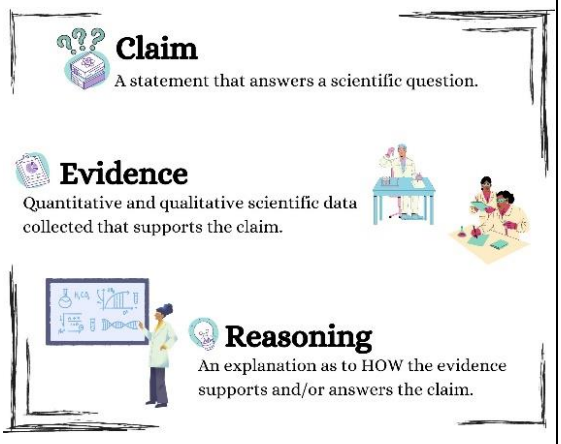
ESS Lesson - Climate Analysis Using Planktonic Foraminifera

Original Version – developed by Dr. Hilary Clement Olson

Standards:	**TEKS** (1) A, D, E, F (4) A-C (2) A-C (7) B, E, F (3) A-C (11) E	**NGSS** HS-ESS2-2 HS-LS2-2 HS-ESS2-7 HS-LS2-6 HS-ESS2-4 HS-ESS3-5
Level:	The original activity was developed for 7th-8th grade students, but this lesson was created for an ESS course in high school. The lesson easily be adapted for elementary level classes.	
Objective:	The focus of this lesson is to integrate data analysis as part of teaching Geologic History and understanding how scientists determine historical atmospheric conditions. Data-driven activities can help students enhance their critical thinking and problem-solving skills as they analyze the data sets to draw conclusions. In ESS courses, many of the standards contain content that is data-driven and lessons can be easily designed to focus on analysis and synthesizing explanations and conclusions. These lessons are formally known as CER (Claim, Evidence, Reasoning) lessons. This lesson focuses on using fossil data to understand how scientists collect information about ancient climate conditions and use this information to predict future trends and changes in Earth's climate. Students are given a set of scientific data that they must analyze to calculate percentages. These percentages are plotted to track ocean temperature changes over 160,000 years. At the beginning of the lesson, you can ask your students as to what they think is the "cause" and what is the "effect" in this scientific problem. The fact that our planet's climate has changed drastically throughout geologic time will be emphasized. Students should recognize that the climate will continue to change and these changes can be tracked in many different ways. As we improve technology and develop new approaches to collect data, scientists can better understand these changes in an effort to predict future trends.	
Time Requirements:	Two Block Periods (1.5hrs/class period)	4 Class Periods (50-55min/class period)
Teacher Preparation:	This lesson can be conducted as a CER lesson. Students are learning how fossils can be a source of indirect data related to historic atmospheric conditions to better understand how Earth's climate changes over time. This fossil evidence corroborates data obtained from ice cores, rock samples, and other sources of data. Foraminifera fossils can also be used to locate potential hydrocarbon (oil and natural gas) reserves. **CER example for this lesson.** **CLAIM** – Earth's climate consistently changes over thousands of years. **EVIDENCE** – Planktonic foraminifera fossils providence evidence that ocean temperatures change over time. **REASONING** – Planktonic foraminifera form their shells in a specific direction (right or left) based on the temperature of the ocean water. Calculating the ratio of right-coiling vs left-coiling can provide an average temperature of the ocean for a specific time period. Graphing the data for the % of right-coiling fossils for each time period can show the rate of change over thousands of years.	

Important vocabulary and concepts addressed in this lesson:

a. Distinguish between ***climate*** and ***weather***.
b. Identify mechanisms which influence climate – 2 most important are solar radiation and atmospheric composition.
c. Atmospheric data collected to track weather and climate changes over time – temperature, precipitation, wind speed and direction, humidity, and air pressure.
d. Definition and description of the ***Greenhouse Effect*** and identify the four major greenhouse gases (GHG's) – carbon dioxide (CO_2), water vapor, methane (CH_4), nitrous oxide (N_2O).
e. Explanation as to why CO_2 has the biggest influence on climate and why CO_2 levels have been exponentially increasing the past 100 years.
f. Definition of ***proxy*** and why climate proxies are valuable to climate scientists.
g. What ***foraminifera*** are, where they live, and their significance to the fossil record and studying paleoclimate.
    i. Since some foraminifera are ***planktonic*** and live in at the surface of the ocean, their fossils can be a proxy for documenting climate temperatures

The lesson is set up in a 5E format. Below guiding information is outlined to help prepare each portion of the 5E lesson. Each section provides background information and strategy for conducting each activity with students.

