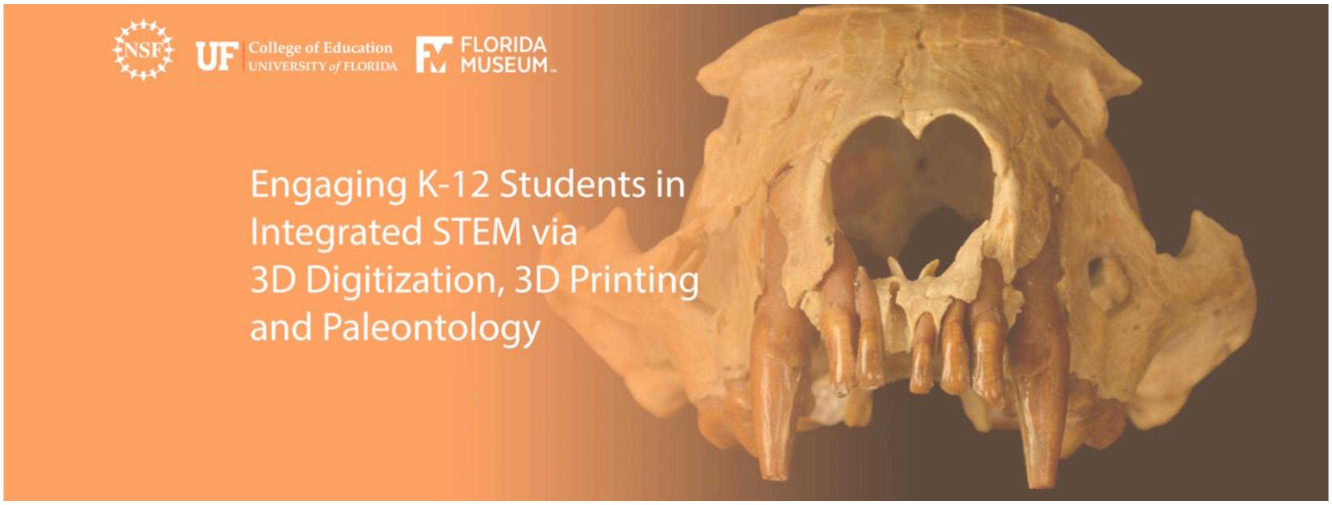


AUTHOR (S)

Julie Hughes

LESSON TITLE

Fan mail

GRADE LEVEL

5th - 6th grade

TIME FRAME

Two 45-minute classes or one 90-minute block

DRIVING QUESTION

How do geological processes affect land, water, and fossils?

LEARNING GOALS

Students will be able to explain how different geological processes work together to create varying land features and explain if those geological processes affect the movement of fossils in a region.

ANCHORING EVENT

The story: Explain to students that your favorite scientific duo, Dr. Sean Moran and Dr. Michael Ziegler, geologists and paleontologists extraordinaire, are off in the Badlands of Nebraska, digging furiously for new specimens for their research. Unfortunately, this leaves no extra time to respond to their fan mail, and they have lots of it! (They are very cool and funny scientists!) Students from around the country write to them asking questions about geology and fossils, and they need help answering them all. They are relying on you, their official amateur assistants, to help them answer these letters. Now, because they are not heartless scientists, they have provided some maps, models, and even fossils to help you answer each letter. They are relying on you and your scientific knowledge to answer their adoring fans.

COLLABORATIONS

Students will be put into small groups to rotate around stations. These heterogenous groups should be made ahead of time with 3 students in each group. To hold all students accountable for working within the group, consider making “role cards” to pass out in the groups. Using index cards, write one role on each card. For these stations, roles could be **leader** (reads the letter, explains how the group should solve the problem), **notetaker** (answers the letter using bullet points, illustrations, diagrams, definitions, etc. in science notebook), and **timekeeper** (keep track of the time and refocus groups if off task). Students can then switch cards when they rotate to a new station.

STEM INTEGRATION

Each station will include a 3D model. This may be a topological map of a region or 3D printed fossils. Students will use these models to integrate their knowledge of geological processes.

ASSESSMENT

a) Formative assessments:
Students will use their scientific notebooks to write notes answering each question in a station.

b) Summative assessment(s):
After students have rotated through each station, each group will randomly be assigned a station to go back to and officially answer the letter. Students can choose to write their response on paper or videotape their answer aloud. All student answers should include the following:

- Directly answer the question using the names of the specific geological processes
- Use a diagram/map/drawing or the 3D models to illustrate the geologic process

PROCEDURE

Initial set up: Each group will rotate through five different stations. Set up two different loops, so each station is running twice at the same time. This will allow a group of 30 students to be broken into two groups of 15, with 3 people at one station at a time.

