Lesson Plan: The Fossilization Game

Special thanks to Joan Sharp (SFU Department of Biological Sciences), Samindi Fernando (Secondary STEM Teacher, SD43), Hazel Walling (Middle School Teacher, SD43), and Erin Barley (Senior Lecturer, SFU Department of Biological Sciences) for developing this activity.

Thanks to Dr. Rolf Mathewes and Dr. Bruce Archibald for providing invaluable scientific knowledge in building this activity.

Before the Lesson

The time required for this activity is 105 minutes, with 30 minutes of instructional time and 75 minutes of activity time. The break down of numbers of supplies is for a class of 30 students, please adjust as needed.

Curriculum Connections

Geology 12

Learning Objectives

After this lesson, students should be able to:

- Describe the process of fossilization.
- Discuss the sources of bias in the fossil record of life on Earth.
- Determine which organisms from an Eocene Forest community in the Okanagan Highlands contribute to the fossil record.
- Compare the differences in the fossil record from the same community in three different environments and analyze the factors that affect fossilization in each environment.

Lesson Plan Overview

1. Introduction
    a. Fossilization
    b. What factors affect the chances of fossilization?
    c. Lagerstätten
2. Main Activity
    d. Introduce the environments
    e. Play the game
    f. Discussion of results
3. Wrap-up

Materials Required:

- Fossils and the fossil record summary **(Appendix I)**
- Game cards **(54 total)**
    - Download the ZIP file which contains these files. Print each PDF once and cut them into cards, which will match the count below:
        - Diatom cards **(17)**
        - Lake cards **(17)**
        - Stream cards **(16)**
        - Instruction cards **(4)**
- Card platforms **(3, one each for diatom, lake, stream)**
- Environment map, printed or as a PowerPoint **(1)**
- Dice (6)

Introduction:

1. Fossilization

Fossilization is a rare event. After death, most organisms are eaten by scavengers or decomposed by microorganisms. To form a fossil, an organism must be buried quickly. **Anoxic** conditions, with low or no oxygen present to allow decomposition by fungi or microbes, increase the chances of fossilization. Fossils represent only a tiny sample of all the organisms that have lived on Earth. Most early **Eocene** fossils from Quilchena in the Okanagan Highlands are found in **sedimentary** rocks formed from sediment deposited at the bottom of the lakes in a warm forested highland.

2. What factors affect the chances of fossilization?

- Smaller and more fragile organisms are less likely to enter the fossil record than larger and sturdier organisms.
- For an organism to fossilize in the anoxic sediments of a lake bottom, it must first land on the surface of the lake.
- Plants that float on the lake surface are more likely to fossilize than plants that live in the forest and only land on the lake surface by accident.
- Leaves with a large surface area are more likely to be blown by wind to a nearby lake or stream.
- Plants that produce winged seeds or fruits (**samaras**) are more likely to fossilize as they may be carried by wind to a nearby lake or stream. Seeds or fruits that are mainly dispersed by forest animals are less likely to end up on the surface of a lake or stream.
- Leaves or winged seeds or fruits that are shed from the upper branches of a tall tree are more likely to be blown by wind to a nearby lake or stream than the leaves, seeds, or fruits of low shrubs.
- Flying insects are more likely to end up on the water surface of a stream or lake than insects that lack wings. Weak flyers are more likely to land near the shore and less likely to be land in the centre of the lake.
- Insects with a large SA:M (surface area to mass ratio) will float for a longer time on the lake surface, where they may be eaten by scavengers, decomposed by microbes, or wash ashore before they sink to the bottom sediments in the lake.
- Deciduous plants that shed their leaves seasonally are more likely to leave leaf fossils than evergreen plants that retain their leaves.

3. Lagerstätten

Lagerstätten are sedimentary sites with exquisite preservation of fossils, often including soft parts. Typically, organisms that fossilized at these sites were buried promptly under anoxic conditions that prevented rapid decomposition of remains. Canadian lagerstätten include:

- Mistaken Point, Newfoundland, with multicellular Precambrian fossils
- The Burgess Shale in Yoho and Kootenay National Parks, B.C., with Cambrian animal fossils
- Miguasha National Park, New Brunswick, with Devonian fishes
- Joggins Fossil Cliffs, Nova Scotia, with Carboniferous fossils including the first known reptile
- The Eocene Okanagan Highlands.

What role did diatom blooms play in the formation of lagerstätten in Eocene lakes?

