Using isotope ratios in a giant clam fossil to reveal ancient climate conditions

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Introduction

- Coastal development and more frequent storms will subject reefs to more turbid conditions in the future, and rising temperature will result in more thermal stress. However, turbidity may help to shield organisms from intense thermal stress[1].
- To understand how reefs will be impacted by future stress, we can study how they have survived in the face of similar stressors in the geologic past.
- Oxygen isotopes in the $CaCO_3$ (aragonite) shells of reef-dwelling organisms reveal climate from when were growing[2].
  - The relative abundance of ^{18}O (10 neutrons) to ^{16}O (8 neutrons) is affected by water temperature and salinity.

Fig. 1: Living *Tridacna Squamosa* (giant clam). Accessed from Rochard (2021, July). *Photo 150106529*. iNaturalist. https://www.inaturalist.org/photos/150106529

Geological context

- Located in the coral triangle which has the highest marine biodiversity in the world[3].

- Kambaniru Reef, late Pleistocene date (<50,000 yr BP), situated near the mouth of the Kambaniru River on Sumba Island, Indonesia.
- Warm, wet season from December to January; cool, dry season from July to August[4].

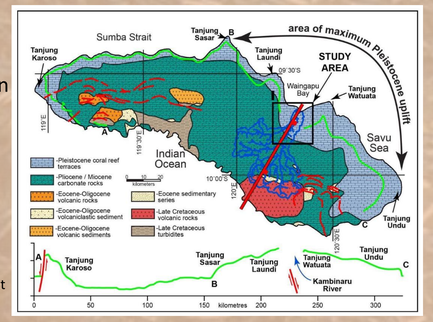


Fig. 2 (top): Map of Indonesia with Sumba Island indicated.

Fig. 3 (bottom): Sumba Island map, Kambaniru River & study area indicated. Map reproduced from Zonneveld et al. (2021) *Berita Sedimentologi* 47(3).

Methods

- Samples were drilled with Dremel tool with 0.5 mm diameter diamond drill bit along growth lines to produce ~ 5 mg of powder.

$$H_3PO_4 + CaCO_3 \rightarrow Ca^{2+} + CO_2 + H_2O + HPO_4^-$$

- Thermo Scientific Delta V Plus isotope-ratio mass spectrometer in dual-inlet mode.
- The analytical uncertainty (2σ) was <0.2‰.
- Data are reported in δ notation with respect to Vienna Pee Dee Belemnite Standard

$$\delta^{18}O = \left(\frac{(^{18}O/_{16}O)_{sample}}{(^{18}O/_{16}O)_{VPDB}} - 1 \right) \times 1000 \quad \text{(Eq. 1)}$$

Fig. 4: After the phosphoric acid and $CaCO_3$ react, the CO_2 gas produced is separated (inside tubes).

Results

- Possibly 3 or more seasonal cycles observed in the $\delta^{18}O$ data.
- Palaeothermometry equation for aragonite from ref [5] was used to reconstruct temperature from oxygen isotopes as shown below:

$$T\,(°C) = 21.8 - 4.69*(\delta^{18}O_{ar} - \delta^{18}O_{SW}) \text{ (Eq. 2).}$$

- Estimate for seawater $\delta^{18}O$ from ref [6] from the Savu Sea was used, assuming salinity is constant.

Fig. 5: *Tridacna squamosa* fossil.

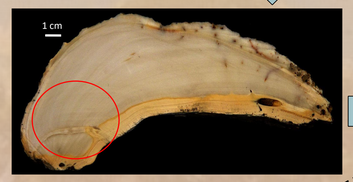
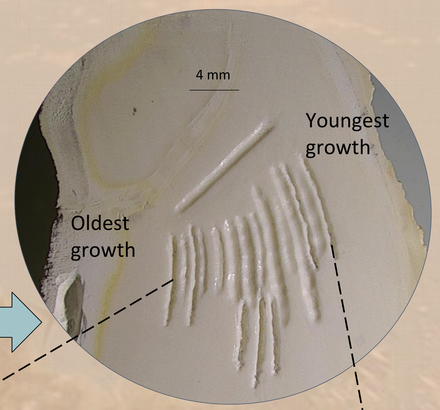


Fig. 6: Clam sample used for isotope analysis with drilled area indicated.



