Regional Class Research Vessel

Oregon State University

Taking the Temperature of Ancient Oceans

Timeframe
60 minutes

Target Audience
Grades 3rd- 6th

Suggested Materials
- 4 small plastic containers (such as a bowl)
- Pebbles
- Marbles (4 different colors, at least a dozen marbles per color): pink, red, light blue, and dark blue preferred
- Poster board
- Cut outs (provided)
  - Mg/Ca meter (Axis)
  - Temperature meter (Axis)
  - Year labels
- Hand Outs (provided)
  - Ice extent on Earth (Reconstruction site)
  - Foraminifera 3d print (optional)
- Powerpoint (optional)
  - Taking the Temperature of Ancient Oceans PPT

Contact:
SMILE Program
smileprogram@oregonstate.edu
http://smile.oregonstate.edu/

Description

In this lesson students will reconstruct Ancient Ocean temperature using Foraminifera fossils, Mg/Ca ratios, and temperature to graph ocean temperature change over time. Students are prompted to make the connection that increases in the Mg/Ca ratio in the fossils indicate increased ocean temperatures over time. There is a positive relationship between the two variables (e.g. Mg/Ca ratio and temperature). Based on the activity and students own graph, they are then prompted to make predictions about other time periods using their Mg/Ca ratios during the wrap-up.

Outcomes

Students will learn that ocean temperature changes affect the composition foram shells (e.g. fossils), and that scientists measure those changes to infer ancient ocean temperatures.

Students will use this fossil evidence to reconstruct a model of ancient ocean temperatures of a particular research site.

Students will engage in graphing, creating a mode, making predictions, and argument from evidence as they reconstruct ancient ocean temperatures and make predictions based on their findings.

Guiding Questions

What are foraminifera and how do researchers use them to reconstruct ancient ocean temperatures?

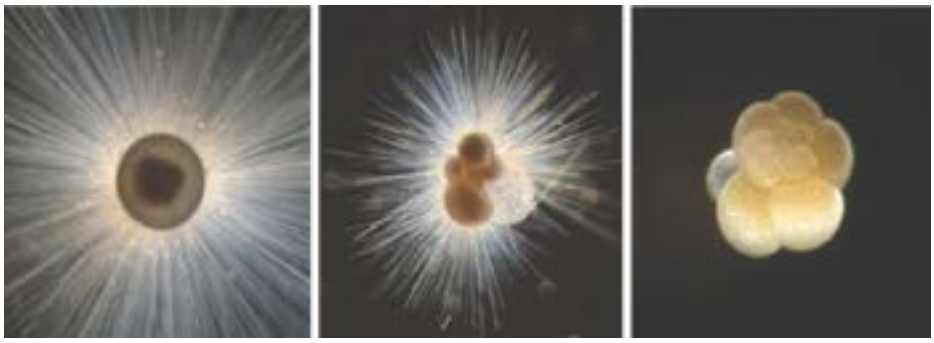
Lesson Introduction

In this lesson students will learn about single-celled plankton called Foraminifera, and how temperature is "recorded" in their shell. Students will pass around 3D printed models of Foraminifera provided by the SMILE Program and the College of Earth, Ocean, and Atmospheric Sciences. Students will learn how researchers obtain fossil Foraminifera using research vessels and equipment (e.g. JOIDES Resolution).

Background Information

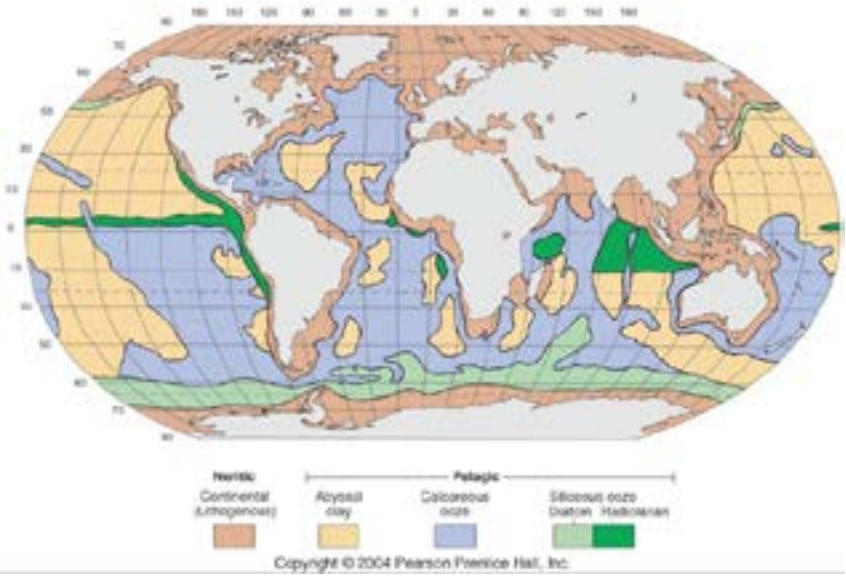
What are Foraminifera?
"Forams" are single-celled plankton that build sand-grain-sized calcite shells. There are ~40 species that live in the open ocean. They are about the size of a period on a piece of paper.

