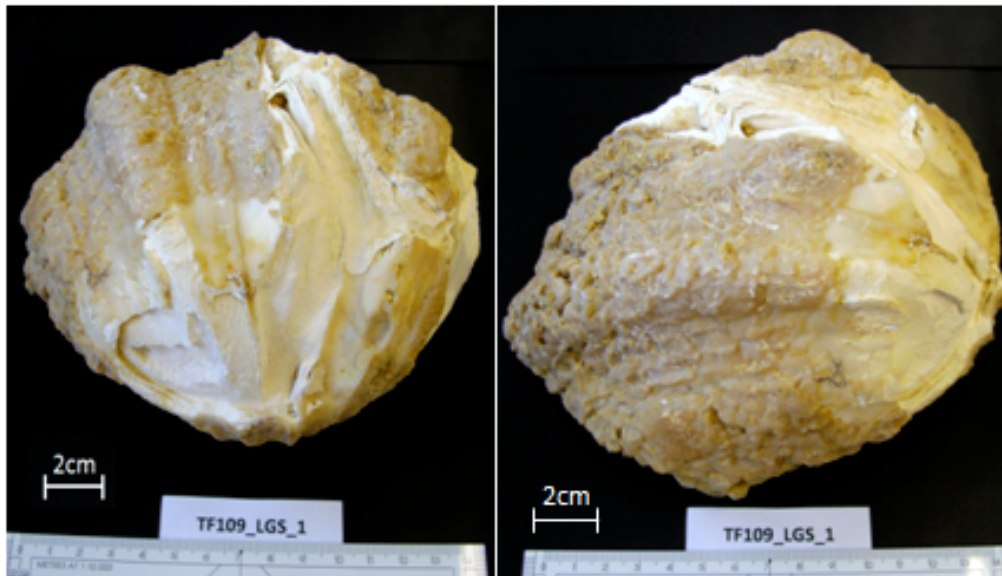
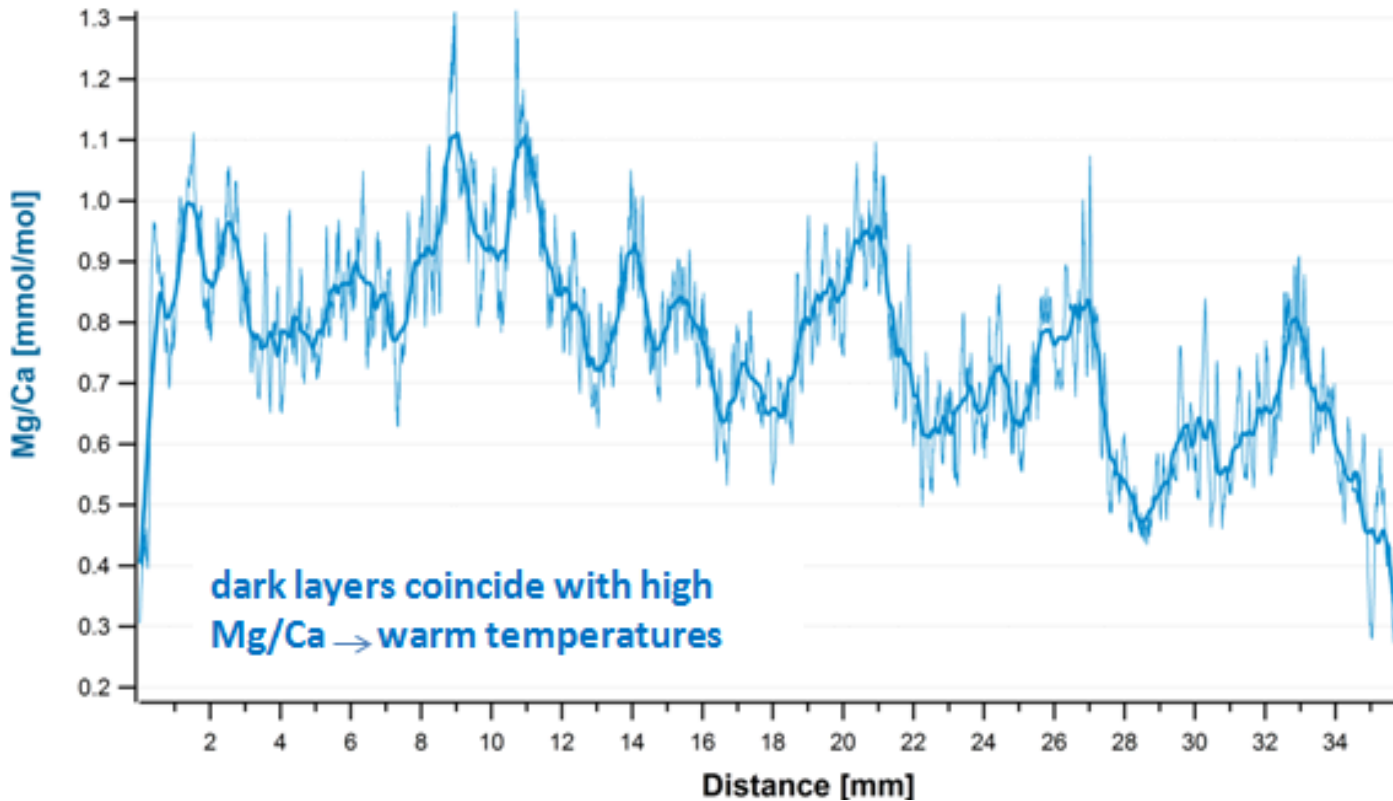


