Sclerosponges: A New Proxy Indicator of Climate

NOOAA Climate and Global Change Program

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Cover: Slab of the sclerosponge Ceraptorella nicholsoni with a carbon isotopic profile superimposed. The pronounced $^{13}$C Suess effect is evident. This particular sample is about 400 years old.
Sclerosponges: A New Proxy Indicator of Climate

Report from the Workshop on the Use of Sclerosponges as Proxy Indicators of Climate

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I would like to thank the many persons who helped make this workshop possible, especially, Dr. Zimmerman (NSF) and Dr. M. Eakin (NOAA) who provided financial support (NSF grant ATM-95xxxx). Thanks should also go to Avis Miller who did an excellent job of organizing the logistics for the meeting. Gratitude also must be paid to Dr. M. Grammer and Dr. McNeill who helped collect the sclerosponges from the Bahamas and who were involved during early stages of the sclerosponge work. Finally thanks to all the participants of the sclerosponge workshop, especially Philippe Willenz, who provided critical input and photographs, Ted McConnaughey, who edited the calcification section and provided many good ideas, Stewart Fallon for trace element data, Florian Bohm for the use of his data and figures, Chris Charles and Mike Moore for use of their data, Jim Rubenstone for contributions to the dating section, Ellen Druffel for editing and constructive comments, and Greta MacKenzie for final editing.

Mike Grammer (left) and Peter Swart with large specimen of the sclerosponge (Calcifibrospongia). Sample measured 50 cm from top to bottom. Unfortunately this species does not appear to be suitable for paleoclimatic analysis as a result of uneven and distorted growth structure which may indicate secondary calcification.

Peter K. Swart, Miami September 23, 1998
ORGANIZER’S SUMMARY

Sclerosponges are slow growing calcareous organisms who secrete their skeletons in carbon and oxygen isotopic equilibrium with their environment, and can therefore provide proxy records of salinity and water temperature over a 100 to 1000 year time range. In this regard they have the capability to augment and in some instances replace records obtained from coral skeletons which are structurally and biologically much more complex and secrete their skeletons well outside chemical equilibrium with their ambient environments.

This report summarizes the findings of a recent workshop on the current state of knowledge regarding sclerosponges and their potential application towards the study of global change. In contrast to scleractinian corals, to which scleroseponge research is intimately linked, the study of sclerosponges is very much in its infancy. For example, there have been numerous published studies on calibration aspects of the geochemistry of coral skeletons, including over the past five years 10 studies calibrating Sr/Ca ratios in the skeletons of various species of corals with temperature. In contrast, there has not been one study calibrating the chemical composition of sclerosponges.

The workshop, which met in Miami in March 1998, had as its mandate to establish the current state of knowledge regarding the use of sclerosponges for paleoclimatic purposes. In particular, the following questions were posed:

1) Do sclerosponges have a dateable chronology in their skeletons? If so, with what methods can the skeleton be dated?

2) Does the skeleton of sclerosponges form in chemical equilibrium with the ambient seawater?

3) What is the mechanism of calcification?

4) Can high resolution records be obtained from the skeletons of sclerosponges?

5) Which paleoceanographic and climatic processes are the most suitable for study using sclerosponges?

This report summarizes the views of workshop participants on these and other issues.
Sclerosponges are long lived marine sources of proxy climate data which can augment and in some instances replace coral records. They are therefore well suited for providing continuous proxy records of ocean/atmospheric variability over the past 100 to 800 years.

Sclerosponges, like corals, incorporate numerous chemical parameters which can not only provide an indication of water temperature and salinity, but also incorporate tracers typically studied in coral skeletons (\(\delta^{13}C\), \(\Delta^{14}C\), Ba, Cd, and Mn).

Sclerosponges can provide this information over a range of water depths, thereby providing unique information on the history of the upper water column.