Example species and their habitat



Orbulina universa	Globigerinella calida	Neogloboquadrina dutertrei
Habitat: Tropics to sutropics	Habitat: Tropics to subtropics	Habitat: Tropics to sub-polar
Depth range: 0-90 meters (0-200 feet)	Depth range: 40-90 meters (~ 130-200 feet)	Depth range: 30-150 meters (~65-500 feet)

Where do Foraminifera Live?
Forams live in the shallow depths of the oceans, from the surface to ~500m, though some species can be found much deeper. When they die, their calcite shells fall to the ocean floor and accumulate in sediments.



Forams are best preserved in the calcareous (calcite rich) ooze (purple regions).

Next Generation Science Standards

PERFORMANCE EXPECTATIONS:

3-LS4-1. Analyze and interpret data from fossils to provide evidence of the organisms and the environments in which they lived long ago.

3-LS4-4. Make a claim about the merit of a solution to a problem caused when the environment changes and the types of plants and animals that live there may change.

MS-LS4-1. Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past.

MS-LS4-2. Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships.

How do Foraminifera Record Temperature?
The composition of their calcite shells depend on environmental conditions (such as temperature or pH) when they grow. Though their calcite shells are composed primarily of the elements calcium (Ca), carbon (C), and oxygen (O), trace amounts of other elements are incorporated into the calcite when they grow and the amount of the trace element incorporated depends on growth conditions.

Temperature is recorded in their shells by the amount of the magnesium (Mg) present. The amount of magnesium incorporated into their calcite shell depends on the temperature of the ocean when they grow. When ocean temperatures are warm, the shells contain more Mg. When ocean temperatures are cold, the shells contain less Mg. Scientists measure the amount of Mg relative to calcium in fossil foraminifera shells and can estimate the temperature at which they grew. The science of reconstructing past temperatures on Earth is called *Paleothermometry*.

How do Researchers Obtain Fossil Foraminifera?
Seafloor sediments are obtained using scientific drilling ships like the JOIDES Resolution. Several thousand sediment cores have been collected from the ocean floors. The sediment cores range in length from under 1 meter to 10's of meters.

The JOIDES Resolution is a scientific drilling ship operated by the International Ocean Discovery Program.

The corer is attached to the ship using a steel cable. The corer is driven into the sea floor by heavy weights or a hydraulic piston. Sediments, including foraminifera, accumulate on the sea floor. Depending on the location, sediment accumulates slowly at rate of ~.1 to 5cm per 1000 years. A hollow steel tube is pushed into the sea floor and fills with sediment. The sediment layers remain intact.

Corer attached to research ships that brings sediment cores (including Foraminifera) to the surface

Sediment cores are processed on the ship and small sediment samples are taken by scientists for later processing and analysis. Forams are obtained after sediment is processed. They are handpicked from the sediment using a thin paint brush.

This image shows the cross-section of cores drilled in the Mediterranean Sea.
Image sources: IODP

Getting Students Started

Activity Set Up

Create 1-2 stations depending on the size of your class. The interactive station should include 4 time labels (provided): 5,000 years ago, 10,000 years ago, 15,000 years ago, and 20,000 years ago. Each time label should be accompanied with a container of pebbles.

In each individual container of pebbles, add 1 color of marbles. Each container should have 1 single color. Add light pink marbles to the container labeled 5,000 years ago, red to the container labeled 10,000 years ago, light blue to the 15,000 years ago container, and dark blue to the 20,000 years ago container.

On a white board, or poster, draw a graph. Label the graph "Taking the

Temperature of Ancient Oceans." Label the X axis "Time." On the time axis, label intervals (from left to right): 20,000 YBP, 15,000 YBP, 5,000 YBP and Today. Label the Y axis "Degrees (F)", with intervals (from bottom to top) of 2 degrees starting at 70 and ending at 80 i.e. 70, 72, 74, 78 and 80. To the left of the graph add the Temperature Meter (provided). The temperature meter should correspond to the colors of the Foraminifera shells, if you used different color marbles in this activity, you will need to adjust the hues of the temperature meter.

