High resolution trace element and stable isotope records in Giant Clams

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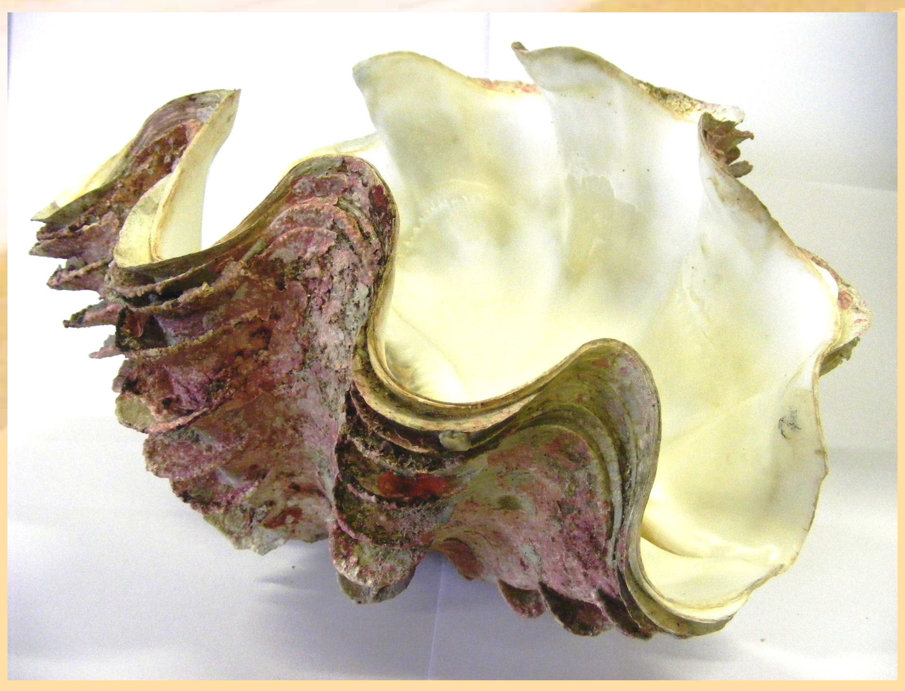


