

Investigating daily trace element patterns in giant clam shells: Implications for multi-annual to daily palaeoclimate patterns

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Highly time-resolved palaeoclimate records are essential for our understanding of the role of (sub)seasonal patterns and extreme weather events in Earth's climate history. (Sub)tropical marine giant clams (*Tridacna*) can provide such records because they grow fast (mm to cm per year) and live long (up to 100 years), making their shells excellent archives of both short-term weather and multi-annual climate patterns. Moreover, these shells also have very good fossil preservation potential.

Here we present results on the sub-daily (trace) element incorporation into the shells of giant clams during day and night growth, as obtained during controlled culturing experiments. These were conducted by alternating between inflowing isotopically labelled (¹³⁵Ba) seawater and regular seawater into the culturing chambers during day and night, respectively. We then show how these daily trace element cycles can be used to create an internal age model for (fossil) shells that are up to several decades old.

Using a large *Tridacna* from the Indonesian Throughflow, we present a ~57-year climate record from the late Miocene (Makassar Strait, E Borneo). This entails oxygen and carbon isotopic compositions at sub-monthly to seasonal resolution, daily growth rates, and elemental ratios (B, Na, Mg, Sr, Ba to Ca) at sub-daily resolution. This late Miocene record reveals multi-annual, seasonal and daily cycles, along with evidence of extreme weather events. We suggest that cycles lasting around three years may reflect a global climate pattern similar to El Niño. Annual cycles may relate to local changes in water inflow, affecting temperature and nutrients. Seasonal changes, likely tied to the movement of the Intertropical Convergence Zone (ITCZ), impacted light availability and primary productivity, which in turn affected clam growth. Extreme weather events, shown by brief spikes in El/Ca ratios, may have caused drops in sea surface temperatures and thus growth disturbances due to increased runoff and turbidity.