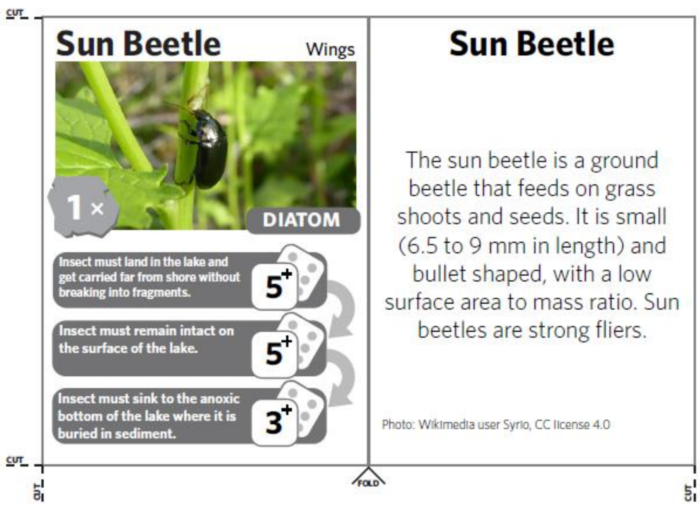
Lagerstätten of the Okanagan Highlands formed when volcanic eruptions released large amounts of silicon (Si). High levels of soluble silica in lake waters near the eruption led to **diatom blooms**, as silica is necessary for diatoms to make their cell walls. Organisms landing on the surface of a lake during a diatom bloom can become trapped by slimy mucous mats secreted by the diatoms. This biofilm protects the organisms from degradation and consumption at the lake surface. As the diatom bloom ends, diatoms die and sink to the anoxic bottom of the lake, carrying organisms with them. The mucous surrounding the organisms binds them to sediment on the lake bottom, increasing their chance of being fossilized and allowing them to be preserved in exquisite detail. Delicate organisms such as insects are far more likely to enter the fossil record under the conditions present in a diatom bloom.

Figure 1: This painting by SFU paleoecologist Dr. Rolf Mathewes shows the Quilchena site from 51.5 mya. Note the rare birds (based on fossil feathers and bones), a giant lacewing insect in the foreground, *Taxodium* (bald cypress) in shallow water with mats of *Azolla* (an aquatic fern), waterlilies, and *Metasequoia* (dawn redwood) and *Alnus* (alder) on shore.

Main Activity: See what fossilizes in your early Eocene environment!

Card printing and assembly instructions:

- Print all three decks of cards (diatom, lake, and stream) for this activity, **single-sided.**
- Cut out the cards in the pairs that they are grouped in by following the lines that are labelled "cut." Each pair is **one card**.
- Fold the middle crease labeled "fold." This will create the front and backside of the card.
- If desired, tape or glue the backs of the cards together so that it holds its shape.



1. Introduce the environments:
   - Split the students into three groups
   - Ensure that each group has a deck of cards and two die.
   - Run through the list of fossilization conditions in bold and ask students to vote if they think it will increase or decrease the possibilities of fossilization with a thumbs up or thumbs down.

i. A plant seed lands on the forest floor

A plant seed landing on the forest floor will likely either germinate and grow into a seedling, be eaten by an herbivore, or die and decompose due to the moist conditions and abundant decomposers in this environment. It is unlikely to fossilize.

ii. A winged plant seed blows on the wind and lands in the shallow water margins of the lake

A winged seed that lands in the shallow water margins of the lake is unlikely to fossilize. It may fragment due to wave action in the shallow water or be eaten by an herbivore. If it stays intact and sinks to the shallow water bottom of the lake, microbes will likely decompose it. The oxygen required by decomposers will be present in this environment.

iii. **A fragile insect lands on the lake surface and is broken into fragments by the action of waves or scavengers**
The fragments of a fragile insect will likely disintegrate and not fossilize. They may be eaten by frogs, fish, spiders, water striders, or birds. They may disintegrate or wash ashore before they can break through the surface tension.

iv. **A plant samara sinks to the anoxic bottom of the lake**
A plant samara on the anoxic bottom of the lake is likely to fossilize, as the lack of oxygen will prevent decomposers from breaking it down. Since it is on the bottom of the lake, it is likely to be buried in sediment, making fossilization possible.

v. **An insect is buried in anoxic sediment on the lake bottom**
An insect buried in anoxic sediment on the lake bottom is likely to fossilize, as the lack of oxygen will prevent decomposers from breaking it down and it is buried in sediment. If a diatom bloom is present, their mucous biofilm may coat the insect's body, stabilizing it and promoting the preservation of fine details.

2. Play the game:

- On a white board at the front of the class, separate out three spaces for each environment.
    i. Fast flowing stream
    ii. Diatom bloom on lake
    iii. Lakeside
- Show the map of the environments and briefly run through the conditions for each environment (i.e., fast flowing stream; diatom bloom in lake).
- Have students roll for the chance to fossilize their species according to the card
    i. The number of dice rolls per species increases with the abundance of the species in this environment.
    ii. Because this is a game of chance, the results will not always be the same
- They can set their cards aside onto their site board, which allows tracking of fossilization. For every species that successfully fossilizes, students can come up and draw what they think the fossil will look like on the board.