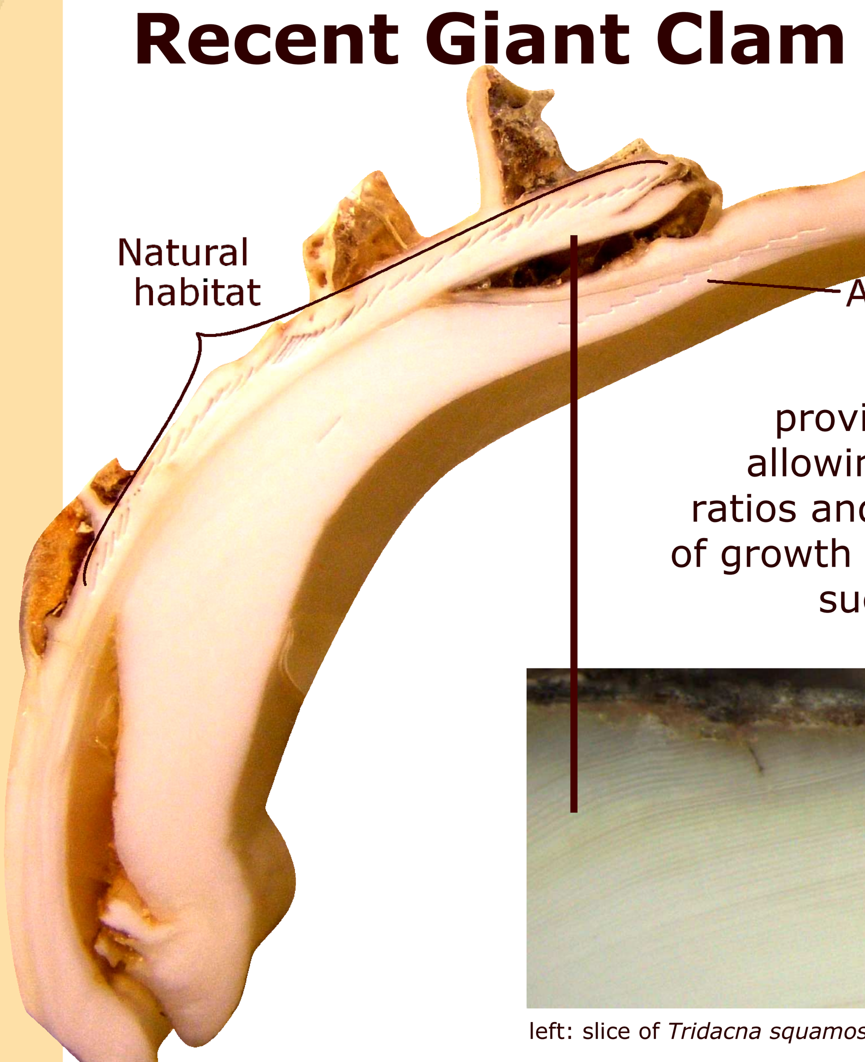
shell of *Tridacna squamosa*

Stable isotopes and trace metal incorporation in biogenic carbonates are increasingly used to reconstruct environmental variables such as temperature and seawater chemistry. However, biological processes involved in biomineralisation potentially interfere with the target parameters. Especially larger organisms, because of their more complex biology, suffer from such interferences, yet their longevity allows for reconstruction of seasonal contrasts. We used giant clams, *Tridacna squamosa* (Lamarck, 1819), grown both under controlled conditions in Burgers Zoo and in their natural environment to establish proxy relationships. A Late Miocene giant clam, *Tridacna gigas* (Linnaeus, 1758), was analyzed for its applicability as multiannual climate recorder.

Methodology

Slices of shell material were cut along the growth axis and polished. In the recent clam, daily growth lines could be observed. With a micromilling device, carbonate powder was drilled parallel to growth lines. In the recent clam, every tenth growth line was sampled. In the fossil clam, sampling was done every 0.5 mm. 30-50 µg of carbonate powder was analyzed for stable oxygen and carbon isotope ratios by mass spectrometry. Trace elemental composition was analyzed with a Laser Ablation-Inductively Coupled Plasma Mass Spectrometer (LA-ICPMS).