Review presentation NTA 5, Kiel  
TF 109\_LGS\_1

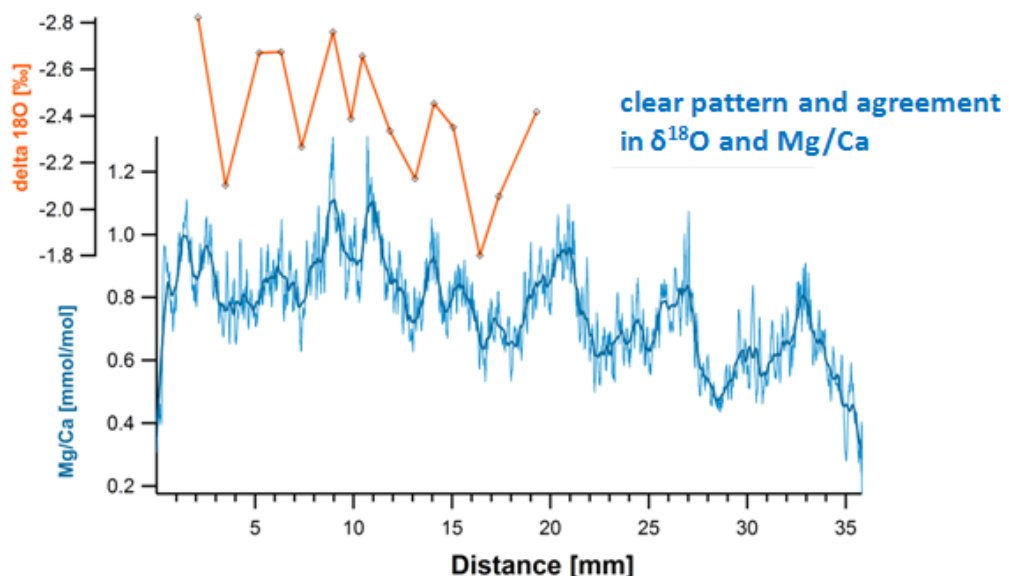
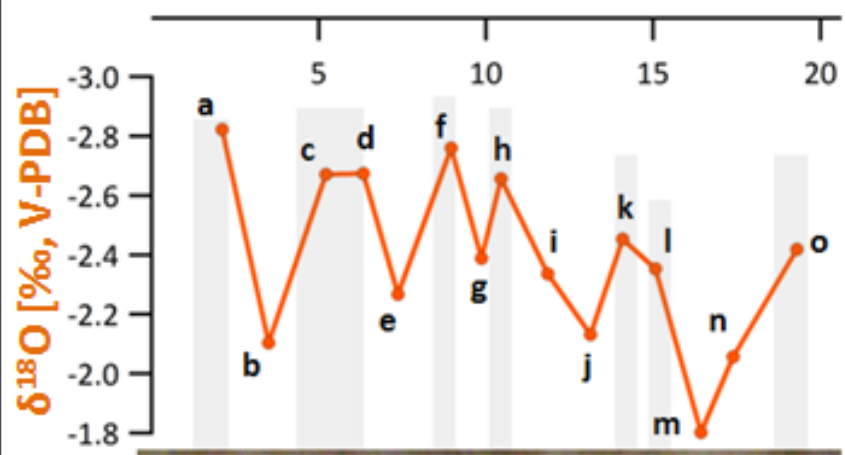


**Excellent preserved internal structure**

peaks of Mg/Ca align very well with darker layers of the shell

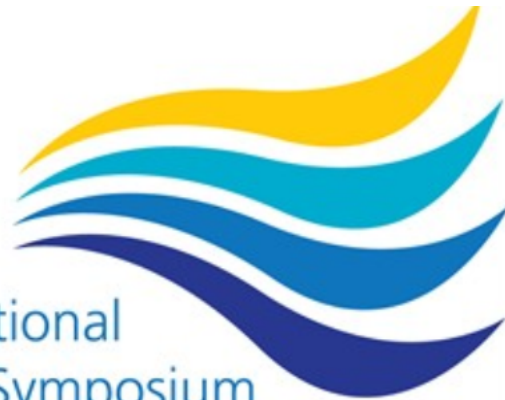


Distance from shell edge [mm]



# What happened since then...

12th International Coral Reef Symposium  
9-13 July 2012 • Cairns • Queensland • Australia



## High-resolution palaeoenvironmental records from Miocene patch reefs (East-Kalimantan, Indonesia)



Viola Warter<sup>a</sup>, Wolfgang Müller<sup>a</sup> and Throughflow Team  
<sup>a</sup>Department of Earth Sciences, Royal Holloway University of London, Surrey, TW20 0EX, UK

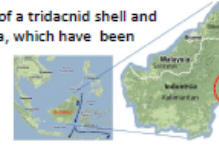


The East Indies Coral Triangle is known as the centre of maximum marine biodiversity. The development of this extraordinary coral reef diversity in South East Asia might be a response to long-term environmental changes resulting from the closure of the Indonesian Throughflow (ITF) during the Oligocene-Miocene transition<sup>1,2</sup>. However, the actual influence of the ITF on the tropical environment, the climatic dynamic and the associated biotic response has not been deciphered yet. High-resolution palaeoenvironmental records throughout the Miocene are an important key element to disentangle this relationship.



*Tridacna spec. indet.*  
(Bontang, 8.8 ± 1 Ma)

We present preliminary data of a tridacnid shell and coral skeleton from Indonesia, which have been subjected to multi-proxy analysis to evaluate their state of preservation and fidelity as palaeoclimate archive.



General map of the study site and ITF passages. Sample locations (in red) along the coast of East Kalimantan.

Strontium isotope stratigraphy (SIS) has been applied to fit the fossil samples into a chronostratigraphic framework. Both samples are of Tortonian age (Late Miocene).