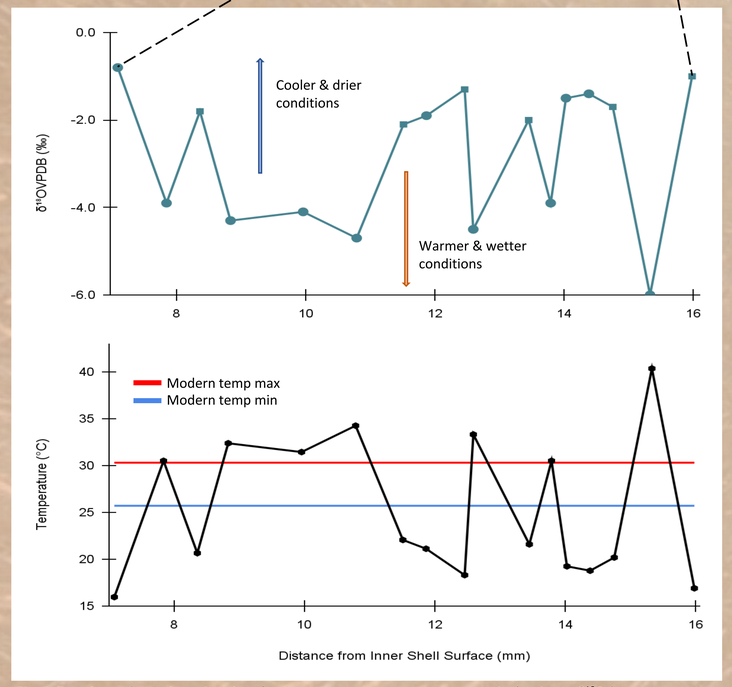


Fig. 7: Top: Clam after being drilled into (each groove corresponds to a growth line), middle: $\delta^{18}O$ for each growth line drilled, starting from oldest to youngest, bottom: seawater $\delta^{18}O$ estimate for temperature reconstructions from ref [6], modern SST estimates from ref [4]. Oxygen isotopes are reported with respect to Vienna Pee Dee Belemnite standard (VPDB).

- Our reconstructed temperatures ranged from 16°C to 40°C, whereas modern temperatures range from 25.7°C to 30.3°C [6].
- From ref [6], changing the time frame of the $\delta^{18}O$ estimate for seawater does not affect the temperature reconstructions by more than 1°C.

Discussion

- Equation 2 assumes salinity is constant, but this is likely not the case.
- Changes in salinity may stem from increased freshwater input during the wet season, as it contains lower $\delta^{18}O$ compared to saline water ($\delta^{18}O$ is positively correlated with temperature, meaning that increased freshwater would increase the calculated temperature)[2].
- Drilling was done manually with a 0.5 mm diameter drill bit. For higher accuracy it would be best to use a smaller drill bit or an automated drilling process.

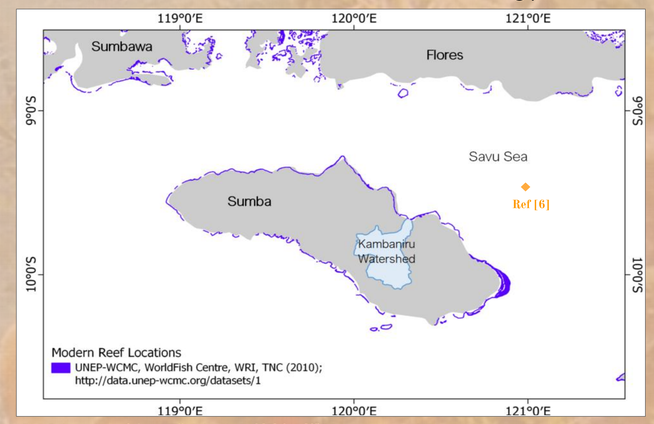


Fig. 8: Location of data collection in ref [6] for $\delta^{18}O_{SW}$ reconstructions.

Conclusions

- The oxygen isotopes strongly suggest that there were seasonal changes in turbidity, but this must be further investigated focusing on carbon isotopes, which provide information about photosynthetic productivity and therefore water cloudiness.
- Reefs are becoming subject to more turbid conditions today, and it is important to understand how they have lived in these environments in the past. Oxygen isotopes provide one lens into the seasonal relationship with turbidity and evidence that the Kambaniru River created turbid conditions at its mouth during the late Pleistocene.

Acknowledgements and References

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Background photo from Busiello, A. (2023, April 4). *Western Caribbean*. Coral Reef Alliance. https://coral.org/en/where-we-work/western-caribbean/