Student procedures: Divide students into groups and assign them to a first station. Explain how they will rotate through each station. Give students 10 minutes per station with 1 minute to transition. Make sure to post a timer to keep all students on track.

- If you teach two 45-50-minute classes, your goal will be to introduce the lesson, divide students, and rotate through three different stations on day 1. On the second day, finish rotating through the last two stations.
- If you teach one 90-minute block, students will be able to rotate through all centers in one day.

Once students have rotated through each station, reconvene students in a large group. Ask students which letters they found easiest to answer. Ask students if they were still stuck on one. Use this opportunity to clarify any misconceptions before students finalize their answers.

Randomly assign each group to go back to one specific station. They will have an additional 10 minutes to formalize their response. Students can either write a response or videotape it, but all responses must include the following:

- Directly answer the question using the names of the specific geological processes
- Use a diagram/map/drawing or the 3D models to illustrate the geologic process

Students will submit their work to be graded on accuracy of the geological process and clarity through their use of visual aids.

Optional extension: Post both responses to a specific station and have students vote on which response should be passed along to Dr. Sean and Dr. Mike.

Station information, help from the scientists, draft of letter	**Ideal student response**
Station 1. Why are there marine fossils in Mt. Everest? Basic answer: uplift and mountain building from two plates colliding **Help from the scientists:** 1. 3D printed gastropod and age *Bellerophon randerstonensis*, 326-359 Million Years Ago (Mya) 2. Map of Indian plate colliding into the Eurasian plate http://dinosaurpictures.org/ancient-earth#50 3. Additional image if needed showing the Indian plate colliding with the Eurasian plate **Basic story:** Dear Dr. Sean and Dr. Mike, My friend Erin told me that there are fossils from the sea found in mountains, but I didn't believe her. Mountains are so tall, and there aren't any oceans near them, so how could ocean fossils end up on mountains? I looked this up on Google and found out that in fact people have found fossil shells on Mt. Everest. Please explain how this is possible! From, Marcus	**Basic explanation:** Plates are constantly moving (plate tectonics), and mountain building happens when two plates collide. There is uplift, and fossils of organisms that lived on either plate are forced into the new mountain. There was ocean in between the two plates that collided. The marine fossils on the ocean floor where then uplifted into the continental crust that formed the mountains. **More advanced:** When plates collide, usually one is forced under another, called subduction because oceanic crust is more dense than continental crust. Sometimes both plates remain on the surface, but this causes a lot of crust to build upwards, creating mountains. In the Himalayas, Indian Plate crashed into the Eurasian Plate, causing massive uplift of the crust. Fossils from the sea that lived before the mountains were formed were then pushed from the seafloor into the crust.

<table>
<tr>
<td>Station 2. Why are the examples of the same fossil, from the same time, on two different continents?
(plate tectonics)

Help from the scientists:
1. Fossil card with the organism, age, where it was found
- Mesosaurus (South America, Africa)
- Other organisms that could be used
  - Cynognathus (South America, Africa)
  - Lystrosaurus (Africa, India, Antarctica)
  - Glossopteris (found on every continent)

2. 3D print of Pangea (kids will have to put it together and use fossil cards to see where different fossils were found) from Thingiverse

3. Resource to see change of Earth's plates and even look up where your address would be up to 170 Million Years Ago: http://dinosaurpictures.org/ancient-earth

Basic story:
Dear Dr. Sean and Dr. Mike,
In science class, we are studying dinosaurs, which is really cool because I love dinosaurs. I got to pick a dinosaur and research it, and I picked Mesosaurus because it has really cool, sharp teeth. But here's the problem. I think some of the websites are wrong. I was looking up where it lived, and on newdinosaurs.com it said that this animal lived in both eastern South America and in southern Africa. But this can't be right. Although this guy was a swimmer, I don't think it swam between South American and Africa. That's a long way! Is the website correct? What's going on?
From,
Cristina</td>
<td>Basic explanation: This animal was alive a long time ago when the continents were together in one super continent named Pangea. Mesosaurus was found on South America and Africa, but during the time of Pangea, those continents were right next to each other. Mesosaurus died, and its bones became fossils. Later, the continents broke apart and moved away into their current positions because of plate tectonics.

More advanced: Hundreds of millions of years ago, when Mesosaurus was alive, the continents where clumped together in a giant supercontinent named Pangea. Because the continents were next to each other, and there weren't oceans between them, terrestrial mammals, like Mesosaurus, was able to travel to different regions. Individuals died, and its bones were preserved as fossils. Later, when the continents broke apart because of plate tectonics, fossils of Mesosaurus were found in South America and Africa because on Pangea, when Mesosaurus was alive, those two continents were right next to each other. The continents continually shift because the Earth's surface is broken into plates, and those plates are constantly moving around the Earth.</td>
</tr>
<tr>
<td>Station 3. Why are there lots of mammoth fossils in a huge ring by the Channeled Scablands?

