

Sclerosponges May Hold New Keys to Marine Paleoclimate

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The potential for using sclerosponges, marine organisms that secrete a hard calcareous skeleton, as paleoclimatic indicators has attracted the interest of a number of scientists. Sclerosponges are composed mainly of calcium carbonate and they are very long lived. Variations in their skeletal chemistry contain proxy information regarding their environment and that information has the potential to augment, if not supplant, data from scleractinian corals in interpreting past water temperature, salinity, and productivity over periods of 100s to 1000s of years.

Sclerosponges, or calcified demosponges, contain aragonite or calcite and a small amount of siliceous material. Lang et al. [1975] report that these sponges grow within a reef framework, under coral talus in the shallower parts of a reef less than 55 m deep and on steep surfaces of the fore-reef between 55 and 145 m deep. The largest and most conspicuous of the sclerosponges described by those authors is *Ceratoporella nicholsoni* (Figure 1), which is reported to attain a diameter in excess of 1 m. These sponges are similar in growth habit to many massive varieties of scleractinian corals, the live sponge inhabiting the upper portion of the skeleton, while the lower portion of the skeleton is essentially dead.

It has not yet been demonstrated that sclerosponges form annual bands, but some species exhibit growth bands, of more or less decadal frequency, that run approximately parallel to their surface (Figure 2). Rates of skeletal accretion are typically only about 0.2 mm/yr for the deeper dwelling sponges and up to 1 mm/yr for the shallower varieties. With these slow growth rates, a specimen 10 cm in diameter may be 400 years old; one that is 1 m in diameter may be 4000 years old. However, information on the distribution of sclerosponges in many locations is scarce simply because of the inaccessibility of their habitats. Shallow-growing organisms can be collected using scuba gear; deeper samples necessitate mixed gas diving gear or submersibles.

Sclerosponges are advantageous over corals as paleoclimatic indicators for a number of important reasons. First, sclerosponges apparently secrete their skeletons in carbon and oxygen isotopic equilibrium with their environments with minimal intersample or interspecific variations. Second, in addition to being very long lived, sclerosponges can be easily dated. Even relatively small specimens can be several hundred years old. Third, sclerosponges live in a range of different depths and therefore it is possible to reconstruct the history of the water column from information they contain.

Isotopic Equilibrium

There have as yet been only a few studies on the stable carbon and oxygen ($\delta^{13}\text{C}$ and $\delta^{18}\text{O}$) isotopic composition of sclerosponges and no direct experimental investigations on

relationships between temperature, physiological variables, and $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$. However, indications are that the $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ of the skeletons are close to isotopic equilibrium with their environments [Druffel and Bervides, 1986; Böhm et al., 1996]. If sclerosponges are in equilibrium, measurement of the stable isotopic composition of the skeletons will allow $\delta^{18}\text{O}$ to be used directly to determine temperature and salinity. Likewise, $\delta^{13}\text{C}$ can be used directly to measure the dissolved inorganic carbon of the water without any corrections for disequilibrium. In contrast, organisms such as scleractinian corals, molluscs, and many foraminifera secrete a skeleton whose $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ are acknowledged to be heavily biased by various types of well constrained and not so well understood vital effects as well as varying degrees of anthropogenic influences and variations in the $\delta^{13}\text{C}$ of the local environment. The $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ equilibrium of the skeletons of sclerosponges may be a result of the relatively simple biology of the organism, a lack of the algal symbionts that are present in corals, and a slow growth rate, which reduces or



Fig. 1. A specimen of the species *Ceratoporella nicholsoni* from Jamaica. Sample is about 10 cm from top to bottom (Photograph by P. Willenz). Original color image appears at the back of this volume.

eliminates kinetic effects (T. McConnaughey, personal communication, 1998).

The most arresting example of this isotopic equilibrium is the almost precise replication of the ^{13}C Suess effect in all the sclerosponges analyzed to date. The ^{13}C Suess effect is the increase in $\delta^{13}\text{C}$ in the atmosphere as a result of the addition of fossil CO_2 . The increase is estimated to be about 1 to 1.25‰ over the past 150 years. Data presented at a recent meeting on the application of sclerosponges to paleoclimatic problems indicate that without exception sclerosponges from both the Atlantic and the Pacific Oceans show this change (Figure 3). The data replicate previous work on sclerosponges by Druffel and Benavides [1986]. Future advances in the dating of sclerosponges will enable differences to be determined in the timing of the addition of ^{12}C to the oceans at different geographic and depth locations and therefore allow inferences to be made about ventilation and mixing rates of the ocean basins.