*Favia pallida*  
(Sangatta, 8.4 ± 1 Ma)

### Diagenetic Evaluation

Combined XRD, SEM-imaging and trace element analysis have been performed to check the preservation of the samples.

#### Macroscopic observations & XRD

Three different carbonate domains can be identified: well-preserved/pristine aragonite (internal shell parts), altered aragonite and calcite (outermost layer/shell edge).

left: XRD spectra of well-preserved aragonite, altered aragonite and calcite. XRD can be applied to distinguish between the CaCO<sub>3</sub> polymorphs calcite and aragonite, but not between well-preserved and diagenetically altered aragonite.

#### Macroscopic observations & XRD

The first impression of the preservation state of the coral is excellent: the coralline skeleton is light, pore spaces are not recrystallised. XRD-analysis reveals 100% aragonitic composition. Fragile features like walls, dissepiments and septa are largely still intact (see SEM images).

#### SEM-imaging

(1) calcitic areas: characterised by the appearance of rhombic crystals.

(2) pristine aragonite: forms a dense, compact, crossed lamellar structure.

(3) altered aragonite: represents elongated, loosely-packed crystals in a relatively coarse network.

#### SEM-imaging

primary aragonite forms smooth, dense surfaces with the original coral ornamentation still preserved.

secondary aragonite occurs predominantly as bundles of fibres in voids or pore spaces of the coralline skeleton.

needle-like, fibrous crystals up to 40µm long.

#### LA-ICPMS Monitoring

Trace element/Ca ratio records obtained from track 3 reveal a significant, and sharp increase with beginning of the diagenetically altered area.

#### LA-ICPMS Monitoring

Trace element ratios recorded along the entire slab show co-variations, confirming their potential as diagenetic monitors.

### Palaeoclimate proxies

Continuous trace element ratio profiles were obtained using a Resonetics 193nm ArF laser ablation system featuring a two-volume laser ablation cell connected to an Agilent 7500ce quadrupole ICP-MS<sup>34</sup>.

#### <sup>67</sup>O & Mg/Ca

A clear seasonality pattern (changing with growth rate) can be observed - bright and dark shell layers produce significantly different <sup>67</sup>O signatures & Mg/Ca ratios:

- bright - heavy <sup>67</sup>O values/low Mg/Ca - cold temp.
- dark - light <sup>67</sup>O values/high Mg/Ca - warm temp.

Mg/Ca & B/Ca  
Mg/Ca and B/Ca are negative correlated with a slight (weekly - monthly) phase shift.

Mg/Ca & Ba/Ca  
Negative correlation for the last 12mm from shell edge (younger shell part).

#### LA-ICPMS Monitoring

Area of high agreement between the palaeoenvironmental tracers (Sr/Ca, Ba/Ca, U/Ca) and the alteration monitor (La/Ca).

Palaeo-environmental records (Sr/Ca, Ba/Ca, U/Ca) show a strong positive correlation with the La/Ca ratio, used as diagenetic monitor.

Despite 100% aragonitic composition, high intra-dielution heterogeneity can be observed.

Co-varying small scale variations and covariance with alteration monitor (La/Ca) appear to indicate overprint or loss of the original geochemical information due to alteration, resulting in unreliable palaeoenvironmental reconstructions.

### Conclusions

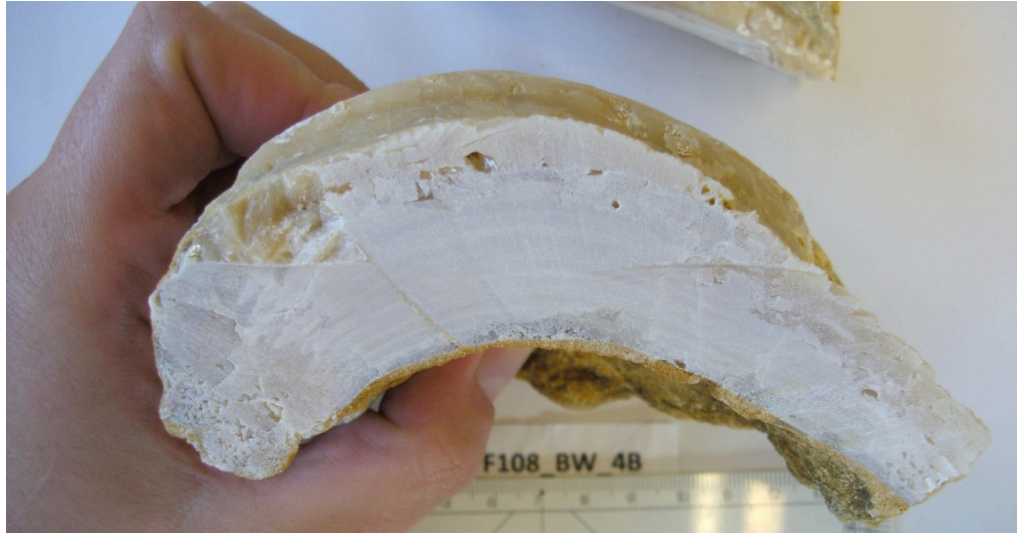
While the outer layer of the Late Miocene *Tridacna* is noticeably diagenetically altered, its internal structure is to a large extent excellently preserved. Preliminary results confirm that it is well suitable as sub-annual palaeoclimate archive and records seasonality information of the Miocene Indo-Pacific region.

Macroscopic observation and the 100% aragonite composition detected by XRD suggest good preservation of the coral. SEM reveals well-preserved (prim. aragonite) and altered areas (sec. aragonite) in immediate proximity. This intra-skeletal heterogeneity is displayed in the trace element record by small-scale variations. Further careful screening is necessary to detect areas unaffected by alteration.





