Lab # 10: Climate reconstruction using Foraminifera in Deep Sea Sediments

Questions
How old are **deep sea sediments**? How are they sampled? How are deep sea sediments used to understand climate change? Can they be dated by relative and absolute age?

Exercise Overview
In this exercise, students will understand how deep sea sediments are collected, and analyzed to identify different **foraminifera** species in order to interpret global **paleo temperature** change. Deep sea sediments are collected in every part of the ocean and analyzed for a number of different parameters. One of those parameters is the analysis for foraminifera, or forams for short, which are single-celled protists with shells. The shells are called tests. Adult formas range in size from ~100 microns to ~20 centimeters in length. The largest living species have a symbiotic relationship with algae, which they "farm" inside their shells. Other species eat foods ranging from dissolved organic molecules, bacteria, diatoms and other single celled phytoplankton, to small animals such as copepods. They move and catch their food with a network of thin extensions of the cytoplasm called reticulopodia, similar to the pseudopodia of an amoeba, although much more numerous and thinner. http://www.ucmp.berkeley.edu/foram/foramintro.html
Forams live in every ocean and are almost always part of the material included in deep sea sediment cores. Different individual species of forams have been used to indicate a number of things but more importantly they indicate ocean temperature. The most important are Neogloboquadrina pachyderma (Figure 4 and 5) and Elphidium excavatum (Figure 6). The Neogloboquadrina pachyderma are unique in that their tests coil to the left or right depending on ocean temperature Left handed coiling tests favor colder water and right handed coiling tests favor warmer water. The coiling direction is difficult to distinguish, even for experts. The Elphidium excavatum also favor colder water and grow larger in colder water. Thus the deep sea sediments can be analyzed for forams which indicate relative changes in ocean temperature. Ocean water changes temperature as the atmosphere changes though at a slower pace.

National Science Education Standards
Life Science

Population sand ecosystems
Regulation and Behavior
The interdependence of organisms

Earth Science

Energy in the Earth system
Earth's history

Purpose

1. To use foraminifera (pasta-seeds) contained in deep sea sediments to determine the relative temperature of Earth during the past.
2. Students will also practice relative and absolute dating techniques.

Materials

Per each student (or student group)

pasta- 1 box of tiny shells, 1 box of medium shells, 1 box , 1 box, 1 box elbows.

1. 4"diameter X 36" long poster tube (substitute PVC tube) per 2 groups of students (already cut the long way in half and taped back together).
3. Sand or dirt as sediment to add character.
4. 5 small buckets or bowls.
5. Tweezers or chop sticks to be used as sediment dissecting instruments.
6. Two types of opposite twilling pasta (Fusilli #29 coil left and Artigiano Pasaio coil right), lentils, split peas, sesame seeds.

Time Frame

This exercise should be set-up the night before class. Set-up takes 30 minutes. Class time takes at least one 45 min class period and can then extended a second day to completely analyze all the data.

Teaching Sequence

Engagement and Explanation

Part1: Set-up

1. Cut the tube in half the long way (Figure 1 and 2).

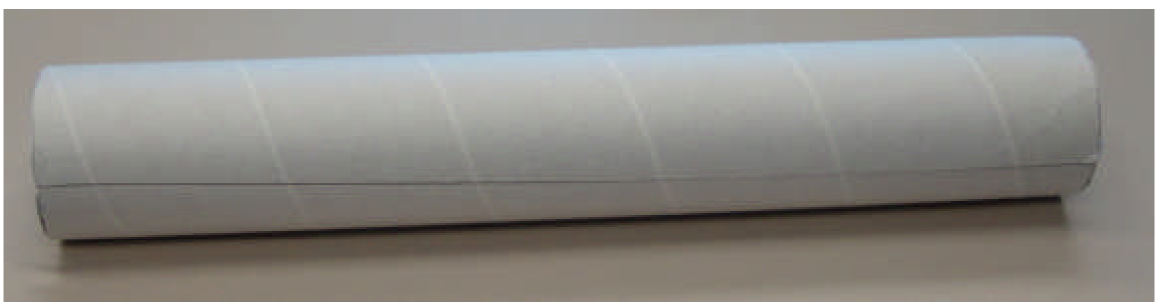


Figure 1: Poster tube.