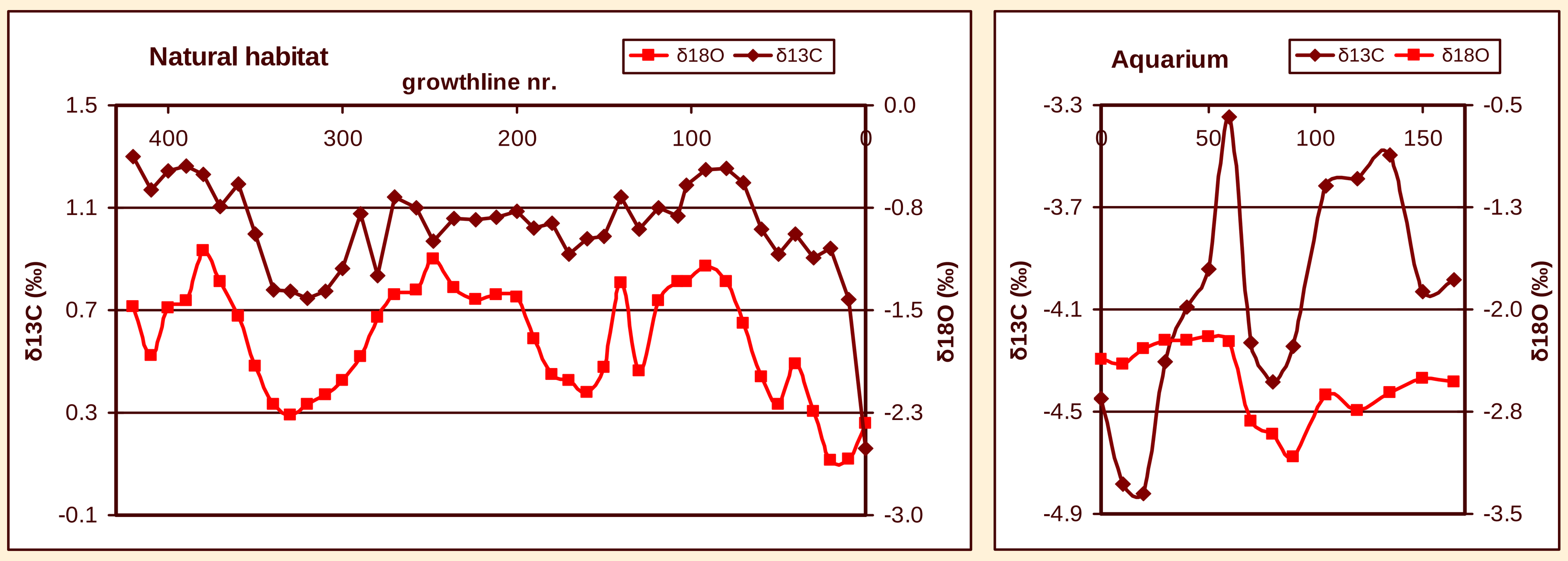
Recent Giant Clam (*Tridacna squamosa*)



Growth lines in the Giant Clam shell provide excellent control on growth rates, thus allowing deconvolution of its effect on elemental ratios and stable isotope fractionation. The number of growth lines compared to the lifespan of the clam suggests that the growth lines are daily.

left: slice of *Tridacna squamosa* shell above: close-up revealing daily growth lines

Stable isotopes

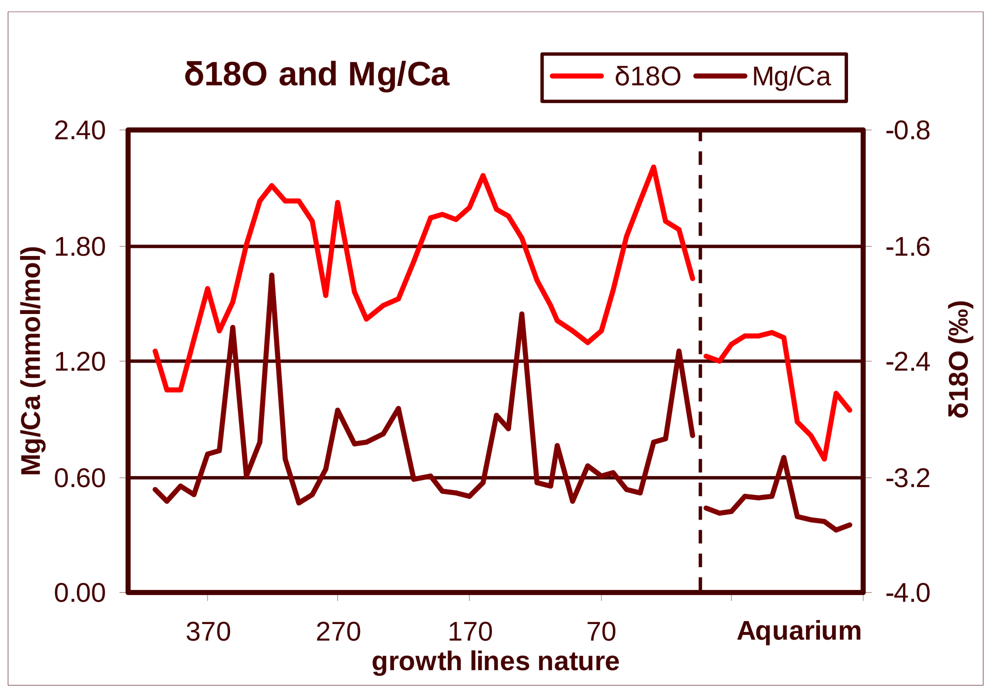


$\delta^{13}C$ and $\delta^{18}O$ in the part of the shell grown in its natural habitat (left) and in the aquarium (right)