The $\delta^{18}\text{O}$ of the sclerosponge skeleton also appears to be close to equilibrium with the ambient environment. Bulk samples from a number of sites in the Pacific show an excellent agreement with ambient temperature; the relationship between temperature and $\delta^{18}\text{O}$ is similar to that determined for inorganic aragonite (Figure 4).

The slow growth rate of sclerosponges also gives them a major advantage over corals. At 0.25 mm/yr, a sclerosponge with a diameter of 10 cm can be 400 years old. But a coral with a growth rate of 1 cm/yr would need to be 4 m high in order to produce a similar length record. Not only are corals of such size extremely rare but if present, their

utility is likely to be reduced as a result of bioerosion. In practice the useful range of corals as paleoenvironmental proxies is limited to about 200 to 300 years, except in rare circumstances. Based on limited studies, sclerosponges have been reported up to 1 m in diameter [Lang, *et al.* 1975] and records of up to 700 years already exist (Figure 3).

Dating Sclerosponges

Radiometric techniques remain the most reliable methods for dating sclerosponges. Radiocarbon has been utilized successfully, although regional variations in sea surface ^{14}C (and bomb effects in very young samples) add uncertainty to the method. At present, mass-spectrometric measurements of U-series isotopes (^{238}U - ^{234}U - ^{230}Th) appear most definitive. Relatively high uranium (up to 7 ppm; J. Rubenstone, personal communication, 1998) and low initial Th concentrations make this method very useful; age uncertainties of only a few years are obtainable even for very young specimens. Growth rates calculated from multiple U-Th ages on individual sponges agree well with biological rate estimates.

Precise age dating of sclerosponges initially presented a challenge, but recent findings offer considerable hope that dating can be accomplished accurately (± 1 year) and relatively cheaply. Unlike scleractinian corals used in paleoclimate studies, sclerosponges do not have any annual density bands. Work presented at the recent meeting, however, revealed that the slight color variations visible in some species of sclerosponges may record annual cyclicity. If this observation is correct, then dating of sclerosponges would

be immensely simplified and essentially would become a matter of counting bands.

Additional annual periodicity may also be present in the carbon and oxygen isotopic composition if the skeleton is sampled at sufficiently high resolution. Researchers at the University of Miami's Rosenstiel School of Marine and Atmospheric Sciences have been able to sample the skeleton of the sclerosponge at increments as small as 30 μm ,

roughly equivalent to 10 samples per year. Spectral analysis of these data, using radiometric methods to establish the chronology, shows clearly a signal from 1.5 to 0.7 years. Such analysis not only supports the radiometric dating, but suggests that the growth rate of the sclerosponges can be tuned to maximize the annual $\delta^{18}\text{O}$ signal and that this itself can be used for dating purposes.

Sclerosponges occur over a wide range of water depths from shallow reefs to as deep as 150 m. Over all ranges of depths the sponges inhabit caves, ledges, and areas under overhangs and are considered to be cryptofauna. The wide range of depths offers the exciting possibility of using the sclerosponges to reconstruct histories of the water column. For example, enhanced wind stress can have the influence of increasing the thickness of the mixed layer which will be translated as an increased annual cyclicity in the seasonal signal of the oxygen isotopic composition. Therefore, for the first time, a technique might be available with which to examine decadal to centennial variability of wind stress.

Studies Needed

Research into the use of sclerosponges as paleoclimatic proxies is still in its infancy and needs support from funding agencies so that critical advances can be achieved. Consider the amount of effort which has been expended over the past decade in calibrating various proxy indicators in corals and foraminifera. At least ten studies have been done on the calibration of the Sr/Ca ratio with temperature in corals alone and a similar number investigating $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$. In contrast, there have been no such studies on sclerosponges.

In view of the promise of sclerosponges for paleoceanographic and climatological interpretation, the participants at the recent meeting proposed a series of recommendations to establish sclerosponges as recognized proxy indicators. For one, participants proposed a series of calibration studies to be initiated involving trace and minor elements as well as stable carbon and oxygen isotopes. The calibration studies would test the ability of sclerosponges to record variations in salinity and temperature and in wind stress and upwelling, the latter so that changes in the mixed layer can be reconstructed. The studies would also determine whether geochemical records can be reproduced from sclerosponge skeletons.

Also recommended was examination of the geochemical response of sclerosponges to naturally occurring climatic anomalies such as the 1997-1998 El Niño. Measurements should include population level responses (such as mortality and new settling), physi-



Fig. 2. Polished slab of a section of a sclerosponge (*Ceratoporella nicholsoni*) from Lee Stocking Island in the Bahamas. The variation in banding can be clearly seen. The age of this specimen is about 400 years based on preliminary U/Th dates (Photograph by Grammar). Original color image appears at the back of this volume.