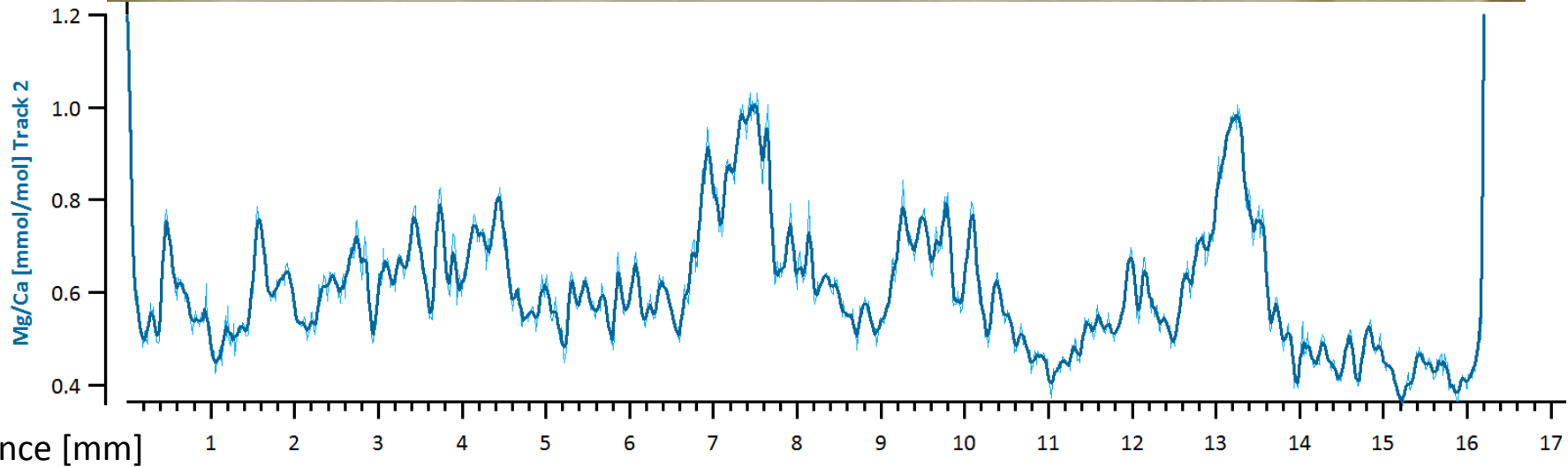
## Back at Royal Holloway...



Internal shell  
surprisingly well-  
preserved,  
with distinct  
bright/dark  
banding pattern