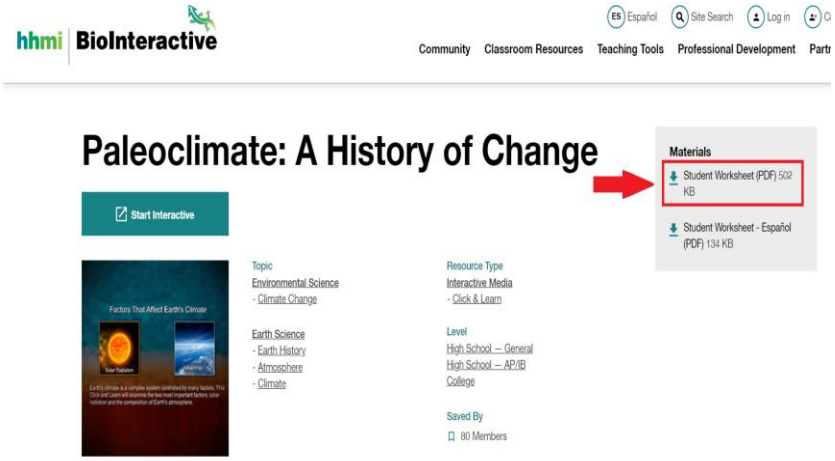
Lesson Sequence:

ENGAGE: The engage activity will give students an introduction to planktonic foraminifera. Students should have an understanding of planktonic foraminifera prior to analyzing the fossil evidence. Planktonic foraminifera are free-floating organisms that reside in the open ocean and make an exoskeleton made of calcium carbonate. Planktonic foraminifera have large populations living in the open ocean, making them ideal candidates for documenting historic ocean temperatures.

Introduce students to foraminifera using this handout. For middle school and high school, a jigsaw activity can be used for students to learn more about foraminifera.

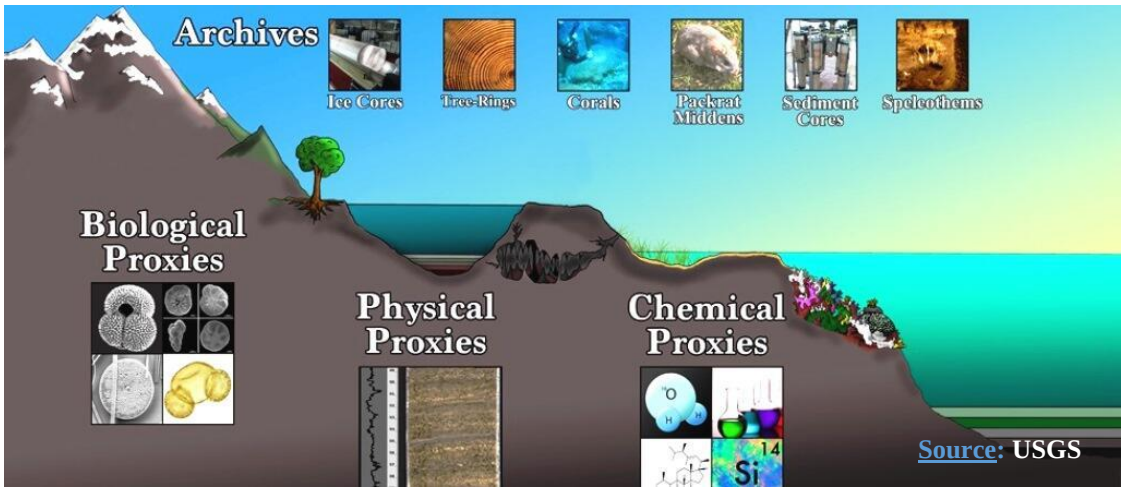
EXPLORE: The explore activity introduces paleoclimate and the mechanisms responsible for altering Earth's climate over time. Discuss with students that our planet's climate has not always been as it is today

Use the BioInteractive activity, Paleoclimate: A History of Change, to connect these activities. The resources on the BioInteractive website are free and provide a very comprehensive overview of climate and why climate changes over time. On the website, there is a pre-made student worksheet you can use to accompany this interactive tool.



