ESS 203 - Glaciers and Global Change

Wednesday February 17, 2021.

Outline for today
- Today's highlights on Friday – *Brendan Beaudette*
- Highlights from last Friday's class – *Lynn Nguyen*

Today
- Past climate from ocean sediments

Friday
- Glacier response to climate changes

ESS 203 - Glaciers and Global Change

Wednesday February 17, 2021.

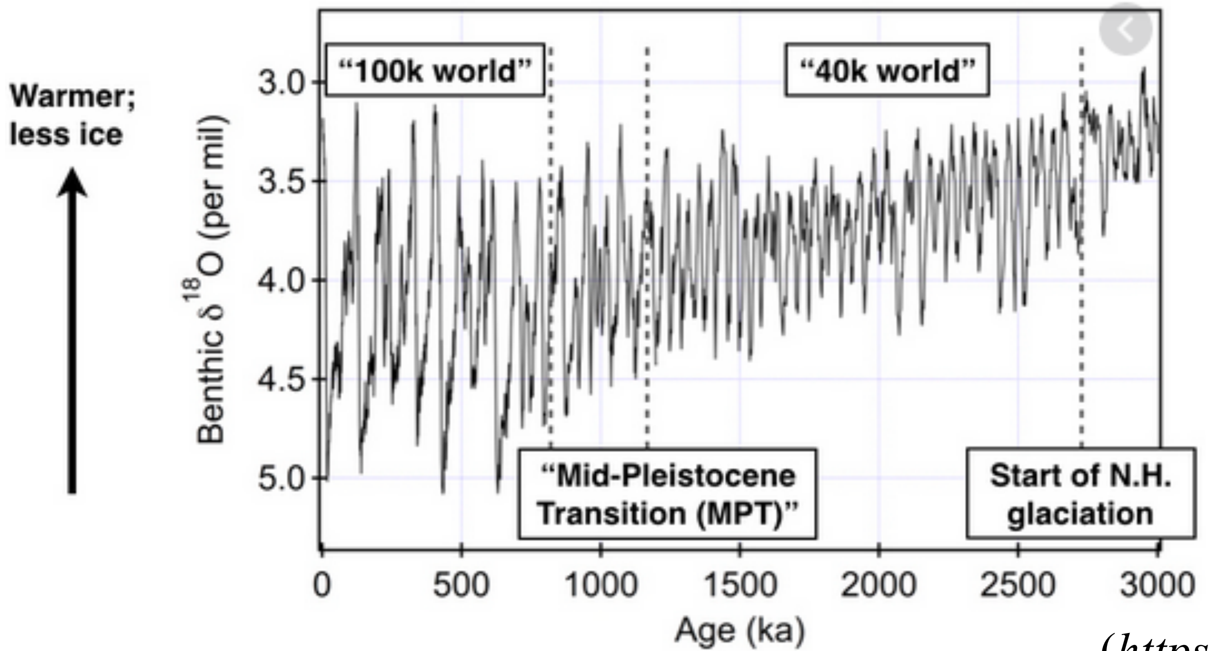
Today – Part 2

- Past climate from ocean sediments

Friday

- Glacier response to climate changes

HW 18 – The Mid-Pleistocene Transition (MPT)



(*https://www.yuzheny.com/mpt*)

Ocean-sediment cores show that prior to 1.2 Ma, the ice advanced and retreated roughly every 40 thousand years ("40k world"), but since 1.2 Ma (the Mid-Pleistocene Transition), the cycles changed to every 100,000 years ("100k world"). But ice cores don't go back to 1.2 Ma (yet). What was CO_2 doing?

- See assignment HW 18 on Canvas to address the MPT challenge.

What have we learned?

Ice cores tell us about temperature, precipitation, and atmosphere composition over the past 800,000 years.

- Some climate changes can be very fast.
- North and South see the same big picture of warming and cooling over tens of thousands of years.
- Patterns can differ over centuries and millennia.
- Greenhouse gases GHG change along with temperature.

But

- do GHG drive climate?
- do they respond to climate?
- or both? ✔

It's a complicated world.

Questions for Curious Scientists about the Pleistocene Epoch (the past 2.6 Ma)

What are your groups' current ideas?

