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Editorial

Looking back over skeletal diaries — High-resolution environmental reconstructions from accretionary hard parts of aquatic organisms[☆]

1. Preface

Twenty-five years have passed since the publication of the standard reference for sclerochronology[1] edited by Donald C. Rhoads and Richard A. Lutz: *Skeletal Growth of Aquatic Organisms — Biological Records of Environmental Change*. This book has had determining influence on the direction in which today's sclerochronological research has developed. During the last few years, the interest in using biogenic hard parts as high-resolution archives of past climatic, environmental and ecological variables has grown tremendously. This is reflected by a rapidly increasing number of publications and research groups. However, the recognition of the full potential of incrementally grown skeletons for environmental and climate research has yet to come. A compilation of recent research activities in a prestigious journal with a broad scope and audience seemed hence long overdue.

This special issue of *Palaeogeography*, *Palaeoclimatology*, *Palaeoecology* focuses on paleoclimate, paleoenvironmental and paleoecological records in accretionary hard parts of aquatic organisms including bivalve mollusks, fish, corals and coralline sponges. The compilation represents an outgrowth of a session held at the 2004 American Geophysical Union Ocean Sciences Meeting in Portland, Oregon. The highly successful session brought people from various disciplines together, stimulated cross-disciplinary communication and fostered cooperative research programs.

Many biogenic hard parts form by incremental growth. This implies that the accretion of new skeletal material is periodically interrupted and results in the formation of growth lines. Growth lines separate the growth pattern into time slices of approximately equal duration, i.e. annual, fortnightly, circadian, circalunidian and ultradian increments. Growth lines and increments can be used to estimate ontogenetic ages and add a calendar date to each shell portion. The regular formation of growth lines and increments is apparently based on biological clocks entrained by environmental pacemakers such as the light/dark cycle, the tidal cycle etc. George Clark's paper focuses on that issue. He reports on periodic growth patterns in pectinid bivalve mollusks. Whereas in shallow water settings the light/dark cycle entrains the biological clocks, tidal currents control shell growth in subtidal pectinids. Daily growth lines can be vital in deciphering high-frequency environmental variations (e.g., the tidal regime in fossil settings) and can add a daily calendar axis to the shell record.

Random changes of environmental variables can influence the growth rates, water chemistry and

[☆] Selected papers from the session *High-resolution Paleoenvironmental Reconstructions using Accretionary Biogenic Hard Parts* held at the American Geophysical Union Ocean Sciences Meeting 2004 in Portland, OR.

[1] The term sclerochronology refers the study of growth patterns of hard parts of aquatic organisms.

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kinetic isotope effects. For example, warmer temperatures result in faster skeletal growth rates and hence broader increments in mid- to high-latitude bivalves. Furthermore, changing environmental parameters control the oxygen and stable carbon isotope compositions (δ^{18}O and δ^{13}C, respectively) and trace elemental ratios (e.g., Mg : Ca and Sr : Ca) of biogenic hard parts. Variations in increment width and geochemistry can hence be utilized as environmental and climate proxy archives. A multi-proxy approach becomes even more powerful through the combination of calendar alignment with growth lines and increments. Studies in this special issue make use of this powerful tool.

Using fortnightly growth patterns, Carré et al. (this issue) aligned the shell sea-surface temperature (SST) record (derived from oxygen isotopes) of *Mesodesma donacium* from the Peruvian coast. This shell-based, high-resolution SST proxy record can be used to reconstruct changes of the El-Niño Southern Oscillation (ENSO). In addition, these authors provide a new paleotemperature equation based on $\delta^{18}O_{shell}$ of *M. donacium* which yields superior precision than other paleotemperature equations.

Jones et al. (this issue) reconstructed seasonal temperatures from $\delta^{18}O_{shell}$ of recent and subfossil bivalve mollusks, *Donax variabilis*, from Florida and found that temperatures were 3.5 °C warmer than today during the mid-Holocene. Values of $\delta^{18}O_{shell}$ were also used to identify the season of harvest by indigenous peoples. Preliminary results point to a preferred collection during fall.

Gillian et al. (this issue) focused on the difficulties in using stable isotope compositions of estuarine bivalves (*Saxidomus giganteus*) from Puget Sound, Washington, as environmental proxies. They investigated the reproducibility of the isotopic signal between individuals and assessed how precisely temperature could be calculated from shell $\delta^{18}O_{shell}$.

Three papers deal with extremely long-lived bivalve mollusks from the Northeast Pacific, the North Atlantic and Europe. Strom et al. (this issue) reconstructed coastal air temperatures from variations in shell growth of *Panopea abrupta* from Protection Island, Washington. By applying the 'regional curve standardization technique', decadal and interdecadal environmental signals (Pacific Decadal Oscillation) were preserved in the master chronology (multiple specimens with overlapping life spans combined in a single composite chronology).

Schöne et al. (this issue) present the oldest ever-reported animal, a 374-year-old bivalve mollusk, *Arctica islandica*, from Iceland. Variable shell growth rates and stable isotope composition from shell carbonate were used as a multi-proxy climate archive covering the period from AD 1495 to 1868. Clear decadal oscillations (North Atlantic Oscillation and teleconnections to the Tropical Atlantic Meridional SST Gradient) were found in the sclerochronological and isotope records.

Shells of freshwater bivalves serve as long climate archives as well. However, Dunca et al. (this issue) advise a judicious sampling strategy when biogenic hard parts are used for climate studies. Whereas shells of freshwater bivalves (*Margaritifera margaritifera*, *Unio crassus*) from undisturbed settings can reliably reconstruct past summer air temperatures, environmental signals are completely camouflaged in specimens from polluted settings (reduced alkalinity, eutrophication, oxygen-deficiency).

Surge and Walker (this issue) reconstructed ecological (migration patterns) and climate conditions of subtropical coastal regions in Florida from fish ear bones (otoliths). The authors analyzed the variation in oxygen isotope composition of modern and archaeological (Little Ice Age, Roman Optimum) otoliths of *Ariopsis felis*.

Corals can be used as monitors of environmental pollution. Gischler et al.[2] (this issue) present the first coral (*Porites lutea*) multi-proxy record (Sr : Ca, δ^{18}O, δ^{13}C) from the Persian Gulf for the period of AD 1980–2002. The authors demonstrated that the massive oil field fires during Gulf War II are recorded as strong δ^{13}C excursions.

Two studies focused on the coralline sponges *Ceratoporella nichelsoni* and *Astrosclera willeyana*. Rosenheim et al. (this issue) analyzed elemental ratios (Sr : Ca, Mg : Ca, Ba : Ca, U : Ca and Pb : Ca) contained in shallow (25 m) and deeper water (146 m) sclerosponge, *C. nichelsoni*, and assessed their use as environmental proxies. Fallon et al. (this issue) addressed the potential use of trace elements ratios as environmental proxies in *Astrosclera willeyana* from

[2] Invited contribution.

deeper water settings and pay particular attention to maximum temporal resolution. Because thickening of the skeleton occurs over a period of up to three years, any environmental record derived from skeletal carbonate will provide a time-averaged record up to three years.

The last paper in this issue is by Schöne et al. and presents an ideal, time-saving technique for visualizing growth patterns in virtually all biogenic hard parts. Mutvei's solution completes three preparation steps at once: gentle etching of the carbonate, preservation of the organic framework and differential staining of glycoproteins contained in the skeleton.

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