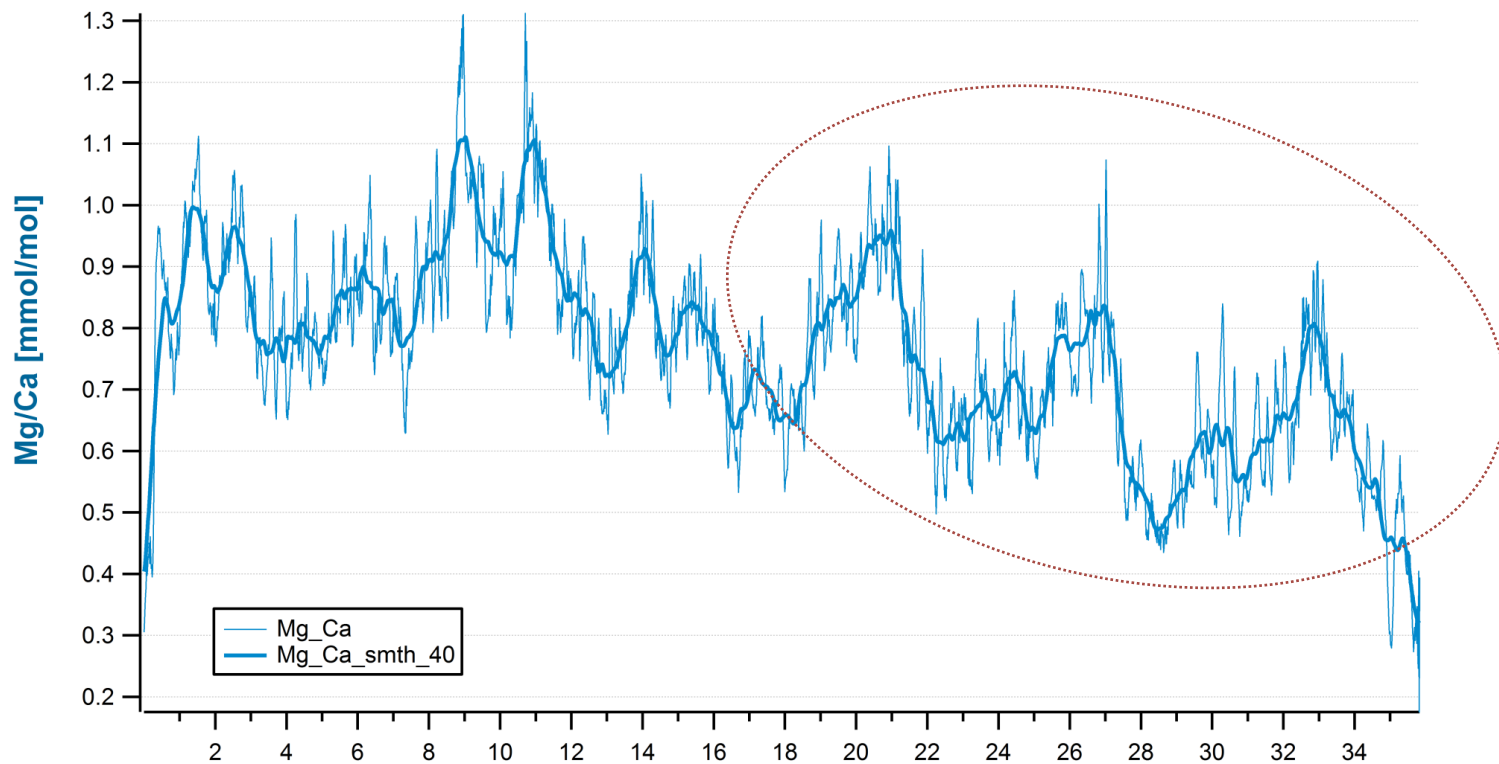


TF108  
BW 4B  
track 2

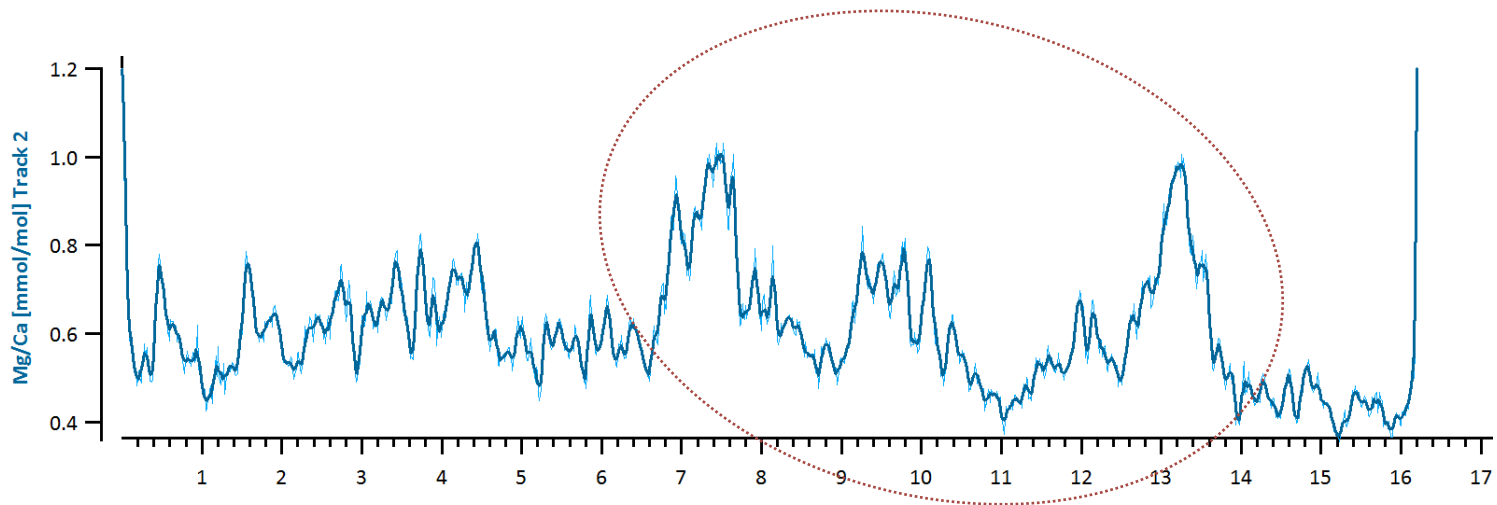