EXPLAIN: Before beginning the Explain portion of the lesson, use the infographic below to introduce geologic time proxies and discuss with students how they are used to study earth's ancient climate. In general, a **proxy** is a stand-in or a representative of something/someone. In this case, these geologic time proxies are representing conditions of ancient environments as they have preserved data for those specific time periods. These proxies provide information related to Earth's historical climate and these proxies are valid sources of data. Just as paleoclimate scientists study ice cores to document atmospheric data, studying fossils can provide data to support information obtained from other proxies.

Explain to students that they are now paleoclimate scientists who analyze fossil evidence showing the changes in ocean temperature over thousands of years.



For the explain activity, students analyze fossils taken from a core. This activity can be completed by students individually or in small groups. There are 2 options for completing this activity with students.

INDIVIDUAL VERSION (click to obtain student handout)
Genial.ly was used to create the activity for students to complete individually. A link to this Genial.ly will provided to students on their handout and they will use the presentation to complete their handout. The instructions and information in the Genial.ly mirror what is found on the student handout. This will help students navigate the presentation and successfully complete the activity.

**Genial.ly is a diverse online platform where educators can create presentations, infographics, interactive games, and so much more. Accounts can be created for free and there are paid memberships.*

(A) Provide the handout containing the **Genial.ly** to students so that they can complete the activity. The student handout mirrors the instructions and content students will see in the Genial.ly. The handout can be given as a Google doc.

(B) The Genial.ly activity will explain to students how fossils can be used to understand the historical climate in Earth's history. Students will be prompted to answer some questions to review their knowledge before they proceed to analyzing the core data.

(C) Students will need to determine which samples are right-coiling and which samples are left-coiling. Students must then count how many are right-coiling and how many are left-coiling. They are to record this data in Table 1.

(D) Next, students will calculate the total the number of fossils found in the core sample for each time frame. Using this total, students will need to calculate the % of the fossils that are right-coiling and the % of fossils that are left-coiling. An example has been provided in the data table.

(E) Once students have all of their data and calculations, their next task is to create a graph. The graph will be created using the % of right-coiling foraminifera. This graph will show the changes in Earth's temperature from 160,000 years ago to the present. % of right-coiling foraminifera is used because students can easily find the periods of warm ocean temperatures (high %) and periods of cold ocean temperatures (low %).

(F) Since the graph is being created in the Genial.ly, have students take a screenshot of their graph and submit using your LMS or create a Google Form students can use to submit their image.

SMALL GROUP VERSION (click to obtain student handout)