$\delta^{18}O$ shows a pattern of two cycles over a one year period, which could be explained by the interplay of temperature and salinity variations. The clam is from Vietnam, where seasonal upwelling can cause considerable variations in temperature and the monsoon can cause strong periodic variations in salinity.
$\delta^{13}C$ and $\delta^{18}O$ are correlated with an R^2 of 0.5, which could be due to the activity of symbiotic zooxanthellae or kinetic fractionation.
Comparison of the shell parts grown in nature and in the aquarium:
$\delta^{13}C$ is more negative and variable in the part of the shell grown in the aquarium, which is probably caused by known strong variations in alkalinity;
$\delta^{18}O$ is more negative and less variable in the aquarium part which is the result of little seasonal variation in temperature (and light).

Trace elements

Oxygen isotope ratios are compared with trace elemental ratios, to test their applicability as temperature proxies. Stable isotopes, as well as trace elemental ratios, are not correlated to linear shell extension rate.



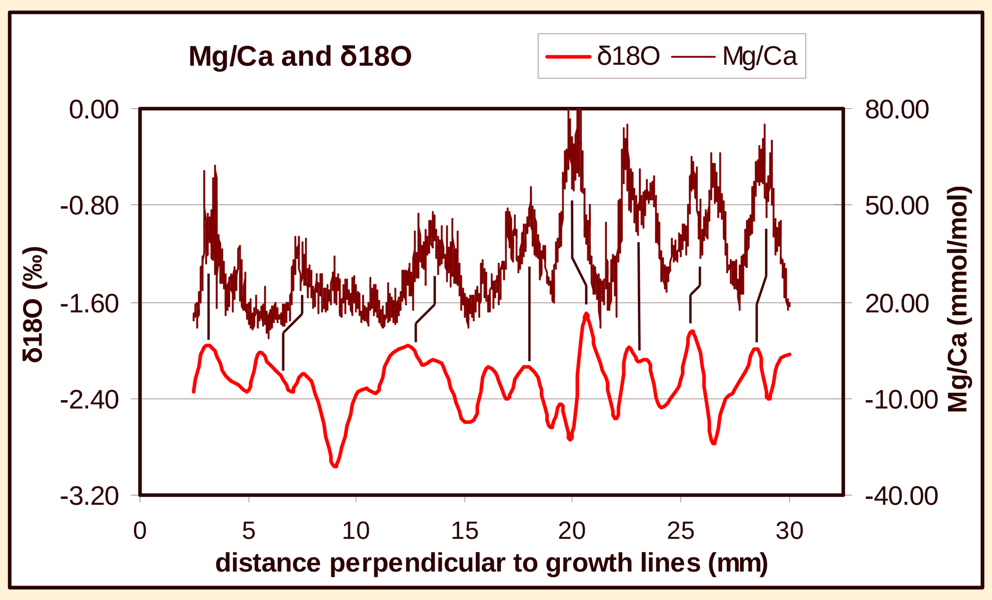
δ18O, Mg/Ca and Sr/Ca for each sample location

Mg/Ca shows considerable variability over a year. The major peaks can be correlated to peaks in $\delta^{18}O$. The covariation of δ18O and Mg/Ca suggests that the two cycles per year pattern is caused by temperature variations, possibly induced by seasonal upwelling.
The Mg/Ca ratios as well as Sr/Ca and Ba/Ca ratios are more variable in the shell part grown in nature than in the part grown in the aquarium.

