Corals, Sclerosponges and Mollusks

T M Quinn, University of Texas at Austin, Austin, TX, USA
B R Schöne, University of Frankfurt, Frankfurt, Germany

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Glossary

δ: Standard reporting notation for light stable isotopes is delta (δ) notation. Delta values are calculated using the equation $(R_{sample}/R_{standard} - 1) \times 1000$, where R is the ratio of the heavy to light isotope (e.g., $^{18}O/^{16}O$).

‰: Standard unit of delta (δ) notation is per mil (‰; per thousand).

$\Delta^{14}C$: Standard reporting notation for radiocarbon (^{14}C) content, which is expressed as the per mil deviation from the $^{14}C/^{12}C$ ratio in 19th-century wood. Units are ‰.

$^{14}C_{AMS}$: Radiocarbon age determinations made using accelerator mass spectrometric techniques.

Introduction

The early identification and understanding of the temporal significance of growth increments in many calcareous skeletons, but especially those in mollusks and corals, facilitated their use as a means to study environmental variability in the Quaternary. Armed with this understanding, geochemical studies of the skeletons of mollusks and corals, and later of sclerosponges, began in earnest. These early investigations established many of the fundamental principles that now form the foundation of nearly all studies using the skeletons of corals, sclerosponges, and mollusks to study environmental and climate change. In this article, we provide a general overview of the use of corals, sclerosponges, and mollusks as archives of variability in the Quaternary Earth system.

Corals

Scleractinian or stony star corals belong to the subclass Zoantharia (Hexacorallia), in the class Anthozoa of the phylum Cnidaria. Scleractinia are polyp animals found exclusively in marine environments, which first appeared in the middle Triassic (~240 Ma). Scleractinians include solitary and colonial forms, many of which secrete a hard calcareous (aragonite) exoskeleton that provides support and protection for the polyps. Scleractinian corals form two ecological groups: reef builders (hermatypic) and non-reef builders (ahermatypic). Hermatypic corals, the best-known scleractinia, contain symbiotic dinoflagellates (autotrophic zooxanthellate) and inhabit shallow waters of the tropical oceans where they secrete massive, calcium carbonate skeletons that, along with calcareous algae, form the physical structure of coral reefs. Ahermatypic corals lack symbiotic algae (azooxanthellae) and hence are not restricted to shallow waters; they inhabit all regions of the ocean.

The corallite is the central macroarchitectural component of the aragonite skeleton of corals, as each corallite houses a polyp animal. A corallite may be thought of as a calcareous tube with vertical walls (theca), radiating vertical partitions (septa), and horizontal layers (dissepiments) at the base of the coral polyp. As the surface of the corallite extends, new dissepiments are formed higher in the theca and old dissepiments are abandoned as the polyp raises itself up its theca. The living tissue, which is the site of calcification, occupies only a small fraction of the coral exoskeleton. Coral growth includes elongation (lengthening of the skeleton over time by extension) and thickening (mass addition of the skeleton over time). The interplay between extension and thickening results in variations in skeletal density and produces annual density bands in most hermatypic corals.

Quaternary environmental reconstructions using ahermatypic corals are in their nascent phase and hold great promise; however, the bulk of the literature is based on studies of massive hermatypic corals and this article will focus on these shallow-water corals. Optimal growth conditions for hermatypic corals include warm, shallow, and protected water (20–26 °C; 5–15 m), low sediment load, and normal ocean salinity. Massive corals are exceptional archives of late Quaternary environmental change in the tropics because: (1) they can be precisely dated (U-series; radiocarbon annual growth increments), (2) they are long-lived (tens to hundreds of years), (3) the geochemistry of their aragonite skeletons provides a record of temperature and salinity variations, and (4) the ecological distribution of some species permit robust reconstruction of sea level elevation. Corals that have proven particularly useful in Quaternary environmental reconstructions include massive *Porites* sp. corals from the Indo-Pacific, massive *Montastraea* sp. from the Atlantic, and to a somewhat lesser extent *Diploria* sp. from the Atlantic.

Patterns of annual density banding reflect variations in a number of environmental variables (e.g., temperature, water quality, light conditions, nutrient availability). These variations may be used to retrospectively monitor growth characteristics of massive corals and infer past environmental changes. The most commonly reported growth variable is linear extension rate, which can vary considerably within and between genera and individual coral colonies from the same reef. As an example, annual average extension rates vary from ~13 mm yr^{-1} in massive *Porites* corals from the Great Barrier