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Sclerosponge growth rate as determined by ^{210}Pb and $\Delta^{14}\text{C}$ chronologies [★]

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Abstract. Measurements of bomb-produced radiocarbon and ^{210}Pb provide concordant estimates of the growth rate of the sclerosponge *Ceratoporella nicholsoni* collected from the reef slope of northern Jamaica. Radiocarbon measurements of older growth bands in the same specimen are similar to the time history of radiocarbon in coral bands from two sites in the northwestern Atlantic. Furthermore, ^{210}Pb and stable Pb analyses reveal that the sclerosponge incorporates this element at much higher concentrations than corals.

Introduction

Sclerospoges differ from common marine sponges in that they accrete a skeleton composed mainly of solid aragonite. Although the ecology and biology of sclerospoges have been investigated (Lang et al. 1975), little is known about their growth rate and growth patterns. The sclerosponge species *Ceratoporella nicholsoni* (Hickson) is an important reef builder and consolidator in the fore-reef and deep fore-reef zones off the northern coast of Jamaica (Lang et al. 1975; Dustan et al. 1976). These sponges accrete aragonite on a framework of siliceous spicules surrounded by organic fibers (Hartman and Goreau 1970). The resulting calcareous skeleton is about twice as dense as that of scleractinian corals, which also accrete aragonite skeletons. *C. nicholsoni* is the most abundant and the largest of Jamaican sclerospoges with a diameter ranging to 40 cm and a height to 25 cm. The sclerospoges grow in caves and on the undersides of small overhangs where they are protected from the sediments that cover every surface that faces upward. They grow under low-light intensity at water depths of 5 to 115 meters (Hartman and Goreau 1970). They are most abundant at depths of 70–95 m. Lang et al. (1975) concluded that lower ambient temperatures below the ther-

mocline (about 100 m) and the reduced rain of organic material, the predominant food of sclerospoges, may significantly inhibit the growth of these animals in deeper waters.

The only available estimate of the skeletal growth rate of sclerospoges was reported by Dustan and Sacco (1982) for an animal living on the deep fore-reef zone at Discovery Bay, Jamaica. They calculated a growth rate of 0.1 to 0.2 mm/yr using the alizarin staining technique. The method involved the transfer of the specimen from 94 m depth to the surface, staining with a water-soluble dye, and subsequent replacement to a cave at a depth of 35 m. The specimen was recaptured 6 years later, slabbed and the growth rate measured. This procedure may, however, have shocked the animal, and thus altered its normal rate of growth.

Aragonite is the form of calcium carbonate that does not exchange its carbonate ions with those in seawater or from other sources. The growth of corals is significantly enhanced by their association with symbiotic algae (Buchsbaum-Pearse and Muscatine 1971). Sclerospoges have no such association, consistent with their growth in low-light locations.

In this report, we give two independent estimates of the growth rate of *C. nicholsoni* calculated from the distributions of bomb-produced radiocarbon and natural lead-210 in the aragonitic skeleton. We conclude that the radiocarbon record in the sclerosponge layers is similar to that found in annually banded corals from two other sites in the Gulf Stream System [Florida Straits (Druffel and Linick 1978) and Belize (Druffel 1980)].

Materials and Methods

A live sclerosponge was collected by Phillip Dustan in 1972 from 26 m depth on Chalet Caribe reef, five miles west of Montego Bay, on the north shore of Jamaica (18°27'N; 77°58'W). The specimen was cleaned in a 5% solution of sodium hypochlorite and stored in air until 1982.

A thin section prepared from the vertical axis of growth was X-rayed in order to ascertain whether density variations existed in the accreted material, similar to those found in hermatypic corals. Despite the use of very high contrast film, no density bands were observed. As a re-