- How do we know there was *more than one* past "glacial period" in the Pleistocene?
- How do we know *how many* former glacial periods there were in the Pleistocene?
- How do we know *when* these glacial periods took place?
- What *caused* these glacial periods?

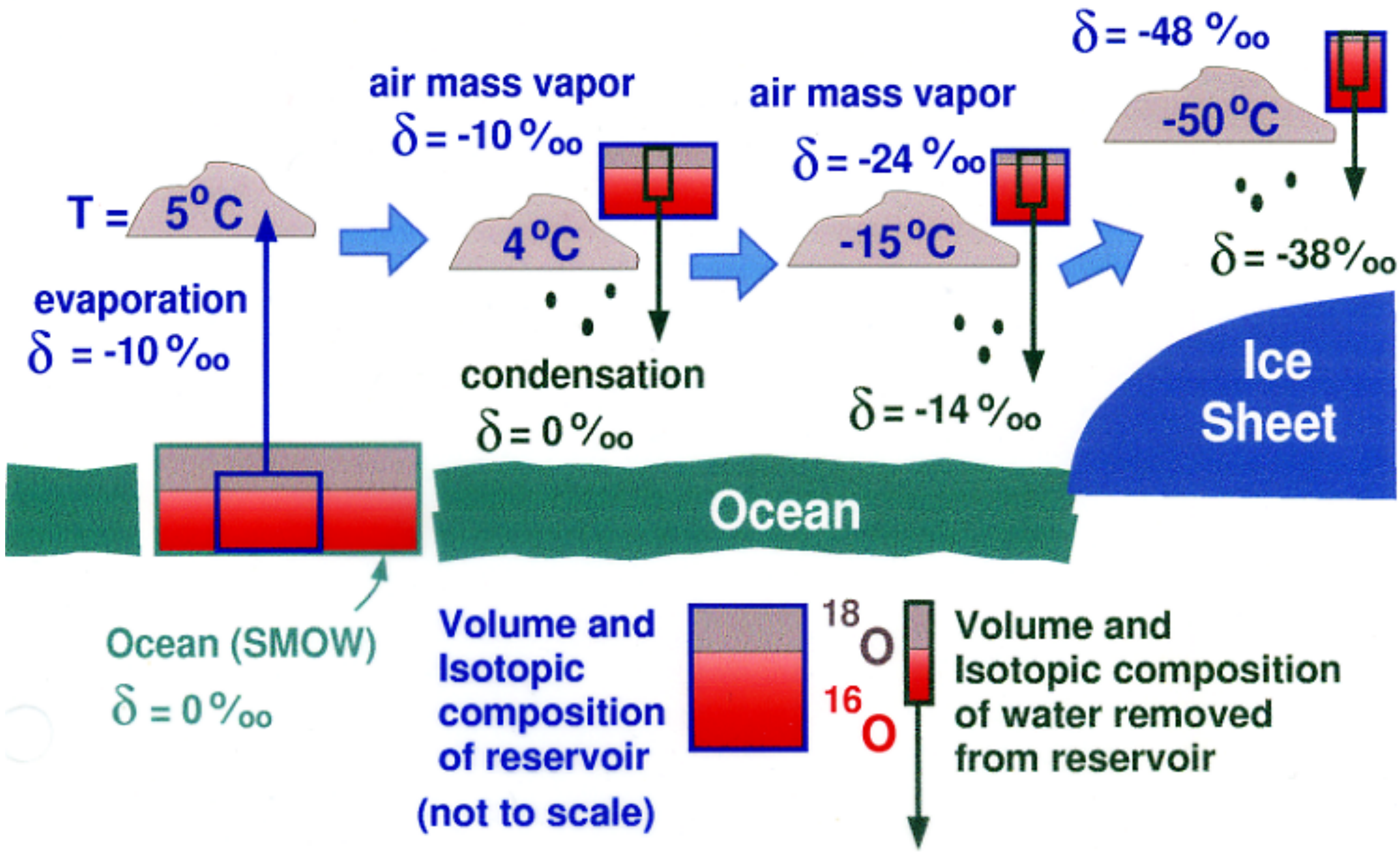
https://docs.google.com/document/d/1ULZS-t1D7sTdjdzUAnPXJdhTVcsJ_J1vwcoJfaCT-I4/edit

More Questions for Curious Scientists about the Pleistocene Epoch

- Why was it difficult to figure out how many glacial periods there had been, based on terrestrial ("land") records?
- Considering the answer to the above question, why would the sea floor be a good place to look for a better record?
- What does this "record" consist of and how would one get it?
- Why would it help to know some biology when studying the sea-floor record?

