BIVALVE SCLEROCHRONOLOGY

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Synonyms

Bivalve shell chronometer; Related to dendrochronology

Definition

Sclerochronology: The study of incremental growth patterns in hard part remains of organisms that grow by accretion (i.e., adding on discrete growth layers throughout the life of the organism). The term “sclerochronology” was introduced for the study of growth patterns in calcareous exoskeletons or shells and applied to study the rate and patterns of coral growth (Buddemeier et al., 1974). It is analogous to the earlier established approach of dendrochronology. The application of the term “sclerochronology” has since broadened to the hard parts of many other aquatic taxa (e.g., bivalves, limpets, fish, and coralline sponges).

Bivalve: Bivalves are in the class Bivalvia of the phylum Mollusca and include freshwater, marine, and estuarine clams, mussels, quahogs, scallops, and oysters. They have a wide biogeographic distribution, extending from the equator to the poles, and occur from shallow to deep water. Furthermore, bivalves have a long geologic history and are archaeologically important. Fossil bivalves document more than 500 million years of evolutionary history. Bivalves from archaeological deposits (e.g., shell middens) provide information on food-gathering activities of historic and prehistoric people and insights into human-climate interactions. Many taxa are relatively short-lived (e.g., *Mercenaria* spp., *Spisula* spp., *Chione*, spp., *Crassostrea virginica*); however, many other bivalve species are extremely long-lived (e.g., *Arctica islandica*, *Neopycnodonte zibrowii*, and *Margaritifera margaritifera*). Their shells are composed of calcium carbonate ($CaCO_3$), most commonly in the form of aragonite and/or calcite. The ultrahigh-resolution (daily, seasonal, annual) records of growth increments enable bivalve shells to serve as unique skeletal diaries.

Introduction

Many hard part remains of aquatic organisms form by accretionary growth, implying that the accretion of new material is periodically retarded or interrupted which results in the formation of growth lines. Growth lines delimit growth increments, i.e., periods of fast growth. Growth increments represent time slices on annual, fortnightly (tidal), circadian (24-h cycle), circalunidian (lunar day; on average, 24 h and 50 min), and ultradian (period shorter than a day, minutes to hours) scales. Together, growth lines and increments can be used to estimate ontogenetic age and season of growth and add a calendar date to discrete shell portions. Biological clocks entrained by environmental pacemakers (e.g., light/dark cycles, tidal cycles, food availability) apparently control the regular formation of growth lines and increments. This entry focuses on the use of sclerochronology in bivalve shells.

Bivalve sclerochronology can provide environmental and ecological data from many different spatial, temporal, and cultural settings. Combining sclerochronology with geochemical analyses (e.g., oxygen and carbon isotope ratios; $\delta^{18}O$ and $\delta^{13}C$ values, respectively) can provide additional environmental and ecological information, such as water temperature, precipitation, glacial meltwater pulses, primary productivity, etc. The key criterion for chronological research, however, is precise time control. The following section provides an overview on the formation of periodic growth patterns in bivalves and focuses on daily, fortnightly, and annual increments. We refer the reader to Schöne and Surge (2012) for a more detailed discussion of bivalve sclerochronology and geochemistry.

Shell growth patterns

Shell growth patterns result from changes in the rate of deposition associated with variations in chemical composition and crystallographic properties. Growth lines separate the growth pattern into time slices referred to as growth increments. Together, growth lines and increments form a shell calendar, providing an ideal method to measure time. They are typically studied in the outer or middle shell layers of cross-sectioned valves cut along the maximum axis of growth. Several methods, such as staining and acetate peels, have been developed to visualize growth patterns (Clark, 1980; Kennish et al., 1980; Tevez and Carter, 1980; Richardson, 1987; Schöne et al., 2005a).

The outer shell layer and portions of the middle shell layer provide a complete and undisturbed shell record, assuming no diagenesis or taphonomic alteration. New shell material is deposited along the shell margins including inner surfaces when the shell is open (gaping). Shell dissolution may occur along the inner shell layer and portions of the middle shell layer when the valves are closed for extended periods of time (e.g., during seasonal anoxia, beyond temperature or salinity tolerances) (Crenshaw, 1980). Therefore, these portions of the shell should be avoided for calendar-dated studies. The outer shell layer and outer portion of the middle layer are not affected by dissolution during shell closure.

Many bivalve shells contain daily microgrowth increments, which are ideally studied in fast-growing, young portions of the shells. Under optimal growth conditions, some pectinids and giant clams (*Tridacna* spp.) form increments corresponding to the number of solar days that elapsed during that growth interval (Clark, 1974, 1975; Parsons et al., 1993; Watanabe and Oba, 1999; Chauvaud et al., 2005). This finding suggests that such microgrowth increments form with circadian periodicity (Clark 1975).