3. Discussion:

- Have the student groups compare the number and type of fossils that formed in each environment.
    i. Discuss why some of these environments have led to a greater chance of fossilization and why some environments have produced few fossils.
- Ask students if they received more or fewer fossils than expected.
    i. Please note that this game enormously exaggerates the chances of fossilization. It is highly un-likely that a fossil will form from any single organism or part of an organism, even under ideal conditions.

Debrief

- Have students think about all the fossil sites in the world (examples in the Lagerstätten section).
  - Work as a class to make a list of bias in the fossil record that affect the types of organisms and the environment that have a greater chance of leaving a fossil record.
    - In most cases, only hard parts of organisms, such as wood, bones, teeth, scales, or shells, fossilize. Species with hard body parts or lignified tissues are more likely to leave a fossil record, while species with entirely soft bodies are less likely to fossilize. Lagerstätten are unusual sites with exquisite preservation of hard and soft body parts of fossilized organisms.
    - Most fossils are found in sedimentary rocks that form from sand and mud, which may be deposited at the bottom of oceans, lakes, rivers, and swamps. Species that live and die in areas of sedimentation such as lake or ocean bottoms are more likely to fossilize, while species that live and die in areas of erosion. Some excellent insect fossil sites are found in shallow marine depositional environments.
    - Fossilization is less likely in hot, moist regions where decomposers are active.
    - Species that are abundant and survive for a long time in geological terms are more likely to leave a fossil record than species that are rare and exist only a relatively short time before going extinct.
- Consider modern environments.
  - Are fossils likely to form in urban environments? Are fossils formed in the past likely to be found in urban environments?
    - A species with large numbers of large individuals, with many hard parts, that lives in or near a swamp, lake, or ocean is relatively likely to leave a fossil record.
    - A species with low abundance of small individuals that is entirely soft-bodied, that lives and dies in a moist, warm forest is unlikely to leave a fossil record.
  - Which species and environments on Earth today are most and least likely to leave a fossil record?
    - In urban environments, buildings and roadways make it difficult or impossible to look for fossils that may be present in underlying sedimentary rock. However, excavation for construction may uncover fossils that had been present, but hidden, in these environments. In 2015, an excavator found a school of 60-million-year-old fossil fish while digging a basement in northwest Calgary: http://bit.ly/4izRrZm

Appendix I - Fossils and the Fossil Record

Summary

Fossils are the remains or traces of organisms from earlier geological periods. After death, most organisms are eaten by scavengers or decomposed by microorganisms. However, in some cases, an organism may be rapidly buried and so avoid being eaten by scavengers. If there is little oxygen and/or few microorganisms present, the organism will not decompose. Under these rare conditions, an organism may be preserved as a fossil.

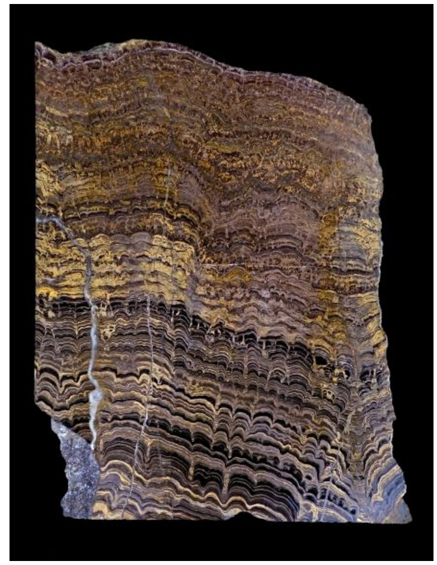


Figure 2: Stromatolite. Wikimedia user Archaeodontosaurus, CC license 4.0.

The actual process of fossilization typically includes chemical changes – minerals fill spaces, cover surfaces, or replace tissues and so preserve the detail of the original specimen. Other processes can lead to the preservation of organisms as well. An organism might make an impression in mud. If the mud becomes sedimentary rock, it may preserve an imprint fossil, long after the original organism has decomposed. Insects may be preserved in amber (formed by resin of trees), and paleontologists have found frozen and desiccated woolly mammoths in arctic permafrost.

The type and quality of information available to paleontologists varies with the type of fossil. Molds or imprint fossils provide information about the external surfaces of an organism. For example, feather imprints on dinosaur fossils provide important evidence about the evolution of birds from dinosaurs. Mineralized fossils can provide information about internal and external surfaces and tissues. Animals that are frozen or preserved in amber may still contain soft tissue. This can be a rich source of information and may even include DNA (though its quality degrades with time).