Help from the scientists:
1. Mammoth cranium 3D printed (see resource section)
2. Fossil localities of mammoth bones (https://paleobiodb.org/navigator/)
3. Graphic depicting glaciation in the Scablands

Basic story:</td>
<td>Basic explanation: Even through the world was very cold during the Ice Age, there was still running water. But there was also a major ice dam, which backed up lots of water and ice. When the dam broke, ice and water was released, causing massive flooding. This killed many mammoths, but their bones were found further away in a circle because the bones were carried away by ice and water and formed a lake called</td>
</tr>
</table>

Dear Dr. Sean and Dr. Mike, I just learned that there's a big bathtub ring of mammoths in the Scablands in Washington state. Like, when you drain the bathtub and there's a ring around it that's gross and your mom makes you wipe it down. Like that! But with mammoth bones in a circle. Did the mammoths live in an ancient bathtub too? Why did they all die like that? What happened? From Colleen P.S. I'm in third grade and I LOVE fossils. Do you like fossils too?	Lake Lewis. The bones were deposited by the water and ice around the ancient lake, which is no longer there. **More advanced:** Glaciation happened during the last Ice Age. In the Channeled Scablands, Lake Missoula releasing a lot of water at once. The water was forced through a gap, which backed up to make an ancient lake, Lake Lewis, before draining into the Clark Fork River. The mammoth bones were deposited through glaciation on the rim of this ancient lake.
Station 4. Were the arches in Arches National Park carved out by people for doorways? (weathering and erosion) **Help from the scientists:** 1. 3D print of the Grand Canyon because it's a similar process (https://sketchfab.com/3d-models/grand-canyon-terrain-map-ca68f671638b48ad96ff558b9fcf9407) 2. Colored pictures of arches from Arches National Park **Basic story:** Dear Dr. Sean and Dr. Mike, I'm in fourth grade, and in class today we learned about one of our presidents, Woodrow Wilson. Did you know that he started the National Park Service? Anyway, our teacher, Mr. Gonzalez, showed us a bunch of pictures of different national parks. One of them has really cool arches, and I thought it was pretty cool that some people carved out these arches. Do you think they carved these arches as doorways for their homes? Thanks for the info! Ari	**Basic explanation:** The arches were not carved out by people. They were created through weathering and erosion. Gravity, wind, and water all caused sentiment to be broken off and washed away, and what is left are these delicate arches. **More advanced:** The whole region near the Grand Canyon (called the Colorado Plateau) rose thousands of feet a long time ago, and weathering caused a lot of the sandstone to break off and fall. The weathering was caused by gravity, wind, and water. Erosion then caused the sentiment to move further downward. Today there is still a lot of weathering through rain, and the sentiments are then eroded down the canyons and into the Colorado River.
Station 5. There aren't any volcanoes in Nebraska now, so how are there fossils covered in ash? (volcanism, hot spots, preserving fossils) **Help from the scientists:** 1. Link to Ashfall National Park (http://ashfall.unl.edu)	**Basic explanation:** The ancient volcano still exists as a hotspot in Idaho under Yellowstone National Park. That hot spot erupted, and the ash traveled to Nebraska, where it killed a lot of animals. They were all gathered at a watering hole to try and survive, but they ended up dying from the ash in the atmosphere.

2. 3D printed fossils arranged together to show that they were found together in the watering hole. (see resource section corresponding to this station) **Basic story:** Dear Dr. Sean and Dr. Mike, I live in Omaha, Nebraska, and I have a question about Nebraska's history, which we have to learn in school. Our social studies teacher, who also teaches us science, told us that Nebraska is a great place to find fossils. Is that true? I like fossils and might want to find some of my own. Anyway, we were talking about this park where a bunch of animals died and were covered in ash from a volcano. But here's the thing. We don't have volcanoes in Nebraska. Is there an ancient volcano living under us that I don't know about? How did these animals die? From, Shawna	**More advanced:** The Ashfall National Park is a preserved fossil site that does have a lot of full animal fossils from about 10-12 million years ago. There isn't a volcano under Nebraska, but there is a hot spot in Idaho under Yellowstone National Park. This is why we have geysers because of the heat from the hot spot. The volcano erupted in Idaho, but the ash traveled from Idaho to Nebraska, killing a lot of animals. Some died immediately, and some were at an ancient watering hole and breathed in the ash. They all died at this watering hole because they were trying to survive with water. They were then covered with a layer of ash and their bones turned to fossils over time.

STANDARDS

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Performance expectations

MS-ESS2-2.	Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.
MS-ESS2-3.	Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of the past plate motions.

