identified. Although major destructive processes that remove and degrade carbonate framework have been reported from reef-front settings, syn- and postdepositional bioerosion in rhodolith beds at 20-m water depth can be very pervasive and produce high volumes of carbonate.

The high-resolution X-ray computed tomography results represent a nondestructive method by which to assess the
potential for porosity and calcium carbonate production in recent rhodoliths. Furthermore, it is possible to analyze in detail the ichnocoenosis and the possible inner-rhodolith coralline thallial arrangement. The quantification of the rhodolith porosity and the calcium carbonate production of a rhodolith pavement is difficult and sometimes inappropriate if slab surfaces or thin-section analysis are used. The method has yet to be tested on fossil rhodoliths (e.g., Bosence, 1991; Bassi et al., 2009; Bassi and Nebelsick, 2010; Johnson et al., 2011; see also Bassi, Iryu, and Nebelsick, 2012), but there is every reason to believe that comparable results should be expected, assuming that secondary mineralization is not too severe.

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LITERATURE CITED