Sclerosponges, by virtue of their slow growth rate, can provide information over time ranges much longer (500 to 1000 years) than accessible using coral skeletons, where records are limited to 200 to 300 years.

Sclerosponges, unlike scleractinian corals, form their skeletons in isotopic equilibrium with their ambient environment, eliminating the need for any type of corrections for species effects or differential growth rates.

Sclerosponges can be easily dated using carbon-14 (\(\Delta^{14}C\)) or uranium disequilibrium methods. High resolution analyses of the chemical composition of sclerosponges reveal the presence of annual cycles in color and chemical composition which can be used to further date the sclerosponges in a manner analogous to the density banding in coral skeletons.
RECOMMENDATIONS

1) The workshop participants propose that several calibration studies be initiated which test the ability of sclerosponges to record variations in salinity and temperature. This calibration should be conducted along the following lines:

- First, to grow sclerosponges in the field, closely monitoring the environmental conditions and then relating these changes to variations in the chemical composition of the skeleton. In particular it should be determined whether the skeleton of sclerosponges can reproduce inter and intra annual variations in temperature.

- Second, to test the ability of sclerosponges to reconstruct changes in the mixed layer caused by variations in wind stress.

- Third, to determine the reproducibility of the stable isotopic composition in sclerosponges at a particular location.

2) Sclerosponges are probably geographically widely distributed, but collecting samples is difficult because of the need to use expensive submersibles. We recommend that ship time be allocated for the search and collection of sclerosponges in climatically important areas.

3) Examine sclerosponge responses to naturally occurring climatic anomalies such as the 1997-98 El Nino. Measurements should include population level responses (mortality, new settling, etc.), physiological responses (growth rates, and regeneration, etc.) and the behavior of skeletal climatic proxies ($\delta^{18}O$, strontium, and magnesium)

4) Investigate the phenomena of partial die-back and regeneration. Partial die-backs weaken the skeleton, complicate chronological assignments, and may be associated with shifts in isotopic or chemical composition. If partial die-backs and regeneration are associated with particular climatic conditions, their expression in sclerosponges can provide evidence for climatic changes. Field studies should look for evidence of synchronous die-backs and regenerations. Correlations with climatic anomalies should be investigated in collections.

5) Determine what causes the 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. Correlations may be possible between
skeletal bands and known past environmental anomalies, and for correlations between bands and environmentally sensitive skeletal indicators including the abundance of organics, trace metals, and stable isotopes.

6) Measure skeletal growth of individual sclerosponges under various environmental conditions, especially temperature.

7) Quantify the vertical distribution of calcification within scleroponse skeletons, using dyes and isotopic tracers. It is especially important to determine where "time zero" lies within the skeleton - is it at the top surface, or closer to the bottoms of the growing pseudocalices? Then develop mathematical models to describe the slurring of environmental signals as recorded by the sclerosponge, and techniques for deconvoluting as much of the slurred signal as possible. Also develop sampling strategies that will minimize vertical smearing of signals detected with microsampling protocols such as laser ablation.

8) Investigate why sclerosponges make their skeletons. This may influence skeletal growth rates and possibly skeletal chemistry. The motivation for skeletogenesis is not necessarily trivial - McConnaughey's "proton hypothesis" (McConnaughey and Whelan, 1997) suggests that corals and calcareous algae calcify largely to generate protons for use in assimilating.

9) Develop a simple "field guide" to sclerosponges and their habitats so that geochemists can collect the most desirable specimens. This should include keys to species recognition and visual indications that particular individuals do or don't suffer from strong bioerosion. It might also include criteria for judging whether a particular cave departs from climatically relevant marine conditions in significant ways, as for example through ground-water seepage or generation of higher alkalinites due to sulfate reduction.
Background