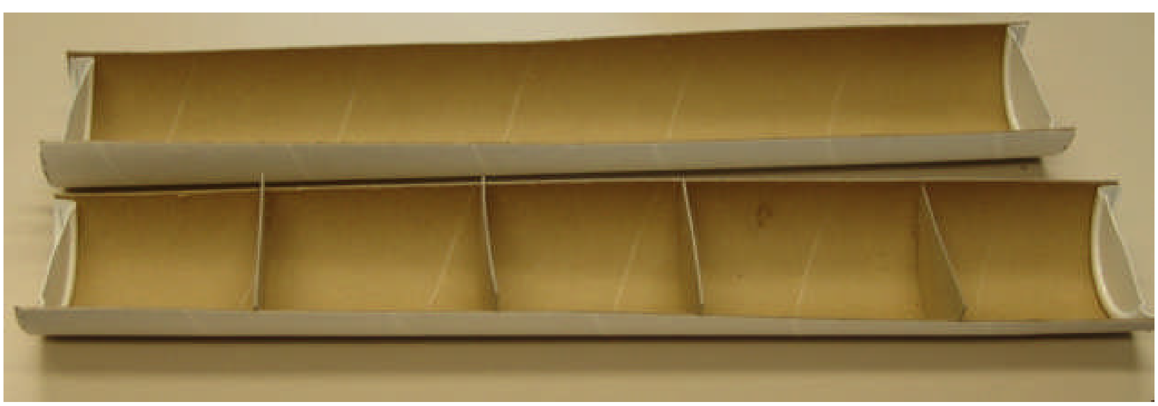


Figure 2: Poster tube cut in half.

2. Cover the bottoms of all the poster tubes with end caps or tape and a piece of

paper. End caps can be added with tape and/or staples (see figure 2).

3. Cut four cardboard dividers to divide the tube into five sections (Figure 2).
4. Mix the sand/dirt in each of five buckets and add differing amounts of each of the five pasta types to each bucket and mix together. Figure 4. Hint: Teachers can stack the results to be closer to the actual scientific by placing more left coiling pasta and a higher percentage of peas to sesame seeds in the same buckets.
   Place the dividers into the tube approximately each fifth section and then fill each section with the mixture from a bucket, repeat with each mixture until each tube is filled with all five mixtures in order. The order of mixtures in each section does not matter but should be the same for each tube (Figure 3).

Figure3: Differing amounts of each pasta/beans/seeds to be mixed in with dirt/sand and used to fill each divided space of the poster tube.

Once tube halves are filled with dirt/pasta mixture the dividers can be removed.

Each half of the tube can be covered with plexiglass or plastic wrap and the tube reassembled. On discover day with the students the tube can be cut-open and it will seem more realistic as an actual core being extracted and cut in half for examination.

Part 2: In class day 1 - day 2

1. Place each tube down on a table and separate the halves so that each group will have one half of a tube. Each group should then mark the top of their tube so that they know which end is up, oldest (deepest) to youngest (surface) (Figure1).
2. Each group should sketch the tube and any visible layers and formas (pasta/seeds/beans) in their journals/student sheet below (quantify all observations). They should also measure the length and position of each layer foram, record in journal.
3. One section at one time, starting at the bottom, should be carefully extracted from the tube and excavated to find all the forams in that section (Figure 3). Record all observations, measurements, foram counts. Foram identification can are as follows:

Left coiling pasta (cold water) - Neogloboquadrina pachyderma
Right coiling pasta (warm water) - Neogloboquadrina pachyderma
Split peas - large Elphidium excavatum
Lentils - medium Elphidium excavatum
Sesame seeds small Elphidium excavatum
Growth due to cold nutrient rich conditions