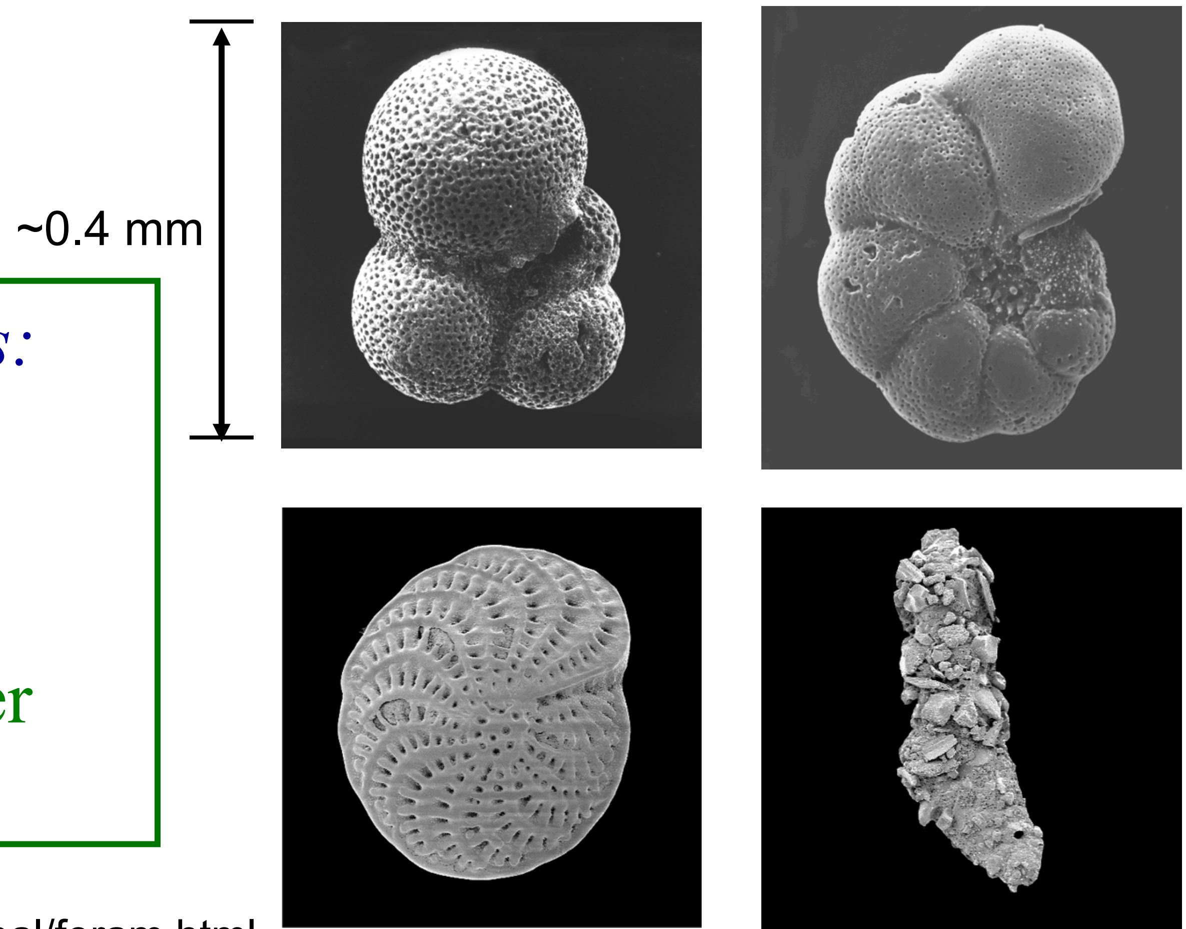
https://docs.google.com/document/d/1QPx4jPMG6gjBGteUqAIXZTskmPqA0j4KVIxhqGzdCxE/edit

In glacial periods, H_2O in big ice sheets was depleted in ^{18}O. Where was that "missing ^{18}O?