Activity Introduction

Share the "Taking the Temperature of Ancient Oceans" PPT or the 'Background Information' above.

Ask Students how they think researchers and scientists are able to know what temperature the Earth was thousands of years ago? Tell them that they will have the opportunity to be Paleothermometrists by reconstructing the past temperatures of Earth!

Explain what Paleothermometry is to your students and that they will be creating a graph that shows the temperature recorded in Foraminifera shells, and how temperature has changed over time! Inform students of Foraminifera and how they 'record' temperature in their shells.

Activity

1. Introduce ways that science studies changes in temperature over time using the Ice Coring and Tree Ring videos in the PowerPoint. Ask students if they know of any other ways scientists reconstruct ancient temperatures on Earth? (Optional Step to supplement the PowerPoint)
2. Play the video link about Foraminifera in the PowerPoint and pass-out the 3D Foram shells (Optional Step to supplement the PowerPoint)
3. After introducing Foraminifera, what they are, where they live, how

they record temperature, and how researchers obtain their fossils; have students look at the empty graph "Taking the Temperature of Ancient Oceans."

4. Ask students to make predictions on how they think the graph should look based on their prior knowledge.
5. Show students "Ice Extent on Earth" Handout (provided). Ask students why they think there is less ice on Earth today than there was in the past. Ask the student if there was more ice 20,000 years ago, does that mean it was hotter or colder than it is today?
6. As a class, in two large groups, or as individuals, have students graph the marbles (Foraminifera shells) onto the poster board.
7. Ask students to make predictions on what future temperatures will look like and how Foraminifera might help Paleothermometry in the future.

Wrap-up

1. Have students hold the cards with the Mg/Ca ratios on them, and have the class try to line them up based on their findings (e.g. oldest with the lowest Mg/Ca ratio to the most recent with the highest Mg/Ca ratio) by "voting" on if they think the card is in the right place. The goal is to show how ocean temperature at the reconstruction site has changed, and to prompt students to make connection between Mg/Ca, Year, and the information from their graph.
2. Once the students are lined up and the class agrees they are in the right order, have the students with the cards switch them to show students the year. Now, students can check the findings with their graph (e.g. model) to see if they were correct.
3. Let students know that ocean temperatures are still warming, and based on that information what do they expect the Mg/Ca ratio to be in the near future (e.g. higher than the most recent year with data).
4. Use the wrap-up opportunity to allow for questions, and group discussion! Push student's thinking further by asking potential causes and solutions to the decreasing ice on Earth/increasing temperatures. Are there other species or indicators that can help with Paleothermometry?

Extension/Scaffolding

For more advanced students, challenge them to use the Mg/Ca ratio to graph and calculate temperature. You can also make the graph with 2 Y-Axis (1 for Temperature and 1 for the Mg/Ca ratio). When using two graphs, students can see the positive linear relationship between the Mg/Ca ratio and Temperature. Note, when ocean temperatures are warm, the shells contain more Mg. When ocean temperatures are cold, the shells contain less Mg. For every 1 degree C (1.8 degrees F) increase in temperature, the Mg/Ca ratio increases by approximately 10%. This is an excellent way to introduce graphing, positive relationships, and

variables to young students.

Older students can also compute temperature based on the Mg/Ca ratio using a simple formula. This can show the process by which scientists compute the temperature. This shows students that the entire process goes from taking core samples, to analyzing the shells, and then to converting the Mg/Ca ratio to temperature. This conversation requires using natural logs to solve, but can easily be done using a calculator to get temperaure in Celcius.

The equation is **Mg/Ca = 0.25 exp (0.10*T°C)**

This project is supported by the Regional Class Research Vessel Program in the College of Earth, Ocean, and Atmospheric Sciences at Oregon State University.

References:

This lesson is based off of the work of Jennifer Fehrenbacher, a professor of Tracer Oceanography in the College of Earth, Ocean, and Atmospheric Sciences at Oregon State University in partnership with the Oregon Museum of Science and Industry.

Bio:

https://www.youtube.com/watch?v=LeDXrg6mXaY

Blog:

http://jenniferfehrenbacher.weebly.com/

Resources:

Background Information on Forams

http://joidesresolution.org/sites/default/files/Mohawk%20Additional%20Background_0.pdf

JODIES Resolution Outreach Page (activities, ship tracker, videos, etc.)

https://joidesresolution.org/

Video Links:

Tree Rings

https://www.cbsnews.com/news/researchers-mapping-climate-change-through-tree-rings/

Ice Cores

https://www.youtube.com/watch?v=teoxnHkcULA

Foraminifera

https://www.youtube.com/watch?v=JLSa8cGJixQ