4. Continue until the entire core is analyzed.
5. Record, and calculate the proportions of each foram types, then graph on student sheet.
6. Use the foram id pictures to make conclusions about the relative temperature of the sea water when each layer was formed.
7. Use each “layer” of sediment to determine the relative age of each layer. Students can also assume that each layer represents 500 year of time and use the relative position of each forma in the column to interpret temperature change within each layer.
8. Absolute age dating of the sediments is done by a number of techniques. One of them being radioactive dating. Teachers can add radiodated “makers” (a stone or any other small object) within the layers of each student’s sediment columns to use as a date reference. The dates of these reference markers can be any date back to 1 million years such as 100,000 years before present. The rest of the layers in that student’s column would then be dated relative to the reference date. If each sediment layer is 500 years of time, then the dates of their layers would be plus or minus 500 years to that reference date.

Extention – teachers can add a reference date to each group of students sediment columns that are separated by 3,000 years in age. Then, when each student group draws the temperature graph for their sediment column they will piece together the relative and absolute dates for all the sediment columns in the class. Thus, each class will have analyzed a portion of a sediment column from the present back to 3,000X years before the present (X = number of groups in class).

For example – student group #1 has a sediment columns that has a radio reference date at 3,000 years, student group #2 has a reference date at 6,000 years before presnt (ybp), etc. When pieces together the class will have an incomplete but continuous picture of the temperature , as indicated by the forams,

Exchange

Students should share/compare their data with the rest of the class and discuss whether a good conclusion can be drawn from each analysis or if the total data of the class needs to be combined and analyzed to draw a better conclusion.

Evaluation-questions

1. How do the size and shape of forams vary with temperature?
2. How do the proportions of each species of foram differ with temperature change?
3. How can the forams be used to interpret temperature change over time?
4. How did temperature change in the location your deep sea sediment core was taken?
5. How does the temperature change in your location compare with the group that got the other half of your core?
6. How does temperature change compare with your classmates?
7. How does the percent of E. excavatum differ between time periods?
8. Would you ever expect to not have one size of E. excavatum?
9. How does the number of E. excavatum compare to each of the N. pachyderma, left and right twisting?
10. Can you draw and conclusions about how the E. excavatum and N. pachyderma indicate temperature/temperature change?

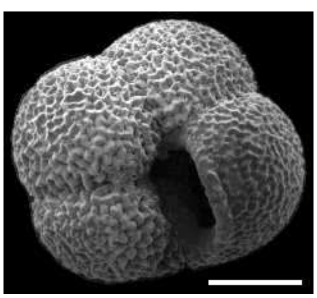


Figure 4: Neogloboquadrina pachyderma (N. pachyderma) (Ehrenberg 1894)
Left-coiled specimen, umbilical view, scale bar 0.1 mm

Collected: Aug. 1991, RV Dalnie Zelentsy, Franz Josef Land sounds, 150 mwd, modern deposits

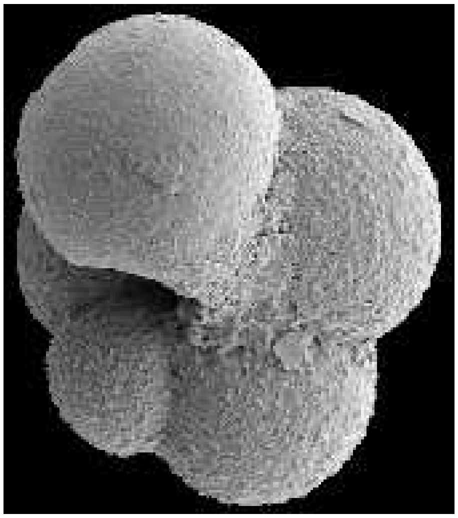
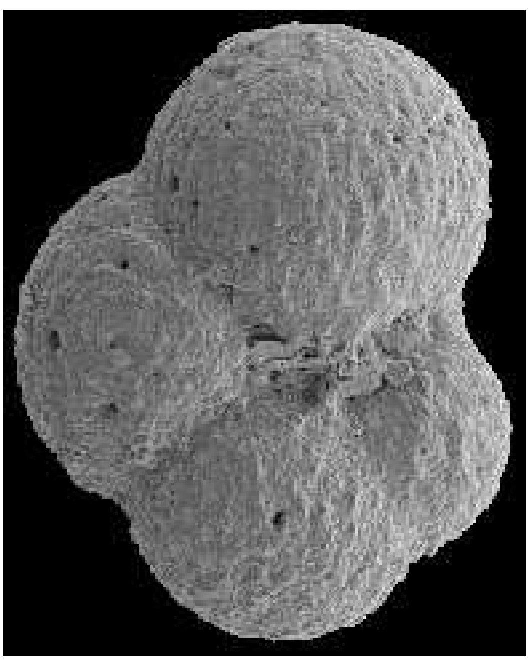