Foraminifera: “bugs” living in the oceans

Marine microorganisms, foraminifera (“forams”), make shells of limestone ($CaCO_3$) using water (H_2O), dissolved Calcium (Ca), and dissolved carbon dioxide (CO_2).



Planktonic forams:

- live in near-surface waters.

Benthic forams:

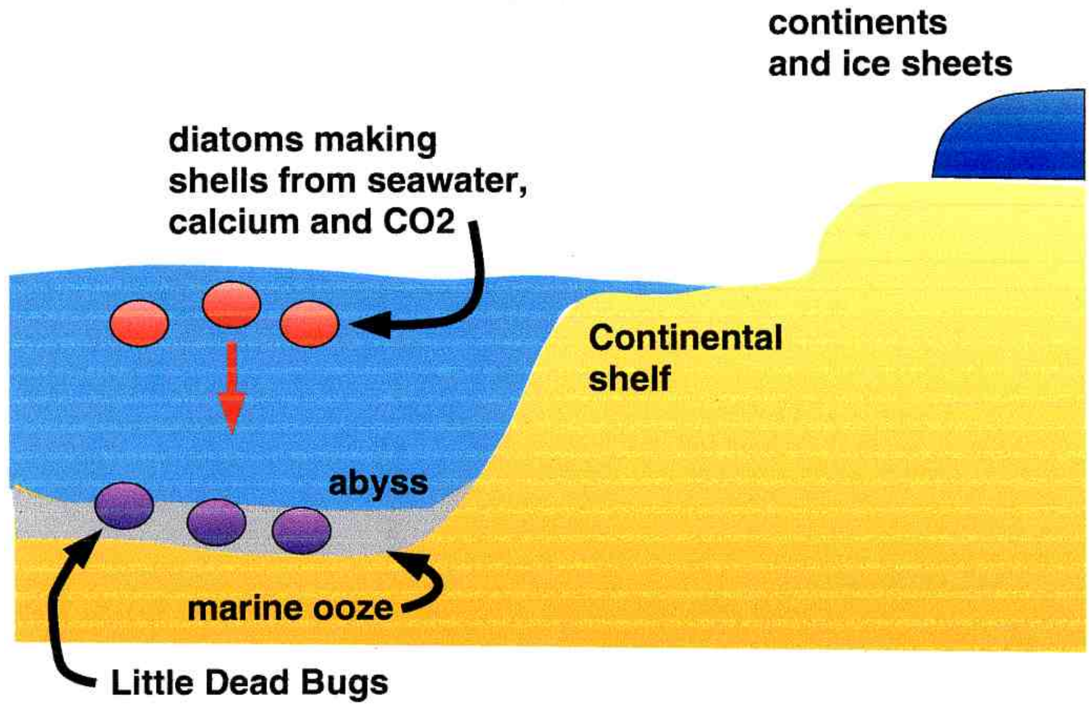
- live in “deep” water (<4000 m).

