Resolving Micron Scale $\delta^{18}O$ and $\delta^{13}C$
Heterogeneity in Cultured Planktic foraminifera

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One of the most important climate archives - the CaCO$_3$
shells of planktonic foraminifera

Pre-sphere, trochospiral shell form of O. universa

Spherical chamber form of O. universa
Most foraminifera grow their shells over 2-4 weeks. The *O. universa* sphere typically thickens for 3-7 days before completing its life cycle.

After 3-7 days, the spines are shed via selective resoraption; the nucleus undergoes meiotic division.
Gamete release generally occurs within 24 hours of spine resorption

Post-gametogenic *O. universa* shell from the laboratory is identical to a million year old fossil. All extant planktic foraminifera follow this development pattern, but non-spinose species do not shed spines.
Crack the sphere open and the trochospiral shell is still evident inside; note sphere thickness (~20-30 µm)
Orbulina universa is a great geochemist

After Spero and Williams (1988)

O. universa HL (So. Cal. Bight & Puerto Rico combined)

LA-ICPMS depth profiling

Deep UV laser (<200 nm) and low pulse energy (~0.1-0.2 GW/cm²)

Each laser pulse shaves ~100 nm layer from test surface

10 laser pulses 100 laser pulses

Gem quality Iceland spar

Pulleniatina obliquiloculata

How small can we go......

Isotopic and Elemental Analysis of Individual Microfossils: A Submicron view of Climate and Environmental Change

Ph.D. Project by Lael ‘Spider’ Vetter, UC Davis

Orbulina universa in culture and after reproduction

• The next generation of paleoceanographic questions:
  • Can we reconstruct depth migration in a single foraminifera shell?
  • Do foraminifera contain geochemical information related to short duration storm events or surface salinity change?
Can we get around the diagenetic problem in fossil foraminifera?

SIMS and LA-ICPMS help answer the question

Cross-section through Orbulina universa shell

(Spero 1988)

Univ. Wisconsin SIMS - Cameca 1280

Spider Vetter, Claudia Mora and Reinhard Kozdon analyzing cultured foraminifera

U. Wisconsin SIMS
SIMS analyses through an *O*. *universa* chamber – can we resolve $\delta^{18}O$ shifts at this resolution?

Ion microprobe spots across *O*. *universa* chamber (2x3 mm)  
NanoSIMS image from a different *O*. *universa* showing Mg banding

SIMS analyses were conducted at the University Wisconsin with R. Kozdon and J. Valley; nanoSIMS image was generated at University of Perth (Kilburn)  
(Vetter, unpublished data)

SIMS (secondary ion mass spectrometry) through an *O*. *universa* chamber – $\delta^{18}O$ analyses with 2-3 $\mu$m resolution

Cross-section through *O*. *universa*

Vetter et al, 2013
SIMS (secondary ion mass spectrometry) through an *O. universa* chamber - δ¹⁸O analyses with 2-3 μm resolution

Cross-section through *O. universa*

Cameca 1280 SIMS can resolve shifts in chamber δ¹⁸O with ~2 um resolution and +/- 0.4‰ precision

Control Experiment in ambient artificial seawater

(Vetter et al., (submitted))
Predicted ambient $\delta^{18}O_c = -2.15\%$; predicted spike $\delta^{18}O_c = +16.9\%$. Full $\delta^{18}O_c$ shift is recorded across 1-2 $\mu$m of calcite!

Daytime spike; note broad bands

(Vetter et al., submitted)

Predicted ambient $\delta^{18}O_c = -2.2\%$; predicted spike $\delta^{18}O_c = +16.9\%$. Full isotopic shift is nearly recorded across 1-2 $\mu$m of calcite!

(Vetter, ms in preparation)
Conclusions

- Experiments combining living planktonic foraminifera with emerging technologies can resolve geochemical changes in biogenic carbonate at the micron level.
- Hi and low Mg banding is an inherent component of foraminifera chamber formation; hi [Mg] bands are produced at night and vice versa.
- Mean LA-ICPMS data through individual shells agrees well with published empirical calibrations from solution ICP-MS.
- SIMS analyses can resolve micron scale changes in test $^{18}O/^{16}O$ ratios.

We’ve come a long way in 30 years, when geochemists and paleoceanographers lumped foram biology into ‘Vital Effects’

*Laboratory and field observations of living planktonic foraminifera*

Allan W.H. Bé et al.; 1977
*Micropaleontology, Vol. 23*

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