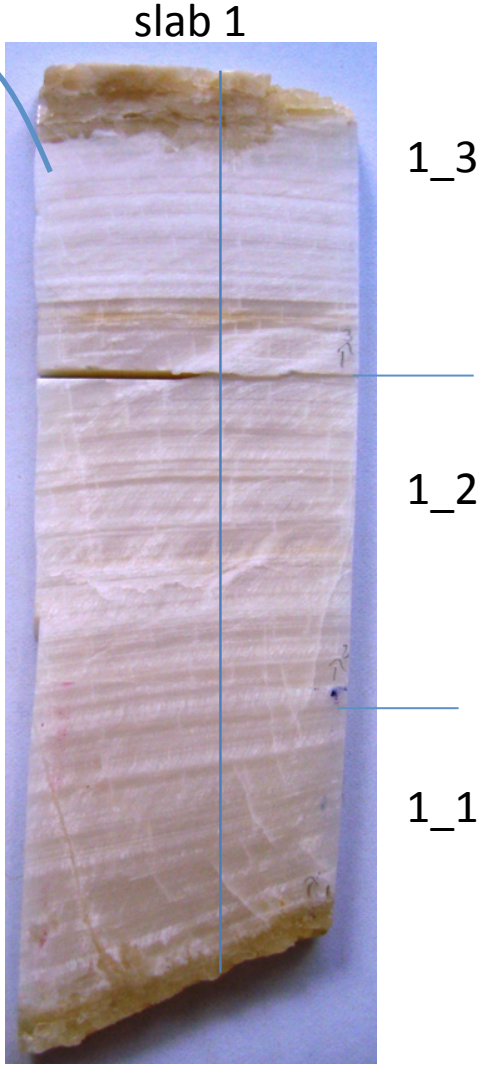
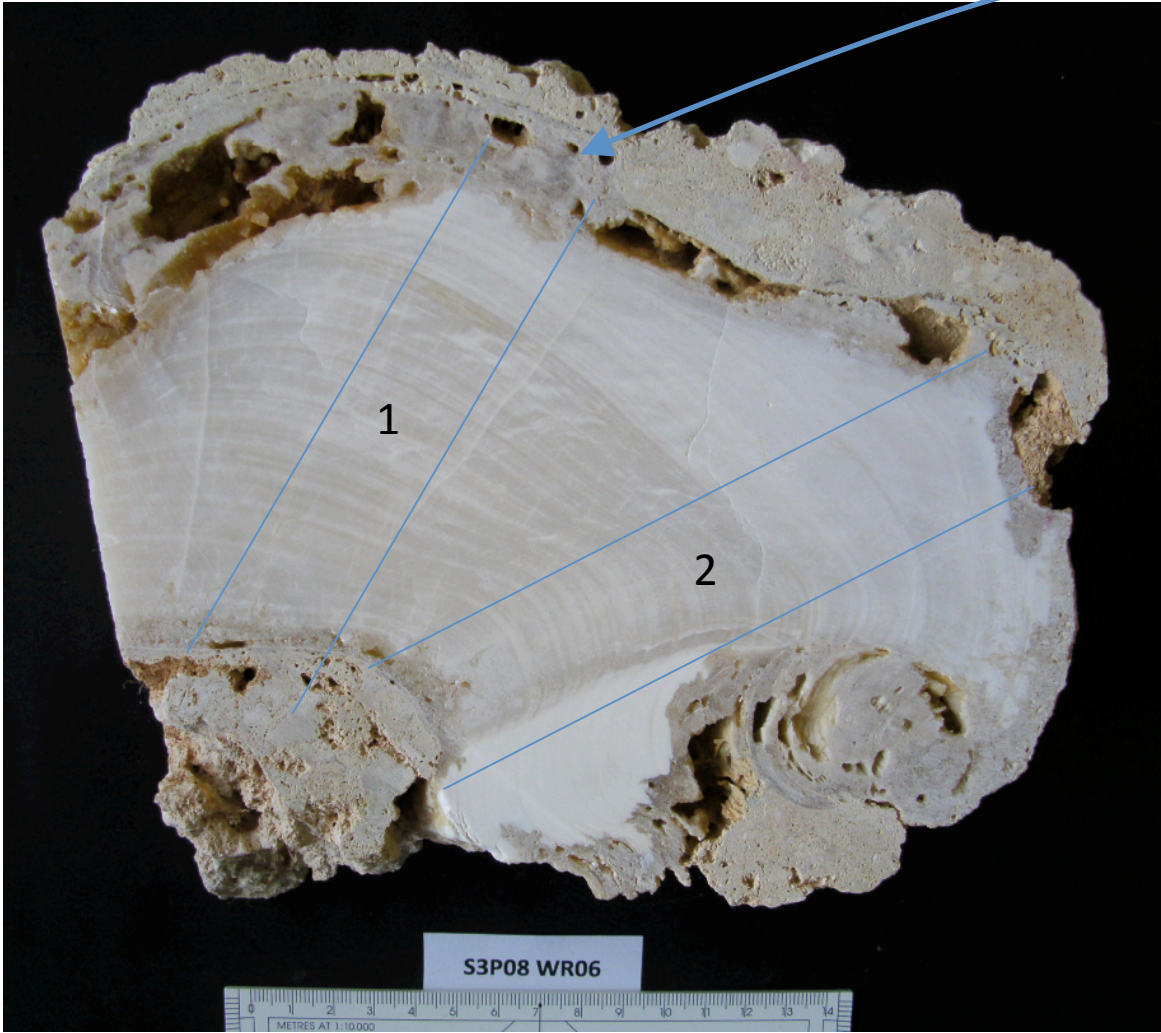
TF109  
LGS 1  
track 2