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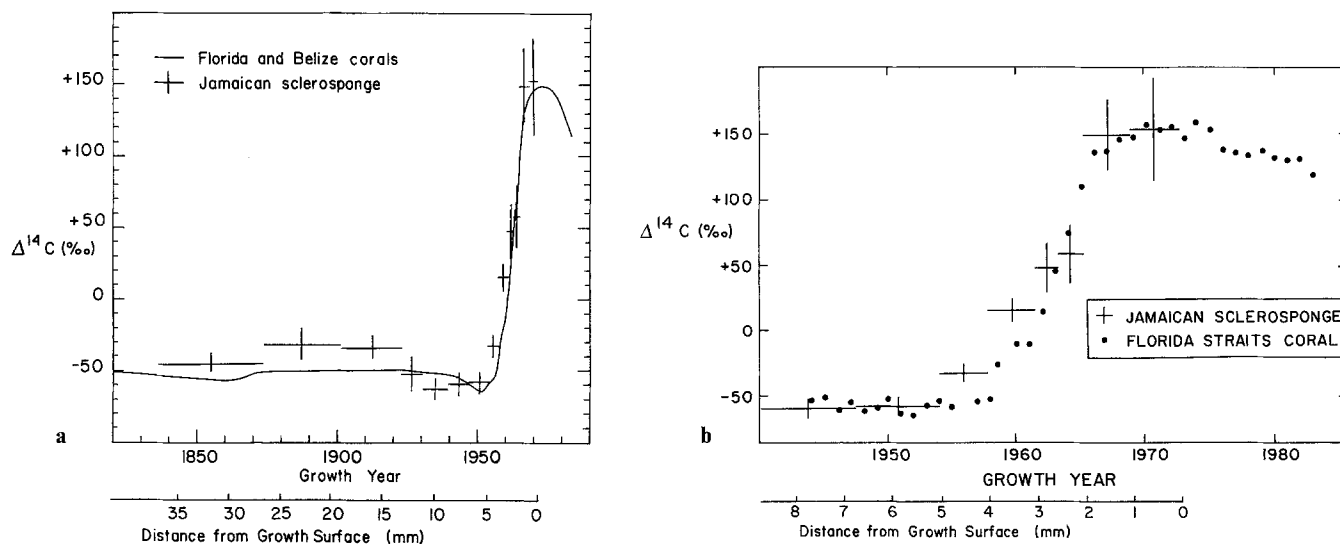


Fig. 1. **a** Radiocarbon measurements of sclerosponge rings. The chronology was established by fitting the sclerosponge results with the radiocarbon trend from coral rings (Druffel and Linick 1978; Druffel 1980) that also grew in the northwestern Atlantic Ocean. **b** Comparison of post-bomb radiocarbon results from sclerosponge and coral bands from the Gulf Stream System. By fitting the sclerosponge values to the coral record, a growth rate of 0.27 mm/yr is calculated

sult, samples were sectioned based on concentric organic matrix bands clearly visible to the naked eye. These bands consisted of dark/light pairs, the darker bands being rich in organic carbon (Hartman and Goreau 1970). This layering was observed in the sample at approximately 1 mm intervals. Although some bands were darker than others, no regular periodicity of the darker bands was observed.

Standard gas proportional beta counting techniques were used to detect radiocarbon in the acid soluble fraction of the sclerosponge layers. A copper counter (volume of 200 cc) and a quartz counter (volume of 750 cc) were used to measure ^{14}C in the samples. Each $\Delta^{14}\text{C}$ measurement (per mil deviation from the activity of 19th century wood standard) was corrected for isotope fractionation to a $\delta^{13}\text{C}$ of -25‰ relative to PDB-1, and for decay since the estimated time of formation. The $^{13}\text{C}/^{12}\text{C}$ ratio for each sample was measured using a V.G. Micromass 602E mass spectrometer.

Lead-210 analyses were performed on the acid solutions which resulted during the preparation of the radiocarbon samples. Polonium-210, the daughter of ^{210}Pb , was plated onto silver disks and then counted on silicon surface barrier detectors as described by Flynn (1968). Radium-226 was analyzed by the ^{222}Rn emanation method (Broecker 1965).

Two samples were analyzed in triplicate for stable Pb by flameless atomic absorption spectroscopy (Shen and Boyle 1983). In contrast to the ^{210}Pb analyses, the samples were initially submitted to rigorous cleaning procedures in an attempt to eliminate particulate and organically-bound lead from the aragonitic mineral phase.

Results

The radiocarbon results obtained for the sclerosponge bands are shown in Figures 1 a, b. They were visually fit using the $\Delta^{14}\text{C}$ trend (Druffel and Suess 1983) in coral bands from Florida and Belize (solid line). The post-bomb radiocarbon trend is displayed in more detail in Fig. 1 b. Assuming a constant upward growth rate, the best fit of the results from the sclerosponge and the Florida Straits and Belize corals indicates a growth rate of 0.27 ± 0.1 mm/yr.