It has been more than three decades since Goreau [1959] described the ecology of the deep Jamaican reefs and found them to contain large populations of the sponge *Ceratoporella nicholsoni*. Although such sponges have been known for a long time, the extent of their diversity has only been realized in the last several decades [Hartman, 1969; Hartman and Goreau, 1966, 1970, 1972, 1975, 1976; Vacelet, 1977a, 1977b, 1979a, 1979b, 1980, 1981, 1984]. Although the calcareous sponges with siliceous spicules were initially ascribed to a separate class, the sclerospongiae, a variety of similarities with sponges lacking calcareous skeletons led to their incorporation into pre-existing groups of Demospongiae [Vacelet, 1981, 1983a, 1983b, 1985; van Soest, 1984]. At the present time, 15 species belonging to 2 classes, 4 subclasses, 8 families, and 11 genera are known. The biology and ecology of the sponges has been well described by Lang et al. [1975], Dustan et al. [1975], Hartman and Goreau [1970], Scoffin and Hendry [1984], Wood [1990], while their growth has been studied by Dustan and Sacco [1982] and Benavides and Druffel [1986]. Lang et al.
[1975] found the sponges growing within the framework and under coral talus in the shallower portions of the reef (above 55m), while below 55m they are found on the steep surfaces of the deep fore-reef. They have been reported growing to depths of 145 m. Of the six sclerosponges described by Lang et al. [1975], the largest and most visible is *Ceratoporella nicholsoni*. In Jamaica this sponge was estimated to cover between 25 to 50% of the available space, attaining sizes in excess of 1 m in diameter (Figs. 1 & 2). The ultra-structure of this species has been described by Willenz and Hartman [1985]. *Stromatospongia vermicola* also grows to a reasonable size (40 cm in diameter) and can be locally more abundant than *C. nicholsoni*. The remaining species of sponges (*Hispidopetra miniana, S. norae, Goreauiella auriculatra, and Merlia sp.*) are relatively small but can be locally abundant.
Dating and Proxies
Radiometric Methods

The growth rates of sclerosponges have been studied both by direct staining using Alizarin Red-S [Dustan and Sacco, 1982], Calcein [Willenz and Hartman, 1985], and by using $^{14}$C and $^{210}$Pb [Benavides and Druffel, 1986]. Both studies were conducted on sponges from Jamaica. In the staining study, specimens of sponges were stained and collected some six years later. Dustan and Sacco [1982] estimated a growth rate of 0.1 to 0.2 mm/yr. The radiometric methods gave slightly higher growth rates (0.27 mm/yr using $^{14}$C and 0.22 mm/yr using $^{210}$Pb). Data on growth rates presented at the workshop generally supported these estimates (Figs. 3 & 4).

Radiometric techniques remain the most reliable methods for long term dating of sclerosponges. Radiocarbon has been utilized successfully, although regional variations in sea-surface $^{14}$C (and bomb effects in samples less than 30 years old) add uncertainty to the method (Fig. 4). At present, mass-spectrometric measurements of U-series...
Figure 6: Carbon isotopic profile from a sclerosponge from Jamaica (Montego Bay) showing the Carbon-13 Suess effect. Compare this profile to figure 8. Similar patterns are seen between the two records extending to around 1500. Prior to 1500 the record in figure 1 shows an even greater increase which may be related to some diagenesis in the sclerosponge [Data from Bohm, unpublished].

Figure 5: Single spectral analysis of the annual component from a sclerosponge collected from 143 m water depth in the Tongue of the Ocean. Annual range varies from less than 1°C to greater than 2°C between 1970 and 1960 and again in the late 1930s. This type of variation could reflect changes in the thermocline [Swart, unpublished].