http://www.ucl.ac.uk/GeolSci/micropal/foram.html

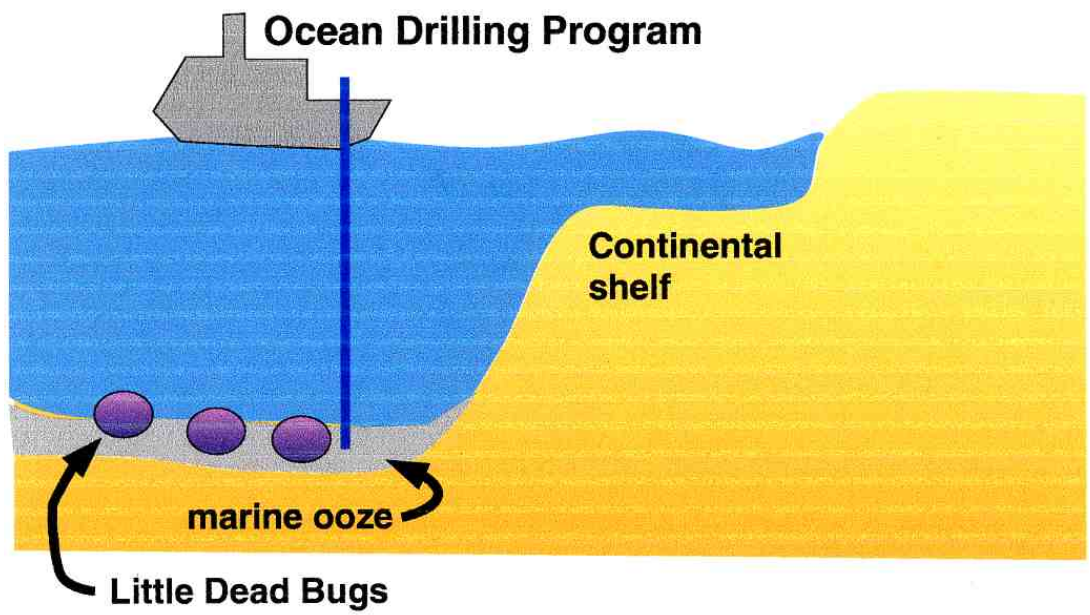
Sea-floor sediments

- Foram shells contain an isotopic record of the environment in which they live.
- O in ocean water H_2O is made up of ^{16}O and ^{18}O.
- When they die, forams sink to the ocean floor and their shells are preserved.
- Over time, layers of sediment pile up on top of one another.
- These layers of foram shells contain an environmental record of the ocean over time (much as layers in an ice core retain a memory of temperature in the clouds).
- But what, exactly, does ^{18}O in those shells record?

Forams and sea-floor records



How can we learn from them?



Interpreting $\delta^{18}O$ in foram shells

Biologists know that the relative uptake of ^{16}O and ^{18}O in forams depends on temperature of water in which they live.

- More ^{18}O is taken up when the water is colder.
- $\delta^{18}O$ in the shells could be a ***paleothermometer*** for seawater temperature.

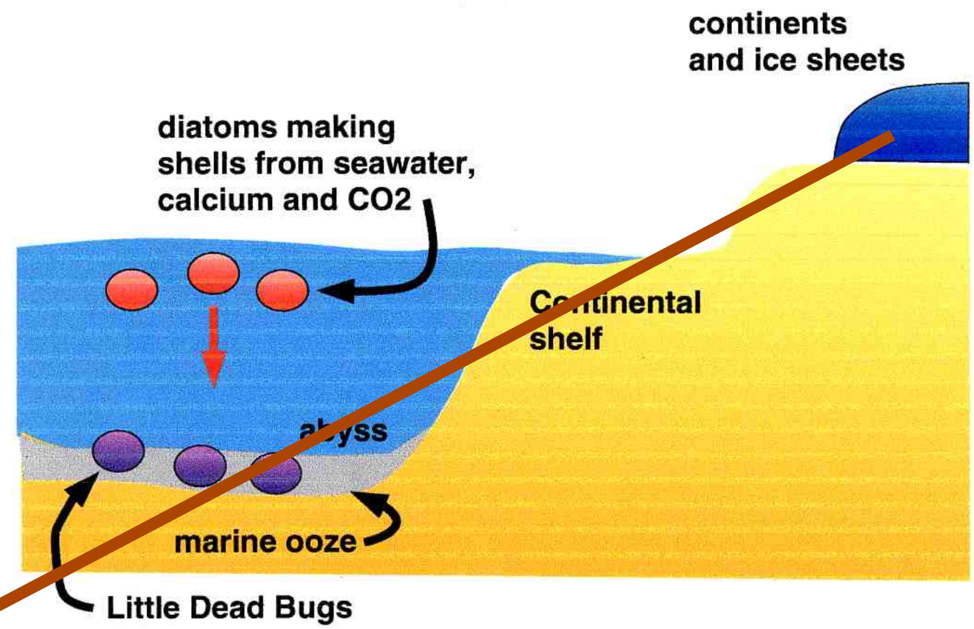
But the relative uptake of $^{18}O/^{16}O$ also depends ***even more strongly*** on the relative amounts of ^{18}O and ^{16}O ***in the seawater*** in which the forams lived.