The ^{210}Pb results obtained for the upper 12 layers (9 samples) of the sclerosponge are displayed in Fig. 2.

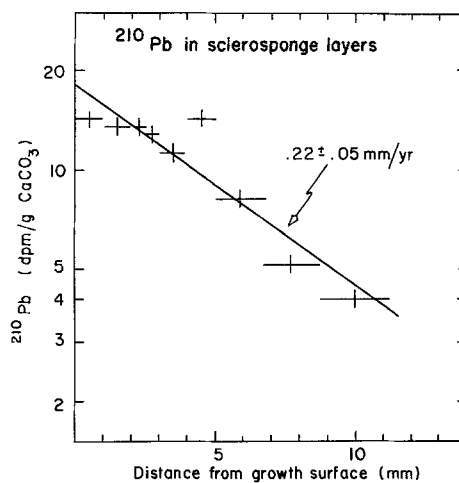


Fig. 2. ^{210}Pb activity versus distance from the growth surface of the sclerosponge skeleton. A least squares fit of these data (correlation coefficient = 0.90) reveals a growth rate of 0.22 mm/yr for the sclerosponge

Lead-210 levels (14 dpm/g in the uppermost samples) are extremely high in comparison to those activities found in banded corals (0.2 dpm/g) (Dodge and Thomson 1974). The distribution of ^{210}Pb in the individual layers reveals a growth rate of 0.22 ± 0.05 mm/yr. The ^{226}Ra activities are very low (less than 0.3 dpm); thus, virtually all of the ^{210}Pb present in the bands is unsupported and was incorporated initially into the skeleton.

The Pb/Ca mole ratio in two layers corresponding to the years (according to the radiocarbon growth rate) 1928–1944 and 1944–1956, were $200 \pm 5 \times 10^{-9}$ and $338 \pm 14 \times 10^{-9}$, respectively. An increase over this time period was anticipated due to increasing anthropogenic lead emissions (Shen and Boyle 1983). Compared to the Pb/Ca mole ratios in Florida coral for the same time pe-

riods (approximately 12 and 20×10^{-9} respectively, [Shen and Boyle 1983]), results from both sclerosponge layers display an enrichment factor of about 17 over those in the coral layers.

Discussion

There is good agreement between the two independent methods of growth rate determinations (0.27 ± 0.10 mm/yr using radiocarbon and 0.22 ± 0.05 mm/yr using lead-210) and the estimate by Dustan and Sacco (1982). The growth rate of this sclerosponge is extremely slow in comparison to hermatypic corals. Assuming a constant growth rate during the lifetime of the sclerosponge, it appears that the animal we sampled grew from 1800–1972. Using a growth rate of 0.27 mm/yr, the pre-bomb ^{14}C data reported here closely match published coral data (Druffel and Linick 1978; Druffel 1980). In addition, the $\delta^{13}\text{C}$ trend in material from 60 small holes drilled along the growth axis of the sclerosponge (Druffel and Benavides, submitted) shows a downward trend of 0.5‰ in rings that grew from 1900–1972. This agrees with the $^{13}\text{C}/^{12}\text{C}$ trend in Bermuda coral (Nozaki et al. 1978) which assumedly reflects the input of excess CO_2 from the atmosphere to the ocean.

This evidence supports the conclusion that the growth rate of this animal is well known for the last 40 years or more. The same cannot be said of the older section of the sclerosponge, as we are basing our estimates only from the fit of the pre-bomb radiocarbon record, which is relatively constant during this short period of time (160 years = 20‰ in $\Delta^{14}\text{C}$ units).

The sclerosponge $\Delta^{14}\text{C}$ results do not exactly match the Florida/Belize coral results. In particular, the data point representative of growth from 1955–1959 appears to contain a greater activity of ^{14}C (by 20‰) than the trend in the coral data from the same time period. This may be due to a variable accretion rate during all or part of the sclerosponge's growth or more likely to an artifact of the accretion process. In much the same manner as corals, the sclerosponge first accretes the aragonitic sclerodermites and then fills them with the same material as upward growth progresses (Hartman and Goreau 1970). Thus, active accretion takes place over a vertical distance of about 1 mm, integrating the growth over a 4-year period.