Bandings Despite an intensive examination using CAT-scan and X-radiographic methods, data presented at the meeting (Lang) suggest that sclerosponges do not have any variations in density which can be used for dating purposes. However, certain sponges such as Ceratoporella nicholsoni have a visible banding pattern, the significance of which is still uncertain (Fig. 2). Data presented at the Sclerosponge Workshop by
Dodge and Swart suggest that there is an annual cyclicity in these banding patterns which might be used for data purposes. In this study Dodge and Swart applied a $\Delta^{14}C$ age model to a digitized spectrum of the color patterns in a slab of a sclerosponge. A spectral analysis of these data suggested an annual signal which could be tuned to refine an age model. Spectral analysis of oxygen isotopic data from sclerosponges suggests a yearly cycle which could be used for dating purposes (See later discussion Fig. 5).

**Chemical Proxies**

**Stable Isotopes**

The first work on the C and O isotopic composition ($\delta^{13}C$ and $\delta^{18}O$) of sclerosponges was conducted by Druffel and Benavides [1986]. These workers analyzed a 160 year old specimen of *C. nicholsoni* collected from Jamaica, at a resolution of approximately one sample every 2.5 years. They concluded that there was no vital effect in the accretion of the skeleton. In contrast to non-zooxanthellate corals which normally possess a positive covariance between C and O in their skeletons,
the study of Druffel and Benavides [op. cit.] showed no correlation, which they suggested was further proof of the absence of vital isotopic effects in the secretion of the skeleton. While they did not observe any age-dependent trend in the oxygen isotopic data, their results showed an average 0.5‰ decrease in the δ13C with increasing age. This decrease which was similar to the decline in δ13C seen in a coral from Bermuda analyzed by Nozaki et al. [1978], is probably a result of CO2 added to the atmosphere from fossil fuel burning (the C-13 Suess effect). Similar findings have recently been reported by Bohm et al. [1996] (Fig. 6) and Moore et al., [1996] (Fig. 7) in sclerosponges from the Caribbean and the Pacific. At the workshop several other groups presented additional data confirming the trend in sclerosponges from the Bahamas and Belize (Fig. 8). In fact the

Figure 8: Stable C and O isotopic record from LSI-BB-19 illustrating the potential of sclerosponges. This record based on a U-Th determined growth rate of 200 um a year is approximately 700 years! The C-13 Suess effect as well as cooling and warming trends in the O signal can be clearly seen. The maximum in the oxygen isotopic record at 1700 corresponds to the minimum in the Manley temperature record from the U.K.
trend seems to be so reproducible in sclerosponges that it has been suggested that the change can be used as a method whereby the sclerosponges can be dated.

Oxygen

In contrast to the abundant work on the calibration of the oxygen isotopic composition of scleractinian corals [Weber and Woodhead, 1972; Dunbar and Wellington, 1981; Leder et al., 1996; Wellington et al., 1996], there have been no reported calibration studies on sclerosponges. Nevertheless, based on the reproducibility of the $^{13}$C Suess effect, there is good reason for optimism that sclerosponges secrete their skeletons in oxygen isotopic equilibrium. Based on preliminary data presented at the meeting the following advances have been made:
Several workers have been able to correlate the oxygen isotopic composition of bulk skeletons with mean water temperatures from the localities where the sclerosponges were collected (Fig. 9).

Long term records appear to correlate with COADS temperature series [Swart unpublished].

Based on high resolution sampling (10 samples a year), a seasonal cycle was identified in the skeleton (Fig. 5).

Based on literature data from Druffel and Benavides [1986] and unpublished analyses from the Caribbean and the Pacific the oxygen isotopic composition can be compared with the annual water temperature data for these locations (Fig. 9).