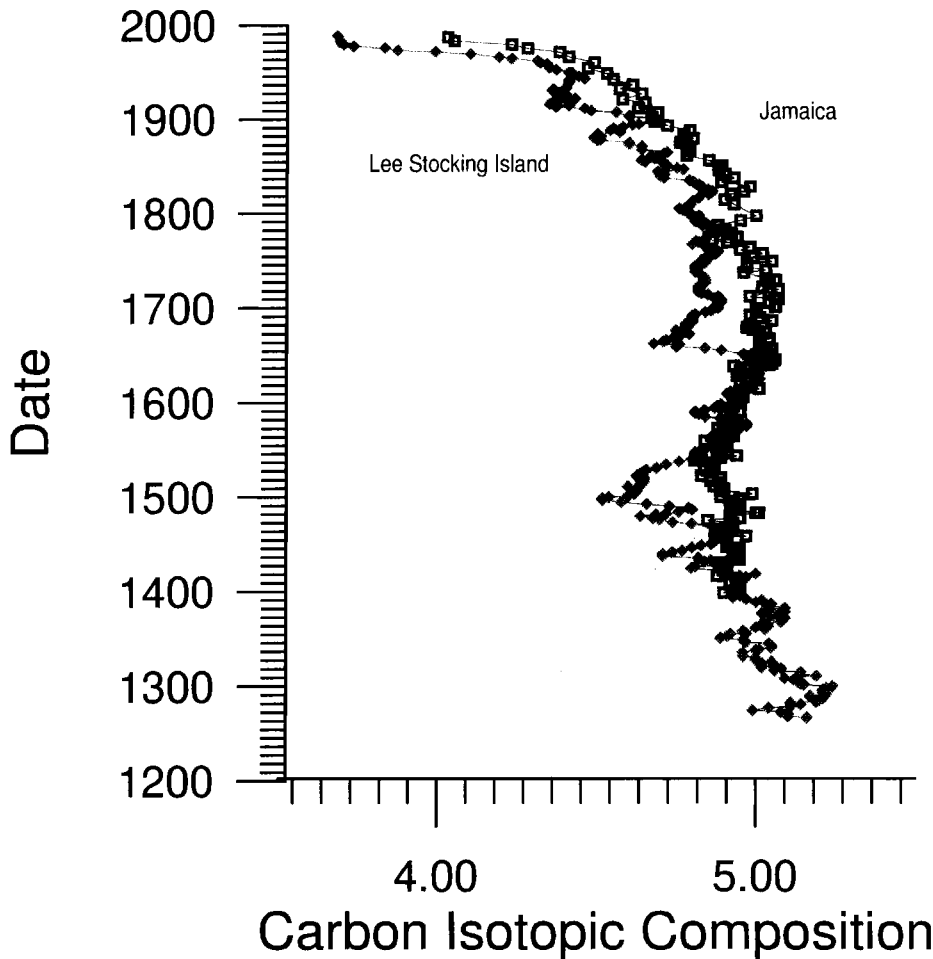


Fig. 3. Comparison of carbon isotopic records from specimens of *Ceratoporella nicholsoni* collected from Lee Stocking Island, Bahamas, and Jamaica (F. Böhm and P. Swart, unpublished data, 1998).

ological responses (such as growth rates, partial die-backs, and regeneration), and the behavior of skeletal climatic proxies. A study also was proposed to determine the cause of visible banding in sclerosponge skeletons. Banding is important both for determining chronology within a skeleton and for cross-correlating different skeletons and developing stacked chronologies. Participants said research also should be done to quantify the vertical distribution of calcification within sclerosponge skeletons, using dyes and isotopic tracers. It is especially important to determine where "time zero" lies within the skeleton and to develop mathematical models to describe the slurring of environmental signals as recorded by the sclerosponge. This will allow the development of sampling strate-

gies that will minimize vertical smearing of signals detected with microsampling protocols for stable isotopes and trace elements.

If sclerosponges have a weakness for paleoclimate interpretative purposes, it is that they often occur in habitats in which they are difficult to collect. In deeper areas, samples have been collected using submersibles as ships of opportunity rather than in projects specifically aimed at sclerosponges. Future development of this exciting proxy will depend on obtaining funding from enlightened program managers who will take a chance on investing in new paleoclimatic and oceanographic proxies.