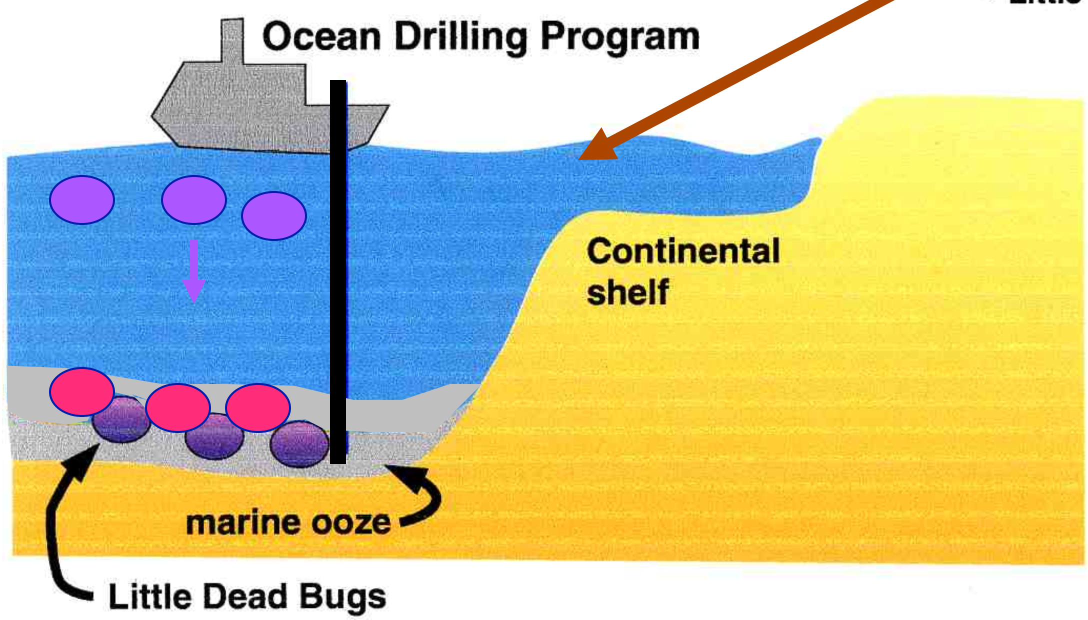
- More ^{18}O is taken up in the shells when the water has more ^{18}O in it. (***You are what you eat and drink***.)

Forams and sea-floor records

Glacial Period

- Ice sheets on land are depleted in ^{18}O.
- Remaining sea water must be enriched in ^{18}O.
- Sea-level is low.
- Forams live in ^{18}O-rich ocean.





Today

- Not so much ice on land.
- Sea-level is high again.
- Forams live in ocean that is now poorer in ^{18}O again.

A Dilemma

$\delta^{18}O$ in foram shells records -

- ➢ $^{18}O/^{16}O$ ratio of seawater in which they lived.
- ➢ Temperature of sea water in which they lived.

- When we measure $\delta^{18}O$ in foram shells, how do we know whether we are measuring past ***ice-sheet volume***, or past ***ocean temperature***?

With two types of forams we can get two types of information

In the deep ocean, temperature is always near $0^{o}C$

- Changes in the $^{18}O/^{16}O$ ratio in deep-water (benthic) forams should mostly reflect changes in the $^{18}O/^{16}O$ ratio of the seawater.
- So, measure these guys first.

Now, we know the change in the ratio $^{18}O/^{16}O$ in the seawater. And it was the same for everybody.

- Remove those sea-water isotopic changes from the record from shallow-water (planktonic) forams.
- The signal that's left tells us about changes in Sea-Surface Temperature (SST).