Data from one sclerosponge site in the Bahamas which has a record extending back in time to 1940 can be correlated with local COADS data. The chronology of this sclerosponge, which is based on C-14 age dating, shows a remarkable correspondence with long term variations in the COADS data set. This sclerosponge was also sampled at a resolution of one sample every 37 µm using a microdrill. This is equivalent to approximately one sample every month (Fig. 5). The oxygen isotopic data were subsequently subjected to spectral analyses to test whether annual variations in the oxygen isotopic record were present. If such variations were present then this would be strong evidence that the oxygen isotopic variations were controlled by temperature. In addition the presence of annual patterns in the skeleton could be useful as an independent mechanism for dating sclerosponges. Using Single Spectral analysis we were able to show the presence of signals corresponding to 0.7 to 1.7 years accounting for 12% of the variance in the oxygen isotopic signal (Fig. 5). The occurrence of a significant peak between 0.7 and 1.2 years in the spectral analysis of the oxygen isotopic signal strongly supports estimates of growth rates based on $^{14}$C and uranium series methods. If there are annual signals in the stable oxygen isotopic signal it might be possible to accurately and relatively inexpensively date sclerosponges to +/- 1 year.

**Trace Elements**

In scleractinian corals the elements B, Mg, Sr, Ba and U show seasonal variations consistent with environmental parameters, predominantly sea surface temperature and variations in upwelling. These elements have
now been analyzed from the sclerosponge (*Astrosclera willeyana*). Samples were collected from Taveuni, Fiji, Ruby Reef, GBR and Truk, Caroline Islands have been analyzed at a sampling resolution of ~40 µm to try to document an annual signal. Without confirmation from an independent dating method we are unable to confirm an annual cycle, although a significant (>99%) spectral peak was observed using singular spectral analysis [Dettinger et al., 1995] at a distance of ~0.2mm. This distance is consistent with previous estimates of annual growth using $\Delta^{14}C$ and U/Th dating methods [Benavides and Druffel, 1986, Druffel and Benavides, 1986, Bohm et al., 1996, Worheide et al., 1997; Worheide, 1998].

When samples are compared at ~100 µm resolution, longer term (annual to several year) patterns appear, which are consistent between the B/Ca, Mg/Ca, Sr/Ca and Ba/Ca cycles (Figure 10). This suggests a common
Figure 11: Comparison of the carbon isotopic composition from sclerosponges from the Bahamas [Swart unpublished] and from Jamaica [Bohm, unpublished] together with Manley temperature record from the U.K. Note the period of greatest cooling during the little-ice age also corresponds to a maximum in the carbon-13 isotope record as well as a maximum in the oxygen isotopic record (Fig. 6).

forcing mechanism for these four elements. One significant difference between corals and sclerosponges is the Mg/Ca cycles are positively correlated to Sr/Ca. Hence it appears that Mg and Sr do not follow the same positive and inverse relationships with temperature which have been documented in corals [Beck et al., 1992; Mitsuguchi et al.,
11/14/ 8/11/8 5/7/90 1/31/9 10/28/ 7/24/9
84 7 3 95 8

Figure 12: Water temperature data from Lee Stocking Island in the Bahamas from different water depths over the past eight years. Sclerosponges collected from this locality should be able to reconstruct variations in the thermocline.

1996]. In addition the boron, magnesium and barium concentrations in these sclerosponges are 2-5 times lower than in corals, with concentrations of ~20 ppm, ~200 ppm and ~4 ppm, respectively. However, the strontium and uranium concentrations are 1-2.5 times higher than in corals with concentrations of ~9000 ppm and ~8 ppm respectively. The variations in the U/Ca cycles appear to be more complicated than that documented in corals [Shen and Dunbar, 1995], being both in and out of phase with respect to the other elemental ratios suggesting a more complicated incorporation of uranium into the skeleton.

Oceanographic and Climate Issues
Carbon-13 Suess Effect

The fact that sclerosponges apparently secrete their skeletons in isotopic equilibrium (Figs.
Figure 13: Comparison of long-term regional SST variability in S.E. Asia (A) to the $\delta^{18}$O records of sclerosponges from the Indonesian Seaway (B-D). Surface waeater flowing through the Indonesian Seaway to the Indian Ocean is mostly derived from the N. Pacific and transits via the Sulawesi Sea and the Makassar Strait. Sclerosponge records from Bunaken (B) and Lapoposang (C) are expected, and are observed, to be similar. Data from Kaspota (D) in the Banda sea shows a different pattern of variability [Moore and Charles, unpublished].