The use of ^{210}Pb for determining the growth rate is based on the following assumptions: 1) the aragonite in the sclerosponge obeys the requirement of a closed system for transuranic elements, which has been confirmed for some aragonite corals (Thurber et al. 1972), and 2) the aragonite is accreted with a constant Pb/Ca ratio throughout the entire growth period.

Lead-210 and ^{228}Ra dating methods have been used to measure the growth rates of corals (Dodge and Thomson 1974; Moore and Krishnaswami 1972; Moore et al. 1973). Dodge and Thomson (1974) found that the time history of ^{210}Pb in banded Bermuda corals adequately

reflected the ^{210}Pb half life. They found an initial ^{210}Pb concentration of 20 dpm/100 g, which was a two-fold increase over that relative to Ca in sea water (11 dpm/100 g). They concluded that the assumption of constant incorporation of lead with time is valid as long as the sampling site is not in a coastal area influenced by significant runoff or particle scavenging, where large deviations in radionuclide concentrations are likely to occur. In contrast, Moore and Krishnaswami (1972) found that the outermost layers of two corals from Discovery Bay, Jamaica and Onslow Bay, North Carolina contained lower $^{210}\text{Pb}/^{226}\text{Ra}$ ratios than the inner layers. They concluded that the corals do not always incorporate the same initial $^{210}\text{Pb}/^{226}\text{Ra}$ ratios into their skeletons. They suggested that high particle flux in coastal areas could cause variable sea water ^{210}Pb concentrations. It is also possible that organically-bound Pb was stripped from the outer layers with an oxidizing agent during initial cleaning of the coral heads.

It is possible that the ^{210}Pb results from the sclerosponge can be fitted by two distinct lines indicating two different growth rates (Fig. 2). The first one may fit through the data from the top 3 mm, and the second through the lower 8 mm. This would yield a growth rate of 0.78 mm/yr for the top and 0.16 mm/yr for the inner skeleton. This, however, would not correlate with the radiocarbon data, as a growth rate of 0.78 mm/yr would mean that the bomb ^{14}C signal (last four points in Fig. 1a and b) occurred over a span of 4 years, instead of 15–20 years. Thus, we conclude that the deviation of ^{210}Pb activities from a straight line is either experimental error or a result of leaching of organically-bound Pb from the upper layers during the initial bleaching of the specimen.

A most remarkable feature of the ^{210}Pb data is the seventy-fold enrichment of this isotope in the sclerosponge compared to that in coral skeletons, whereas the ^{226}Ra concentrations are approximately the same. In addition, an enrichment of stable lead is observed, although not as high as that for ^{210}Pb . This difference in lead enrichment factors may be explained by the different methods of preparation of the aragonitic samples. The ^{210}Pb analyses were performed on acidified samples that had not been cleaned, other than ultrasonically. The stable lead samples, however, were treated in various oxidizing and reducing media in order to eliminate lead present within the organic matrix and within the detrital phase. Thus, our results may indicate the relative amounts of Pb contained within each phase. The stable and isotopic lead results suggest that only 25% of the total Pb is lattice bound while 75% is associated with organic matter and detritus.

The fact that lead appears at much higher concentrations in sclerosponges than in corals may be due to the fact that the feeding mechanism for these animals is different. Corals take up and excrete water and food through the same opening (stomodeum). In contrast, sclerosponges have incurrent and excurrent channels. Large volumes of water flow into these channels and

through chambers lined by flagellated cells that supply the motile power for maintaining the current of water. Minute particulate matter is ingested by cells (chiefly amoebocytes) lining the water-filled spaces of the sponge. Thus, in contrast to corals, the feeding of the sclerosponge appears to be highly non-specific. The mechanism responsible for the enrichment of lead in the skeletal material of sclerosponges may, in some way, be a result of this non-specific feeding.

Conclusions

Measurements of bomb-produced radiocarbon and ^{210}Pb provide concordant estimates of the growth rate of the sclerosponge *Ceratoporella nicholsoni* collected from the reef slope of northern Jamaica. Radiocarbon measurements of older growth bands in the same specimen were similar to the time history of radiocarbon in coral bands from two other sites in the northwestern Atlantic. Furthermore, ^{210}Pb and stable Pb analyses revealed that the sclerosponge incorporates this element at much higher concentrations than corals. This may be the result of non-specific feeding habits in sclerosponges.

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