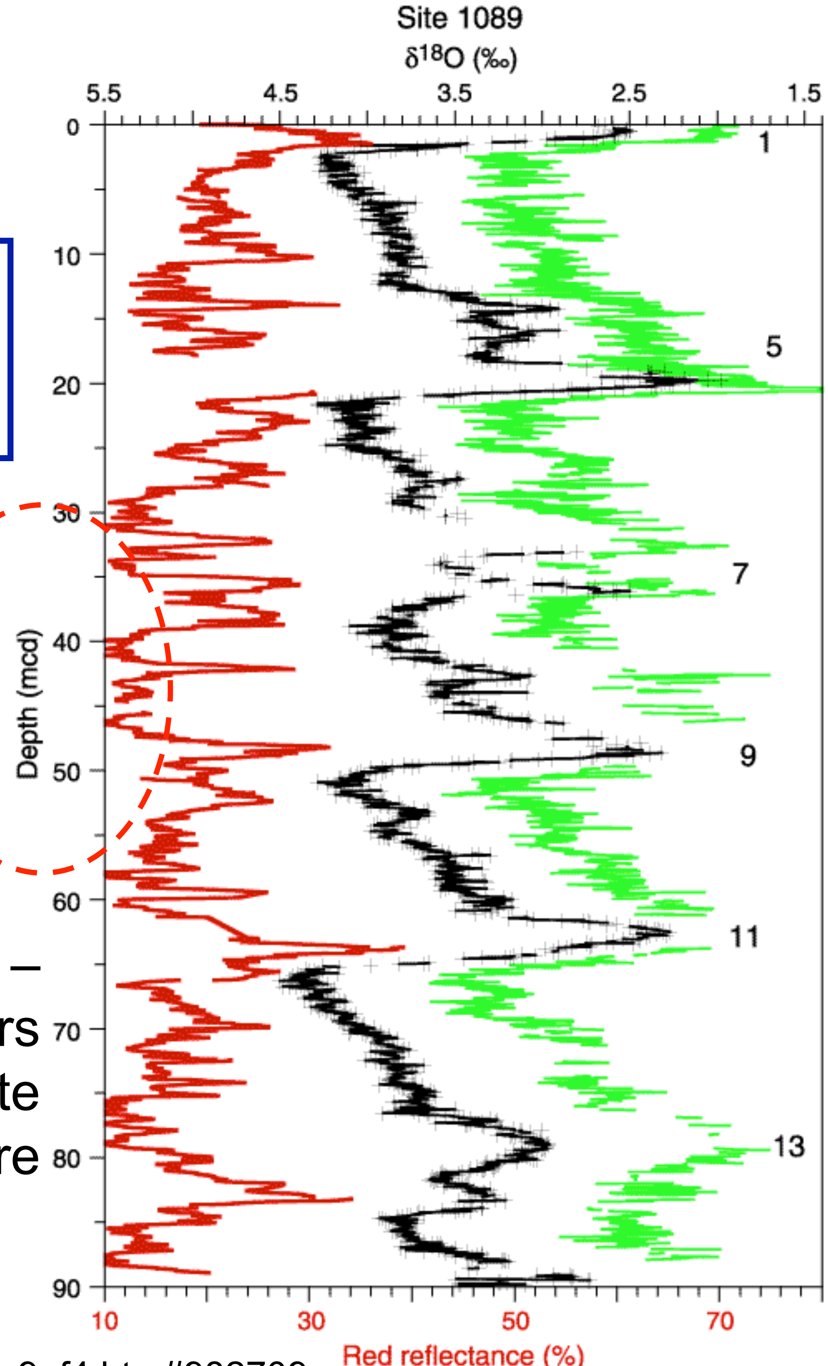
A δ^{18}O record from the sea floor

Benthic ———
Planktonic ———
Red – core % reflectance

Benthic and planktonic records are very similar.

- So the the major signal is ice volume on land.
- Temperature signal (in planktonic) is a subtle addition.

mcd – meters composite core



- High δ^{18}O ➞ large ice volume
- Low δ^{18}O ➞ Small ice volume

http://www-odp.tamu.edu/publications/177_SR/chap_09/c9_f4.htm#982709

Oxygen isotope record in deep-sea sediment

$$\delta^{18}O = \frac{R_{sample} - R_{standard}}{R_{standard}} \times 1000, \qquad R \equiv \left(\frac{^{18}O}{^{16}O}\right)$$

or,

$$\delta^{18}O = \left(\frac{R_{sample}}{R_{standard}} - 1\right) \times 1000$$

- $\delta^{18}O$ **more positive** => relatively **more ice** on land
- $\delta^{18}O$ **more negative** => relatively **less ice** on land

… δ shows changes are relative to the standard used, which is based on modern-day sea water … so relative to present-day ice volume.

But, how can we ***date*** the ocean sediments?
(There are no annual layers to count.)