Figure 5: Neogloboquadrina pachyderma (N. pachyderma) (Ehrenberg 1894)

Right-coiled (Dextral) specimen, umbilical view

Collected: summer1992 U.S.G.S. cruise, Arctic continental slope off Alaska (Chukchi Borderland, 75∫ 44.65íN, 160∫ 55.73í W), 2103mwd, modern hemipelagic mud

The most abundant planktonic foraminifer of high latitudes; as any planktonic foraminifer, avoids low-salinity and shallow waters. The left-coiled morphotype prevails at lowest temperatures and occurs throughout the Arctic Ocean. On the Barents-Kara shelf, tests of N.pachyderma are abundant mostly in sediments underlying Atlantic-derived waters, that is, in troughs 300-600 mwd extending from the continental margin to the shelf interior.



Side view, scale bar 0.1 mm

Figure 6: Elphidium excavatum (Terquem) clavatum (E. excavatum) Cushman 1930

Collected: summer 1991, RV Akademik Karpinski, SW Kara Sea, 72mwd

Remarks: A most abundant calcareous foraminifer in cold-water areas (temperatures below 2^{o}C) on the Arctic shelves; inhabits all sediment types; has a complex pattern of distribution; often dominates foraminiferal assemblages in extreme environments, such as low salinities, turbid waters, and low food supply, including sites proximal to tidewater glaciers. Morphology varies, possibly because of complex ecology, which has promted the discrimination of several species by some authors (Gudina & Levtchuk 1989). E.e.clavatum tests are found in the deep Arctic Ocean, where they are believed to be redeposited from shelves.
http://www-bprc.mps.ohio-state.edu/foram/species/neogloboquadrina_pach.htm

References

http://www-bprc.mps.ohio-state.edu/foram/species/neogloboquadrina_pach.htm
http://www.ucmp.berkeley.edu/foram/foramintro.html

Also see the quick-time movie of deep sea sediment analysis by Dr. Jerry McManus at Woods Hole Oceanographic Institute.

Bibliography

Deep Sea Sediment – Sediments collected, using by a drilling ship, in the deep oceans. These sediments contain a geologic record of material deposited through the past.

Foraminifera- Zooplankton that live in the ocean. Different species of foraminifera thrive at different water temperatures.

Paleo temperature- Temperature of ancient environments some time before the present.

Years before present (ybp) – a method of dating geologically that starts with the present time and counts backward in to time.

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Student Sheet

Observations

Procedure

Data

Sketch of visible forams in sediments before extracting

Deep Sea Sediment Core

	Oldest ⟵ Section 1	Section 2	Section 3	Section 4	⟶ Youngest Section 5
N. pachyderma (left)					
N. pachyderma (right)					
E. excavatum (largest)					
E. excavatum (medium)					
E. excavatum (smallest)					

Data Chart : Numbers of each foram species.

Graph of relative temperature as concluded by foram count

Warm

Average

Cold

Oldest (deepest) Youngest (shallowest)

Sketches of Forams

Neogloboquadrina pachyderma
(left coiling)

Neogloboquadrina pachyderma
(right coiling)

Elphidium excavatum (Terquem) clavatum