A workshop report and abstracts of papers presented at the recent sclerosponge meeting are available on the sclerosponge

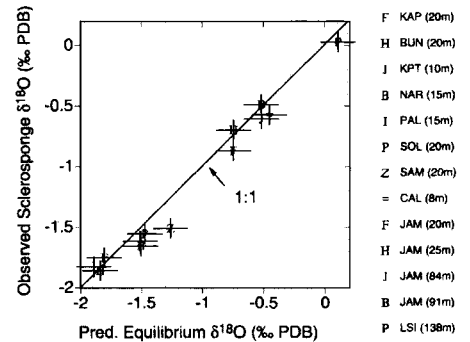


Fig. 4. Observed and predicted oxygen isotopic equilibrium for sclerosponges from a number of locations throughout the world (M. Moore and C. Charles, unpublished data, 1998). Sites are Kapoposang Island (KAP), Bunken Island (BUN), and Kapota Island (KPT) in the Indonesian seaway; Naru (NAR), Palau (PAL), and the Solomon Islands (SOL) in the western Pacific; Lee Stocking Island in the Bahamas (LSI), and Jamaica (JAM). (Data from Jamaica are from Druffel and Benavides [1986] and Böhm et al. [1996]). Estimates of mean annual temperatures and $\delta^{18}\text{O}$ are based on field observations and atlas data.

Web site (<http://mgg.rsmas.miami.edu/mgg.htg/groups/sil/workshop.htm>). The meeting, sponsored by the National Science Foundation and the National Oceanic and Atmospheric Administration, was held in Miami, Florida, in March 1998.

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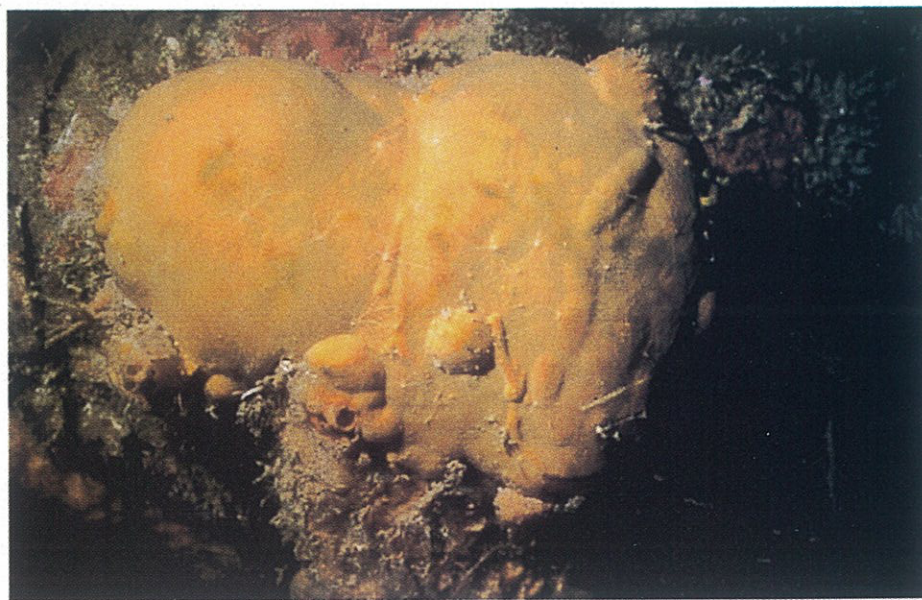


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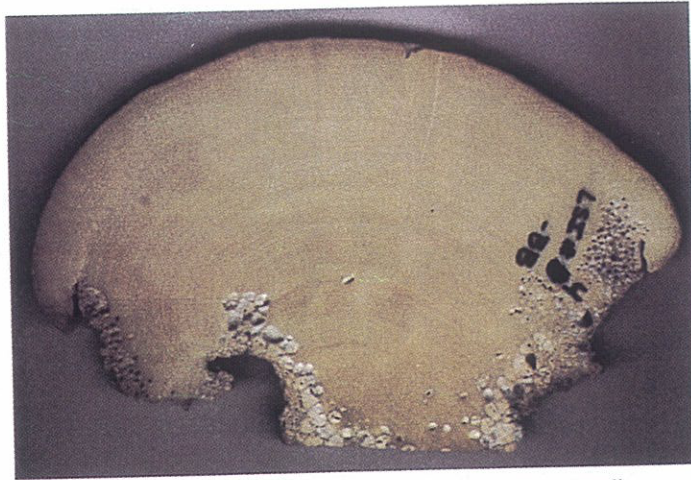


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