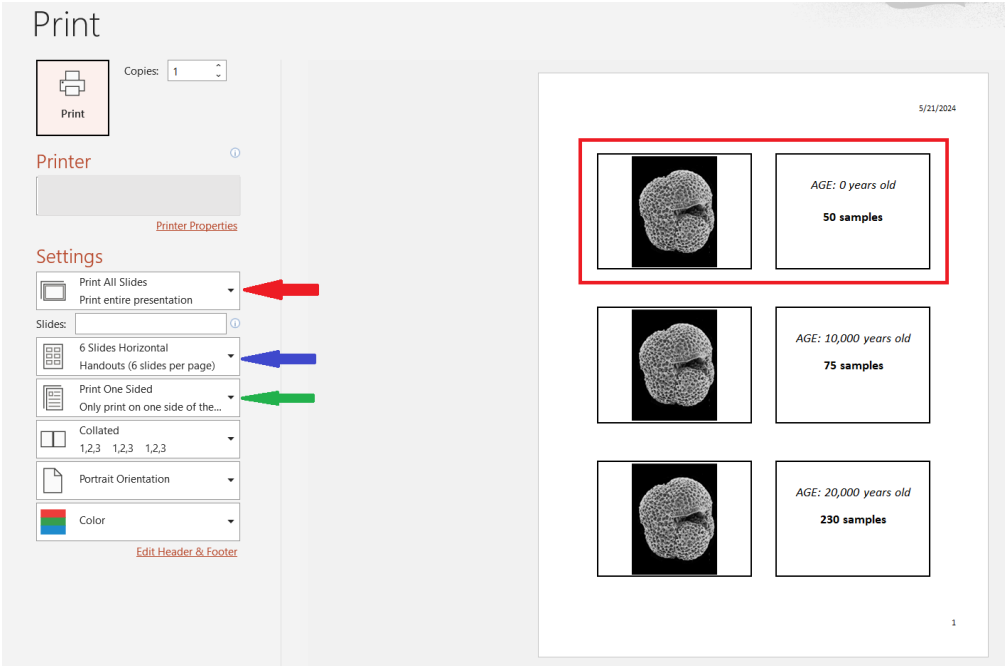
(A) This version of the activity is best completed with students in small groups. Make a set of foraminifera cards for each group to analyze.

(B) Students will compile their data in the table and create a graph on the paper handout provided.

REFER TO IMAGE BELOW: The document is set up so that when you choose to print slides, they can be cut and combined to make a front and back card. The image of the right or left-coiling foraminifera will be on the front and the age and quantity of foraminifera fossils would be on the back of the image. The cards can be laminated to preserve their integrity for future use.

To print the slides correctly, choose **6 Slides Horizontal** configuration and be sure they print **One-Sided**. You can download the files to print the foraminifera fossil slides.

- **Right-Coiling Foraminifera**
  Left-Coiling Foraminifera



	An answer key to the data chart is provided for you in Table 2. In addition, the students should know how to plot scientific data on graph paper. A blank graph is included in the online presentation. **EVALUATE:** Students can be given a formal or abbreviated summative assessment based on where in the unit this lesson is conducted. A formative assessment is provided below and can be used as-is or modified at the teacher's discretion. This formative assessment can be used to develop a summative assessment if needed. Formative Assessment – This formative assessment is a **Google Form** and can easily be shared with students and the results collected in a Google Sheet. When the link is clicked, a copy will be created and saved to your Google Drive. This **file** is a Word document containing the questions in case an alternative program or document needs to be used. When the link is clicked, a copy will be downloaded and saved to your computer. **ELABORATE:** Teachers can devise their own elaborate exercise based on the time constraints. If the activities in this lesson took more time in class, an elaboration activity can be omitted OR provided to advanced students. A consideration is to follow this activity with a discussion of the causes for climate change, past, present and future. This exercise can foster discussions on current climate change. The class could discuss current evidence for climate change and what might be the potential causes, both natural and man-made, for this change.

Table 2. Answers to *Neogloboquadrina pachyderma* coiling rations worksheet

Age (years ago)	Right-coiling *Neogloboquadrina pachyderma*	Left-coiling *Neogloboquadrina pachyderma*	Total number *Neogloboquadrina pachyderma*	% Right-coiling *Neogloboquadrina pachyderma*	% Left-coiling *Neogloboquadrina pachyderma*
0	230	50	280	82%	18%
10,000	220	75	295	75%	25%
20,000	70	230	300	23%	77%
30,000	45	300	345	13%	87%
40,000	50	302	352	14%	86%
50,000	65	389	454	14%	86%
60,000	20	140	160	13%	88%
70,000	56	287	343	16%	84%
80,000	63	267	330	19%	81%
90,000	212	56	268	79%	21%
100,000	120	23	143	84%	16%
110,000	87	45	132	66%	34%
120,000	203	66	269	75%	25%
130,000	56	205	261	21%	79%
140,000	45	332	377	12%	88%
150,000	89	135	224	40%	60%
160,000	123	166	289	43%	57%

Figure 1. Climatic signal derived from coiling ratios of *Neogloboquadrina pachyderma*.