Miocene Giant Clam (*Tridacna gigas*)

The reconstruction of seasonal changes in sea surface temperatures in the tropics, especially on longer geological time scales (Myrs), remains problematic. For instance coral records are often affected by diagenetic overprinting. Shells of Giant clams are relatively robust proxy recorders for constraining tropical surface water temperatures further back in time. The multi annual record of a giant clam, *Tridacna gigas* (Linnaeus, 1758), from the Late Miocene of Java can potentially be used to reconstruct El Niño scale variability.

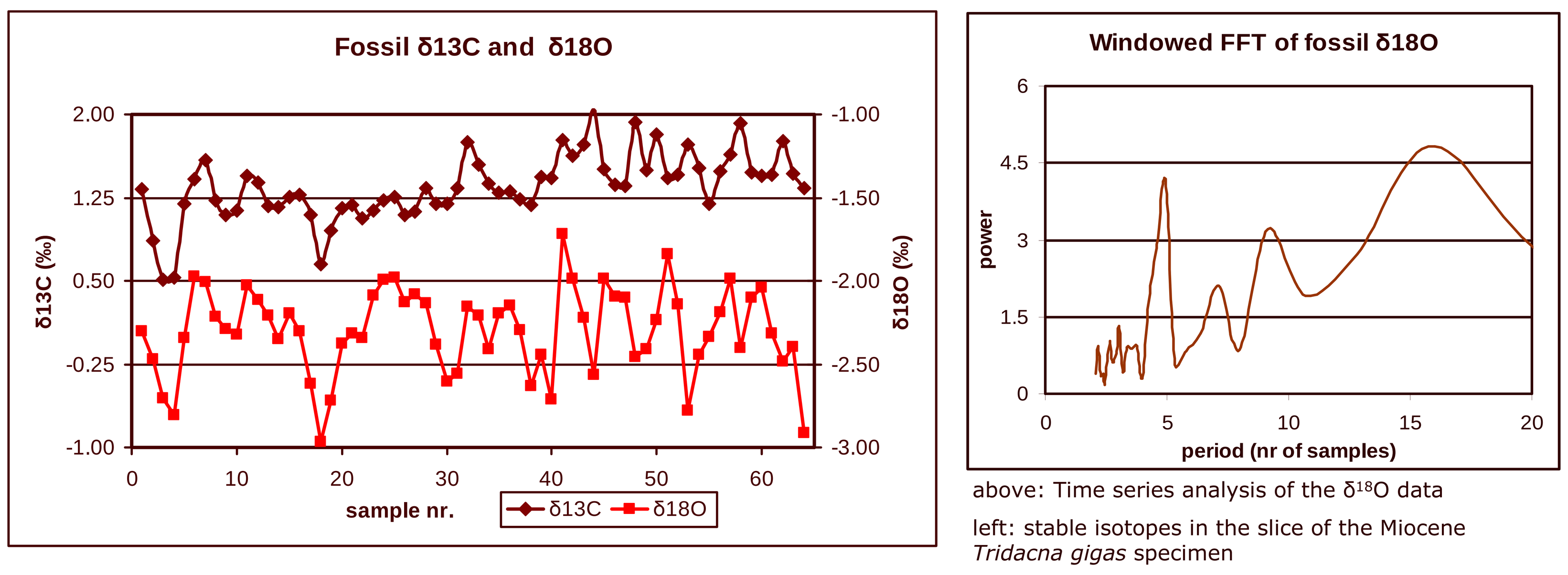
Trace elements



A LA-ICPMS transect was measured across the shell. The $\delta^{18}O$ and Mg/Ca record are connected by following the growth increment pattern on the shell cross section. The covariance of these records suggests that $\delta^{18}O$ reflects temperature accurately.

left: Mg/Ca and $\delta^{18}O$. Mg/Ca measured on a transect (not at the exact sample locations for stable isotopes)