6,7,8 & 10) with respect to their environment allows them to be used to address a variety of climatic and oceanographic issues. The coincidence of the decrease in the carbon isotopic composition of 1 to 1.5‰ detected in sclerosponges from both the Pacific and the Atlantic Oceans suggests that sclerosponges (Fig. 10 and 12) can be used to determine the timing of the penetration of the anthropogenic increase in the CO$_2$ of the oceans. For example figure 10 shows a comparison of perhaps the two best records measured to date, one from Jamaica and one from the Bahamas. Both show remarkable coherency, although there appears to be a real offset between the two records. Similarly, records from the Pacific also show real and significant differences in the carbon-13 profiles between different locations. Although similar changes in the carbon isotopic composition have been seen in corals, the changes are often masked and confused making sclerosponges ideal for studying the decrease in the carbon isotopic composition of the oceans related to the build up of fossil derived CO$_2$ in the atmosphere (Carbon-13 Suess effect).
Changes in the Carbon and Oxygen Isotopic Composition of the Mixed Layer

As a result of the wide depth distribution of sclerosponges, they can be used in conjunction with scleractinian corals to determine variations in the temperature and salinity of the water column as a function of depth and time. This would therefore provide information on the thickness of the mixed layer which in turn can be related to wind stress. An example of the type of temperature record which might be reconstructed is shown in Figure 12.

Comparison of long-term regional SST variability in SE Asia

Figure 13 shows a comparison of long-term regional SST variability in SE Asia to $\delta^{18}$O records from sclerosponges in the Indonesian seaway. Sclerosponge records from Bunaken(B) and Kappaposang(C) are expected to be similar as both sites are influenced by the same water mass. Furthermore, the records reproduce the regional SST response, in particular the strong cooling trend. The dotted line in (b) shows a replicate transect. The record shown in panel D, from the Banda Sea shows a different pattern of variability as might be expected given its different water supply.

Calcification

Sclerosponges appear to grow in a manner analogous to scleractinian corals, with the living organism inhabiting the upper portion of the skeleton of the sclerosponge, and the lower portion being devoid of living tissue. In the species Ceraptorella nicholsoni, the tissue layer occupies the upper 1 mm of the skeleton. This essentially represents three to four
years worth of skeletal growth. In contrast, the living portion of scleractinian corals typically occupies 50% of one year’s worth of skeletal growth. Calcification in sclerosponges occurs essentially at two sites, the base of the pseudocalices (primary calcification) (Fig. 14) and the apex of the walls separating the pseudocalices (secondary calcification). However, the relative proportion of calcification at these two sites is not known and may vary between species, rendering certain species more suitable for paleoenvironmental reconstruction than others. Secondary calcification has also been documented to take place in the interstices of some species. Evidence to this effect was presented at the Sclerosponge meeting (Reitner). However, it is not known to what extent this phenomenon occurs in the skeletons of all sclerosponges and it does not seem to take place in species such as Ceraptorella nicholsoni.

Sclerosponges are clearly excellent environmental recorders and in many respects, have significant advantages over scleractinian corals. The close agreement with equilibrium values which is evidently shown by these organisms is undoubtedly a result of the slow growth rate of these animals. Sclerosponges are unlikely to remain passive at all times. Active behavior is especially likely during climatic extremes, and failure to recognize this might cause climatic mis-interpretations at precisely the most interesting climatic periods. We therefore advocate special efforts to determine the limits of accurate climatic recording by sclerosponges.
REFERENCES


Hartman, W.D. & Goreau, T.F.,


Nozaki, Y, Rye, DM, Turekian, KK and


Vacelet, J., 1981. Éponges hypercalcifiées ("Pharétronides" "Sclérosponges") des cavités des récifs coralliens de Nouvelle-


# Sclerosponge Workshop Participants

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