Palaeoenvironmental signals and growth rates of rhodoliths – a geochemical approach

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Electron microprobe and stable isotope studies were undertaken on Recent rhodolith specimens (coralline red algae) in order to accurately determine their growth rates and palaeotemperature signal. Results show a cyclic variation of the Mg/Ca ratio and an amplitude of the oxygen isotope curve that accurately reflects the sea-surface temperature.

Geochemical signals extracted from coral growth bands are commonly used as long term high-resolution palaeoenvironmental indicators for reconstructing temperature and salinity variations of surface water masses. The main constraint in using corals is their limited geographical range of distribution, which is confined to tropical and subtropical seas. In order to deduce high resolution geochemical sea surface water signals from non-tropical seas, mollusks have been employed by various authors in recent years. This paper introduces rhodoliths as a new organism for palaeoenvironmental analysis of tropical and non-tropical seas.

Rhodoliths, which live in the subtidal zone to water depths of 100 m, are defined as nodules and unattached branched growths with a nodular form composed principally of coralline red algae (Bosence, 1983). The High-Mg calcite skeleton can exhibit different growth morphologies which range from spherical to ellipsoidal and can be thickly or thinly branching, with individual branches reaching up to 1cm in diameter. Rhodolith morphology is a result of frequent overturning due to water motion (during storms) or biogenic activity (bottom feeding fish, in- and epifaunal organisms). Vertical growth rates of coralline red algae are poorly studied but have been reported by various authors to range from 200 μm to 5 mm/year (see Edyvean and Ford (1987) for a compilation of growth rates). We have selected rhodoliths for geochemical studies because (1) they show well developed growth bands, (2) their geographic range spans from tropical to Arctic seas and (3) they exhibit longevity (specimens with an age of several hundred years have been reported; Bosellini and Ginsburg, 1971). This latter will allow us to eventually acquire palaeoenvironmental records dating back further than those derived from molluscan shells. This will have special importance for assessing Arctic records, which, if they are derived from mollusks, do not date back more than a few dozen years.

For the present study we collected live (or partially living) specimens of *Lithothamnium* sp. from the southern Gulf of California, Mexico, where rhodoliths are the second most important carbonate producers after corals. *Lithothamnium* sp. is most abundant in 2–5 m water depth and individuals with diameters of up to 10 cm have been reported (Foster *et al.*, 1997). For this study we prepared polished thick sections of branches with widths of up to 0.8 cm and lengths of up to 3.5 cm. The COADS SST data set for this site shows an average sea surface temperature range from 19.9–30.8°C, however, the geochemical signal could be complicated by nearby seasonal upwelling events.

Rhodolith thick sections were element mapped with an electron microprobe for Ca and Mg and individual growth bands were microsampled for stable isotope analysis using a bandwidth of 40 microns and a drill depth of 60 microns. Complicating factors during the microsampling were the high concavity and slight irregularity of the growth bands and the extremly small sample size (<10 μg) that was obtained by drilling along growth bands for a maximum length of 3 mm.

Mg/Ca ratio

Coralline red algal growth patterns have previously been studied by either in situ staining methods, which require a long term approach, or by sectioning and subsequent light microscopic analysis. However, our observations using reflected light microscopy and SEM reveal the difficulty of accurately defining growth bands and growth cyclicity and therefore determining the age and growth rate of rhodoliths. Element mapping with an electron microprobe for major elements is a rapid and simple approach to obtain the above information. Mg/Ca values range from a minima of 0.17 to a maxima of 0.3 (14–25 mol% $MgCO_3$) which can be correlated to the lightest and darkest areas, respectively. A range of 11 mol% for a temperature fluctuation of 10°C is in agreement with a general 1 mol% $MgCO_3$/°C increase in coralline algae (e.g. Heinrich *et al.*, 1996).

Interestingly, a growth cycle is defined by four distinct growth bands, which is in contrast to other calcifying organisms like corals that deposit one light and one dark band during a yearly growth cycle. Future studies must determine if the observed growth pattern is inherent to rhodoliths worldwide or if it is specific to the southern Gulf of California rhodoliths. If it is a local effect, a possible factor governing growth is nearby summer upwelling, that can result in distinct winter and summer bands which in turn are separated by spring and fall growth bands. Individual growth bands have widths ranging from 70–110 microns resulting in a yearly vertical growth rate of 280–400 microns. This is in range with subtropical rhodoliths studied by Bosellini and Ginsburg (1971) who report growth rates of 400 microns/year.

Stable oxygen isotopes

Microsampling of individual rhodolith growth bands and subsequent stable isotope analysis shows $\delta^{18}O$ values ranging from −2.41 to −4.61. Using the Epstein equation, where 0.221 in $\delta^{18}O$ equals a temperature change of 1°C (Epstein *et al.*, 1953), a yearly temperature amplitude for the Gulf of California rhodoliths of 10°C can be calculated. This closely mirrors the average SST amplitude of the southern Gulf of California, which according to COADS SST data is 10.9°C (average of ten years). Growth rates can vary for different years. Growth cycles range in vertical thickness from 200 to 420 microns, and are possibly influenced by the amount of light received by the particular branch of the rhodolith during a given year. Light flux can be obstructed due to overgrowth by fleshy algae or partial burial in the surrounding soft sediment for part of the year. Based upon studies of cold water rhodoliths (Heinrich *et al.*, 1996), coralline algae manage to store enough energy during the Arctic summer to calcify (albeit slower) in the dark winter. Hence, the Gulf of California rhodoliths apparently can continue calcification during partial burial or algal overgrowth. Compared to the COADS SST data set, the rhodolith isotopic curve shows a pronounced asymetry, which reflects a slowdown of calcification between the summer and winter season. However, since the amplitude of the isotopic signal closely reflects the SST, it can be concluded that calcification is continuous throughout the year. In conclusion, apart from rapid assessment of coralline red algal growth rates, geochemical studies of rhodoliths can potentially provide useful worldwide long term environmental and surface water temperature data due to slow growth rates and longevity of these widely distributed calcareous algae.

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