Stable isotopes



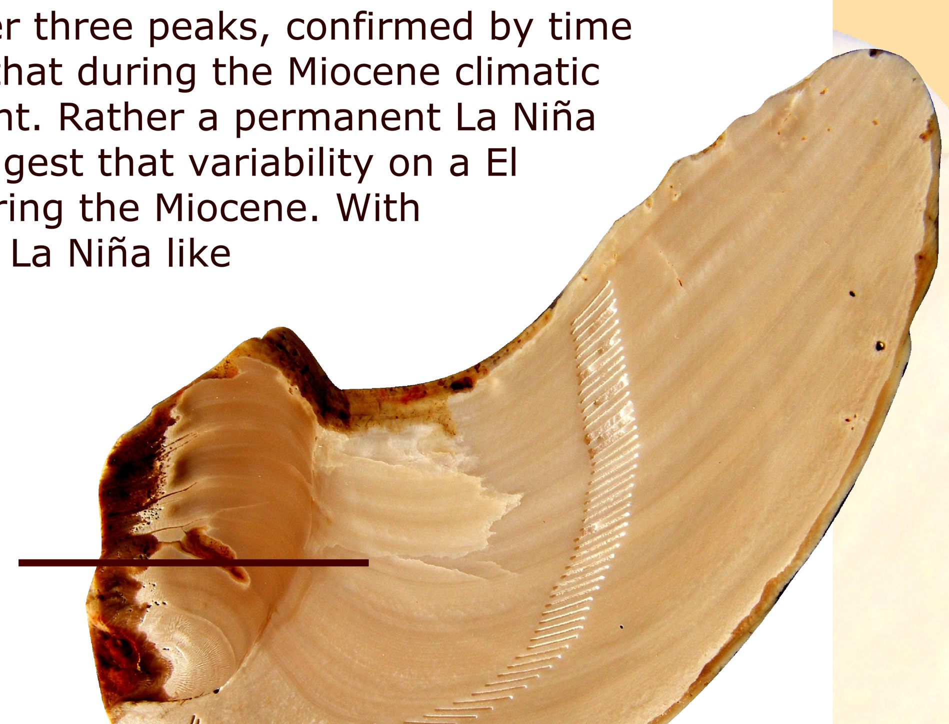
above: Time series analysis of the $\delta^{18}O$ data

left: stable isotopes in the slice of the Miocene *Tridacna gigas* specimen

$\delta^{13}C$ and $\delta^{18}O$ in the fossil giant clam are not correlated (R^2 of 0.1).

Pattern in $\delta^{18}O$: strong negative shifts after three peaks, confirmed by time series analysis. It has been hypothesized that during the Miocene climatic optimum El Niño type variability was absent. Rather a permanent La Niña climate has been proposed[1)]. Our data suggest that variability on a El Niño- La Niña time scale persisted also during the Miocene. With every cycle in $\delta^{18}O$ representing one year, La Niña like conditions prevailed every three years.

The fossil giant clam specimen shows a distinct banding pattern, with ca. 11 dark bands. No clear correlation with stable isotopes or trace elemental ratios could be observed, however.



Slice of Late Miocene *Tridacna gigas* specimen

Concluding remarks

Giant Clams have a dense shell, high growth rates and a long lifespan, enabling detailed multi-annual climate reconstruction. The shells of *Tridacna gigas* precipitate near equilibrium with ambient seawater, in contrast to corals, where $\delta^{13}C$ and $\delta^{18}O$ are affected by kinetic and metabolic effects.
This study shows the excellent potential of Giant Clams in reconstructing Neogene and Quaternary climate regimes, including El Niño-La Niña variability in the tropical Indo-Pacific.

. naturalis

BURGERS' ZOO Natuurlijk in Arnhem

References

1)Rickaby, R. E. M. and P. Halloran, Cool La Niña during the warmth of the Pliocene?, Science 307, 1948-1952, 2005