Reconstructing Environmental Conditions During the Cretaceous:
An Analysis of Carbon and Oxygen Isotopes of Benthic Foraminifera in Relation to their Preservation and Shell Chemistry

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LAWRENCE
National Science Foundation

June-August 2010

INTRODUCTION

Microfossils are commonly used to gain insight into the conditions of past oceanic environments. Well-preserved calcareous shells of foraminifera (single-celled protozoans) reflect the chemistry of their environment at the time the shell was formed. More specifically, carbon and oxygen isotopic signatures ($\delta^{13}C$ and $\delta^{18}O$) of ocean water are reflected in the isotopic signatures of the calcite. Because planktic foraminifera live in the water column, these species are typically used for isotopic studies to analyze surface water paleotemperatures, which by extension relate to issues of global climate and ice cover. Benthic species of foraminifera, living in or on bottom sediment, have slightly more complex chemical environments due to pore water flow and varying sediment composition. Diagenesis, which is a change in shell chemistry or mineralogy after death and burial of the organism, poses challenges in that the isotopic signatures of the shell often change. Foraminiferal studies depend on using well-preserved shells, but such samples are not always common. Before benthic foraminifera can be used for reconstructing environmental conditions, the amount of chemical alteration during diagenesis must be better constrained. Here, we use multiple techniques to compare shells that are considered well-preserved and poorly-preserved in several benthic species.

METHODS

Sample Selection

- **Where**: Samples come from sediment cores taken in the Tanzania Drilling Project.
  - Samples are from the Turonian stage (~93.6 to 88.6 million years ago) of the Cretaceous
- **What**: Benthic species of foraminifera, including those in the genera *Lenticulina*, *Epistomina*, *Lingulogavelinella*, and *Berthelina* were picked out of sediment samples.
- **How**: Foraminifera were picked out of sediment with a picking brush and light microscope (Fig. 1). For each species, poor and well preserved specimens were chosen.
  - "Good" specimens = glassy appearance, smooth texture, no cement infilling
  - "Poor" specimens = whitish color, bumpy surface, opaque

Figure 1: Light microscope and picking station

Analyses

To get a comprehensive look at the shell geochemistry, several techniques were employed on samples of varying preservation.

Tool	Information Provided:
Light Microscope	Species identification, texture, color
Scanning Electron Microscope (SEM)	Surface texture, shape
Cathodoluminescence Microscope (CL)	Mineralogy and qualitative chemical composition
Microprobe	Quantitative composition, trace elements
Mass Spectrometry	Carbon and oxygen isotopic signatures

RESULTS

Example:
- Comparison within a genus: *Lenticulina*

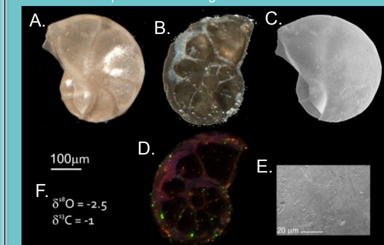


Fig. 2: *Lenticulina* of good preservation

A. Light microscope
B. Light microscope of cross section used for CL and microprobe analyses
C. SEM image
D. CL image
E. Detail of shell surface from SEM
F. Mass spectrometry readings (‰VPDB)

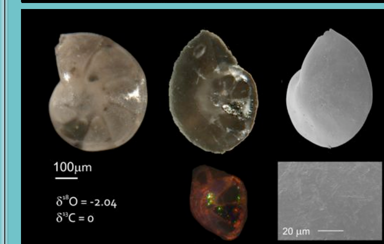


Fig. 3: *Lenticulina* of good to medium preservation

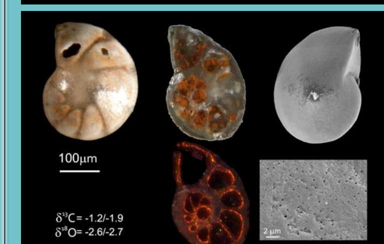


Fig. 4: *Lenticulina* of medium preservation

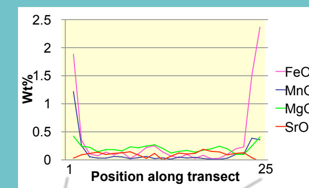
Fig. 5: *Lenticulina* of poor preservation

Trace Elements
- Fe and Mn are higher in cements than in original shell.
  - Fe and Mn are higher in poor specimens.
- The CL shows a bright orange rim around the poor shell (Fig. 5, 6), which suggests there is cementation of a different composition.
  - Mn is responsible for the bright luminescence.
- Strontium is higher in well preserved samples.
  - Possible replacement of Sr due to recrystallization

Isotopes
- $\delta^{18}O$ values are more negative with poorer preservation.
  - Original shell composition can be changed by pore waters during early diagenesis and by meteoric waters during late diagenesis.
- $\delta^{13}C$ values are also more negative with poorer preservation.
  - ^{12}C is released from remineralization of organic matter.

Texture
- The texture shows bumpy alterations, indicating shell recrystallization.

Microprobe analyses for *Lenticulina*:



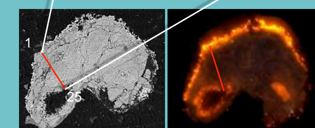


Fig. 6: Backscattered SEM image of *Lenticulina* in poor preservation and CL image with microprobe transect. Microprobe took 25 readings from location 1 to 25.

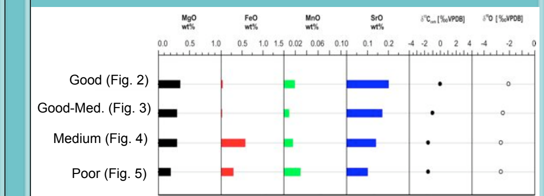


Fig. 7: Microprobe readings for *Lenticulina* of varying preservations

Further Analysis: "Vital Effects" Between Species

- Shell chemistry may differ between species due to different physiological requirements of the species. These vital effects were evident in the well-preserved samples.

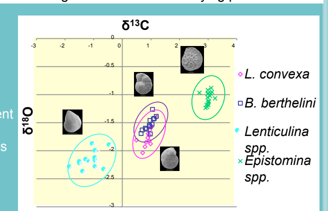


Fig. 8: Characteristic isotopic signatures for benthic species

CONCLUSIONS

- The processes that change the translucence of a specimen do not have a large effect on its stable isotopic composition- at least not outside the variability usually seen within a population.
- However, when cement is present, there is a clear shift in isotopic signatures. Specimens with cement should be avoided when choosing foraminifera samples to reconstruct environmental conditions.
- As evidenced by Fig. 8, reconstructing paleotemperatures from oxygen isotopes will depend on the species used.

Acknowledgments
Many thanks to Cristián Samper for supporting the NHRE program; to Elizabeth Cottrell, Gene Hunt, and Virginia Power for running the NHRE program; to NSF for funding TDP; to Ken MacLeod for conducting isotopic analyses; to Amelia Logan and Timothy Rose for CL and microprobe assistance; and to Carlos Rodriguez-Russo and Shannon Haynes for assistance in sample picking.