TF108  
BW 4B  
track 2

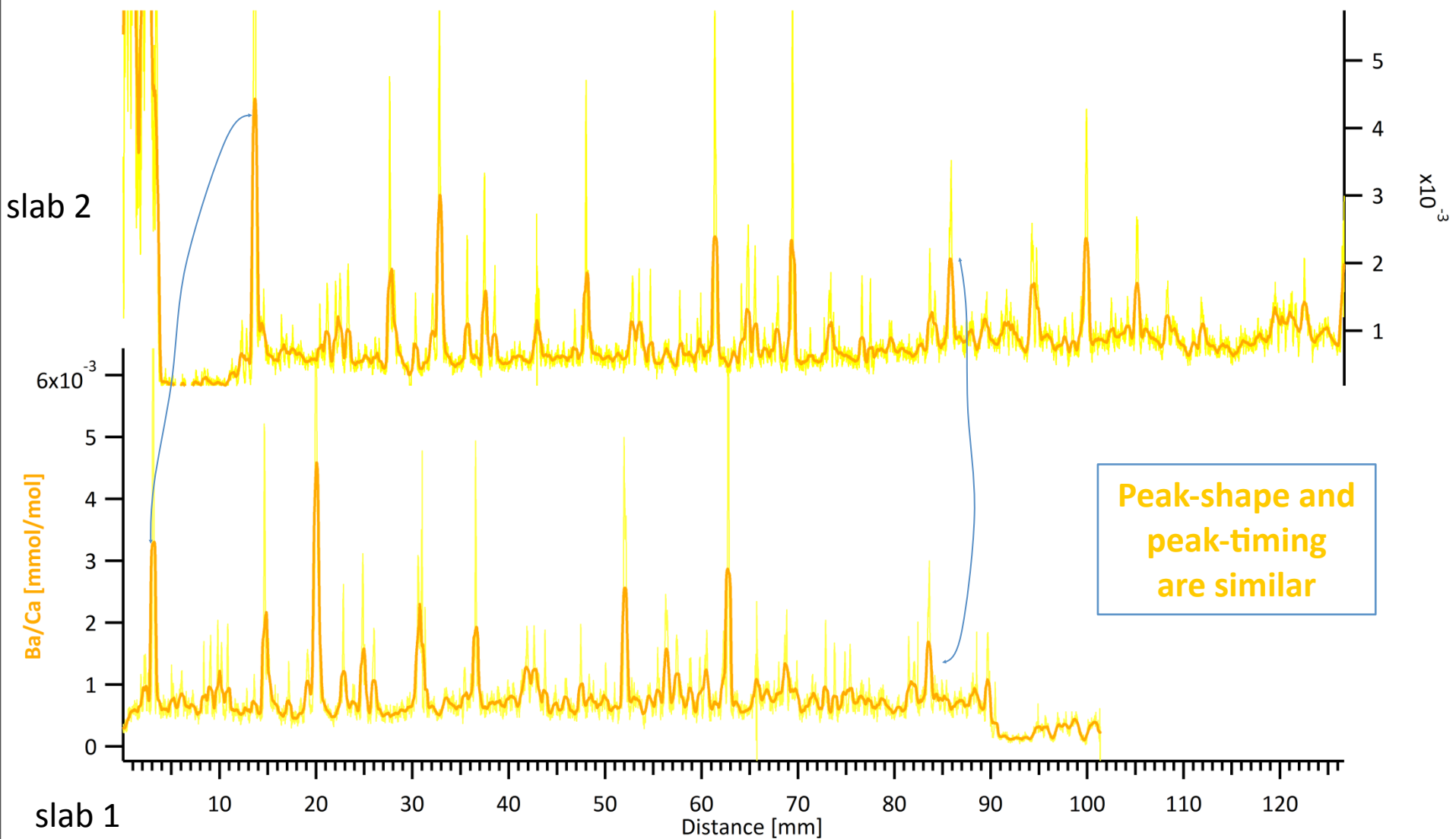


# Malaysian Tridacna (Sabbah) – estimated age late Pliocene (3.6 – 2.6 Ma)



# Malaysian Tridacna

## Ba/Ca ratio - Comparison between slab 1 and slab 2



# SIS (Strontium Isotope Stratigraphy)

$^{87}\text{Sr}/^{86}\text{Sr}$

- Coral
- ▲ Tridacna

0.7092  
0.7090  
0.7088  
0.7086  
0.7084  
0.7082

Sabbah

Sangatta

Bontang

Sangkulirang

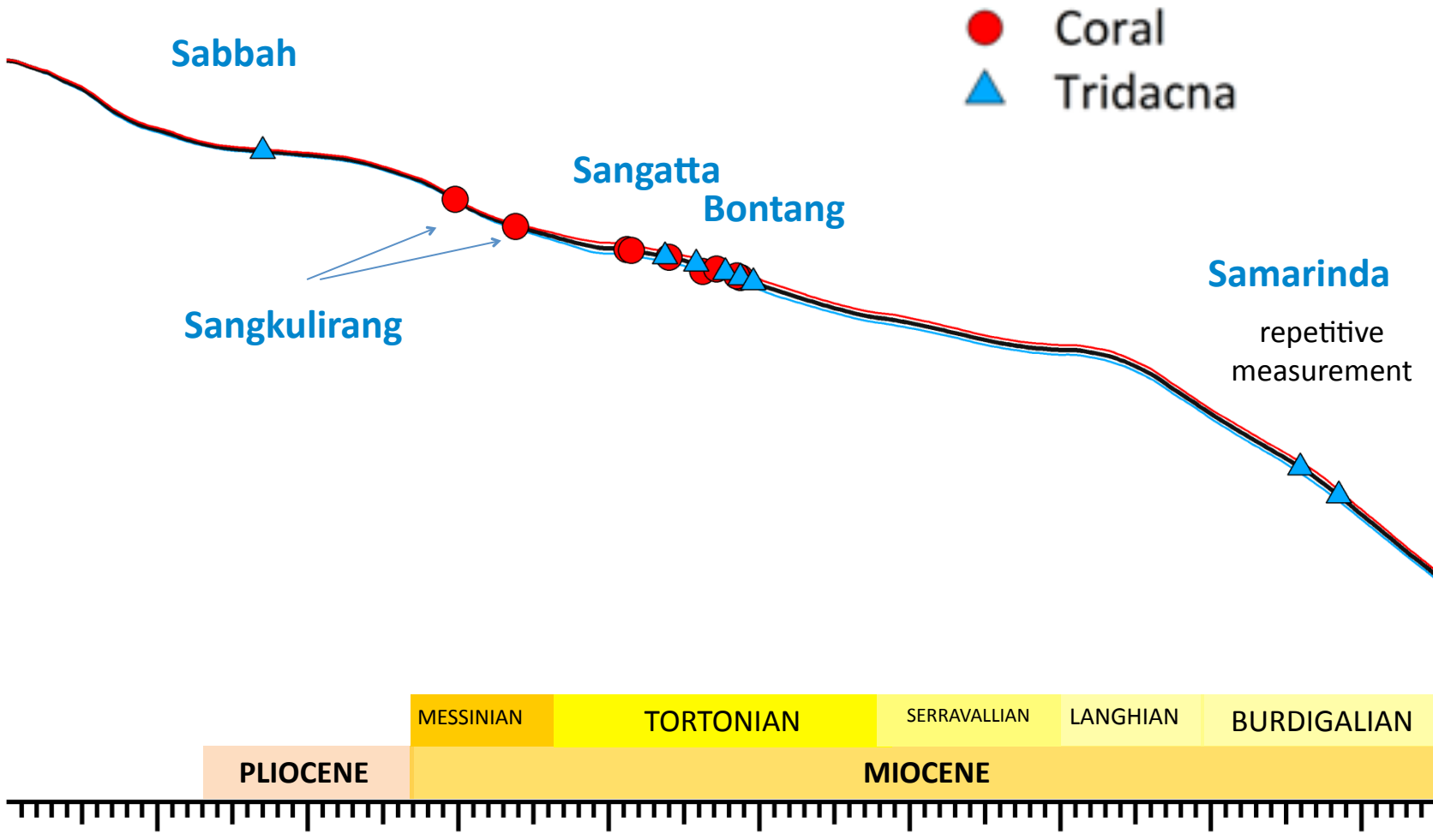
Samarinda

repetitive measurement

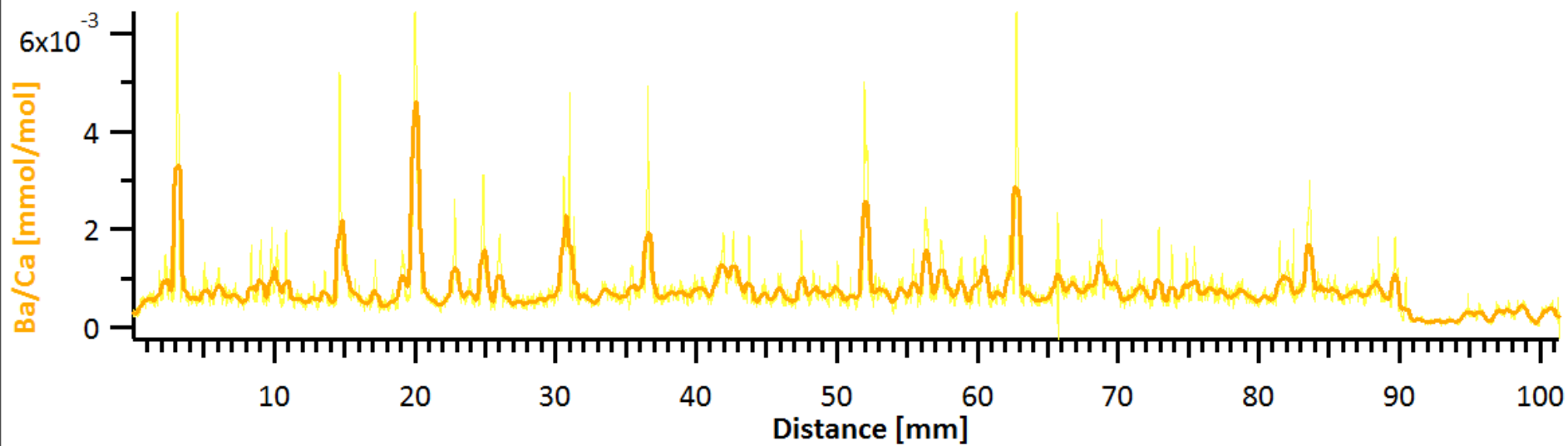
PLIOCENE      MESSINIAN      TORTONIAN      SERRAVALLIAN      LANGHIAN      BURDIGALIAN  
MIOCENE

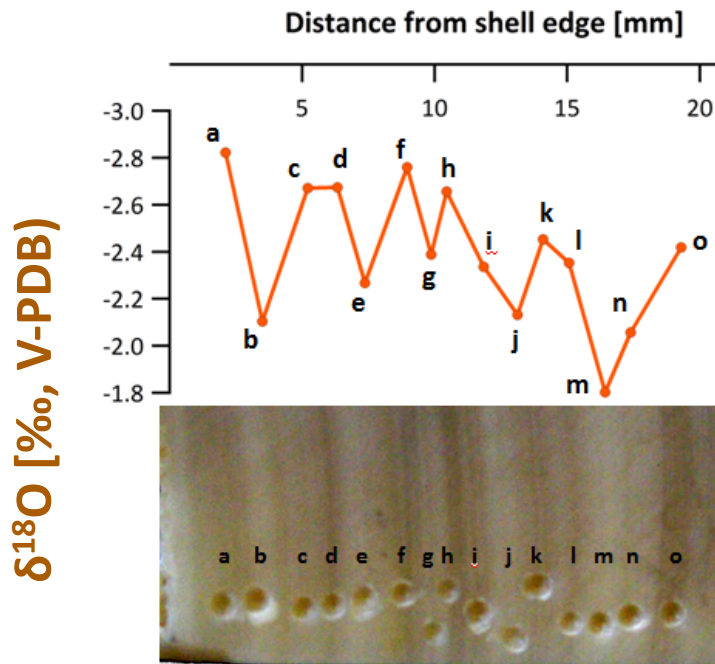
2.0      4.0      6.0      8.0      10.0      12.0      14.0      16.0      18.0

Age [Ma]









In reference to **Batenburg et al., 2011** same temperature equations and assumed  $\delta^{18}\text{O}_{\text{sw}}$  of  $-0.88\text{‰}$  are used to transfer stable isotope data to SSTs.

### Aharon (1983)

$$T^{\circ}\text{C} = 21.3 - 4.42 (\delta^{18}\text{O}_{\text{aragonite}} - \delta^{18}\text{O}_{\text{sw}})$$

Max SST: **29.88°C**; Min SST: **25.38°C**

Average SST: **27.99°C**

Max. fluctuations: **4.51°C**

Fluctuations between individual summer/winter couplets:

**1.6°C to 3.2°C**

### Grossmann & Ku (1986)

$$T^{\circ}\text{C} = 21.8 - 4.69 (\delta^{18}\text{O}_{\text{aragonite}} - \delta^{18}\text{O}_{\text{sw}})$$

Max SST: **30.91°C**; Min SST: **26.13°C**

Average SST: **28.39 °C**

Max. fluctuations: **4.78°C**

Fluctuations between individual summer/winter couplets:

**1.7°C to 3.4°C**