In most cases, only hard parts of organisms, such as wood, bones, teeth, scales, or shells, fossilize. Most fossils are found in sedimentary rocks that form from sand and mud deposited at the bottom of oceans, lakes, rivers, and swamps. This means that aquatic organisms are much more likely to fossilize than terrestrial organisms. Very few organisms form fossils and most fossils are destroyed by natural geological processes (e.g., erosion or tectonic activities). Of those that survive, only a few are exposed at the surface where they are available for examination. Thus, known fossils represent only a tiny sample of all the organisms that have lived on Earth - and only a tiny sample of all of biodiversity on earth is still living.

Factors affecting fossilization

Fossilization is a rare event. After death, most organisms are eaten by scavengers or decomposed by microorganisms. To form a fossil, an organism must be buried quickly. Anoxic conditions, with low or no oxygen present to allow decomposition by fungi or microbes, increase the chances of fossilization. Fossils represent only a tiny sample of all the organisms that have lived on Earth. Most early Eocene fossils from Quilchena in the Okanagan Highlands are found in sedimentary rocks formed from sediment deposited at the bottom of the lakes in a warm forested highland.

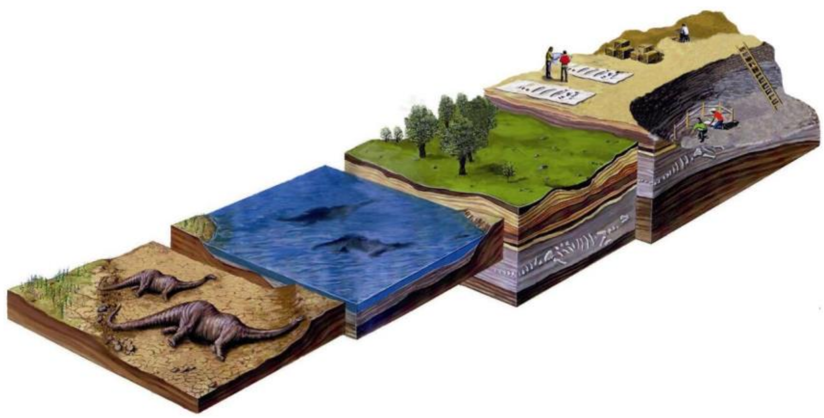


Figure 3: The fossilization process. Wikimedia user Xabier Murelaga - Elhuyar Fundazioa, CC license 3.0.

What factors affect the chances of fossilization?

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- Deciduous plants that shed their leaves seasonally are more likely to leave leaf fossils than evergreen plants that retain their leaves.

What is the fossil record?

The fossil record is considered to be all of the known fossils and where they belong in history. As previously mentioned, the fossil record remains largely incomplete due to the nature of fossilization. Placing the fossils in a timeline can be done in a number of ways. One of these is superposition. This is a form of relative dating, where the age of fossils at an excavation site can be ordered by their relative position to each other. Simply the further down in the earth the fossil is found, the older the fossil is. As technology has improved so has dating fossils. Using radioactive decay, scientists can determine the age of a fossil with much more precision than previously possible. Radiometric dating is performed by calculating the amount of decay an isotope has undergone up until the present day. Although carbon dating is undoubtedly the most famous, many different isotopes such as uranium or potassium can be used for radiometric dating.

Resources:

Geological time | Digital Alas of Ancient Life
https://www.digitalatlasofancientlife.org/learn/geological-time/

Fossils 101 | National Geographic
https://www.youtube.com/watch?v=bRuSmxJo_iA

Footprints in Time | Beaty Biodiversity Museum
https://footprintsintime.ca/

Appendix III - Additional Resources for this activity

Fossilization Game – Gameplay Video
https://www.youtube.com/watch?v=mgdnKhEcSW0

Fossil | National Geographic
https://education.nationalgeographic.org/resource/fossil/

Fossilization – How do fossils form? | Smithsonian
https://naturalhistory.si.edu/education/teaching-resources/paleontology/fossilization-how-fossils-form

The process of fossilization | Digital Atlas of Ancient Life
https://www.digitalatlasofancientlife.org/learn/nature-fossil-record/the-process-of-fossilization/

Appendix IV - Glossary

Anoxic: Deficient in or without oxygen.

Eocene: The epoch that occurred approximately 56 million to 34 million years ago. It is associated with extreme climate change, as well as the rise of mammals.

Diatom: Photosynthetic, single-celled organisms that are a key source of the earth's atmospheric oxygen.

Diatom bloom: An event in which there is a boom in the presence of diatoms. Often caused by high temperatures and large concentrations of nutrients.

Lagerstätten: A sedimentary layer of rock that contains a large amount of well-preserved organic remains such as soft tissues or skeletal remains.

Sedimentary: Formed from pre-existing rock or sediment. Sedimentary rocks often have distinct sediment layers.