Science Practices	Connection to the Lesson
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories. • Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe nature	Students will have to construct an explanation for each letter. They will use established theories like plate tectonics, glaciation, and weathering and erosion to explain the geology question.

operate today as they did in the past and will continue to do so in the future.	
Disciplinary Core Ideas	**Connection to the Lesson**
ESS2.A: Earth's Materials and Systems • The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future.	Students will need to explain plate tectonics in stations one and two. Students will explain subduction and mountain building in station one, and they explain gravity as it applies to weathering in station four.
ESS2.B: Plate Tectonics and Large-Scale System Interactions • Maps of ancient land and water patterns, based on investigations of rocks and fossils, make clear how Earth's plates have moved great distances, collided, and spread apart.	Specifically, students will explain how the Indian plate collided with the Eurasian plate to form the Himalayas in station one. Additionally, in station two, students will show how Pangea broke apart to form our modern continents.
ESS2.C: The Roles of Water in Earth's Surface Processes • Water's movements—both on the land and underground—cause weathering and erosion, which change the land's surface features and create underground formations. •	Students must explain how weathering and erosion carve out natural features on land in station four.
Crosscutting Concepts	**Connection to the Lesson**
Scale Proportion and Quantity • Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.	3D models will be scaled down to show students various products of geological processes. They will have a scaled down version of Pangea to demonstrate plate tectonics, a scaled down version of the Grand Canyon to demonstrate weathering and erosion as well as scaled down versions of 3D fossils to model mass extinctions.

CCSS STANDARDS

RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). (MS-ESS2-3)

RST.6-8.9 Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic. (MS-ESS2-3)

RESOURCES & MATERIALS

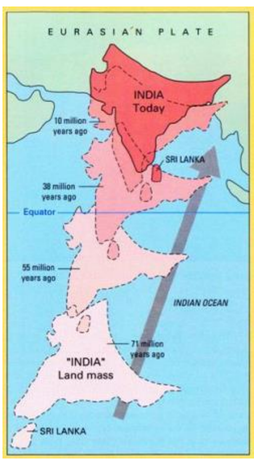
Station 1 (Marine fossils on Mt. Everest) materials:

1. .stl file of *Bellerophon randerstonensis*
http://www.3d-fossils.ac.uk/fossilType.cfm?typSampleId=60343
http://www.3d-fossils.ac.uk/fossilType.cfm?typSampleId=25001296

FYI, the fossil species came from this paper:
https://www.researchgate.net/publication/240776376_Late_Permian_Lopingian_Gastropods_from_the_Qubuerga_Formation_at_the_Qubu_Section_in_the_Mt_Everest_Qomolangma_Region_Southern_Tibet_Xizang_China

2. Link to online global models of plate movement throughout geologic time
http://dinosaurpictures.org/ancient-earth#50

3. Additional image for more scaffolding



Station 2 (Same fossils, different continents) materials:

1. 3D file (.stl) of Pangea puzzle on Thingiverse
https://www.thingiverse.com/thing:1360459

2. Mesosaurus fossil card (see format below)

Mesosaurus

Quick Mesosaurus Facts

- Lived 299-271 mya during the Early Permian Period
- Lived in what is now Africa and South America
- Was about the size of a Dachshund dog
- Lived in freshwater rivers and lakes
- Ate plankton and small marine animals

*Information from www.newdinosaurs.com/mesosaurus/ and http://www.edgarlowen.com/fossils-minerals.shtml

Station 3 (mammoths in the Scablands) materials:

1. Mammoth cranium from The Natural History Museum, London https://www.myminifactory.com/object/3d-print-mammoth-cranium-at-the-natural-history-museum-london-5939 or https://sketchfab.com/3d-models/mammoth-from-the-nat-museum-san-diego-a8fcc4dbeaee4ec5b3e367cbe30bc1a8

2. Fossil localities of mammoth bones: (https://paleobiodb.org/navigator/)

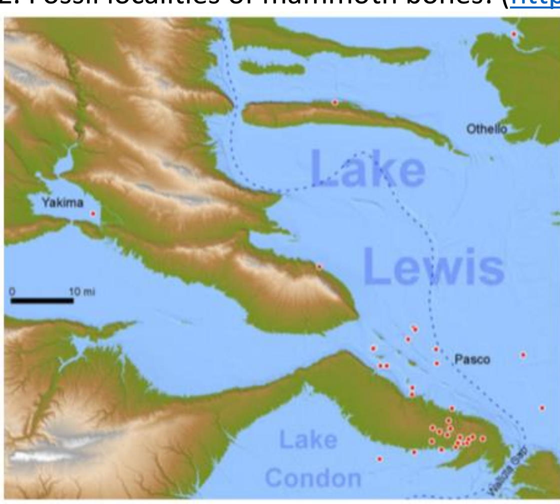


Figure 2. *Location of Mammoth finds relative to the maximum water level of temporary Lake Lewis (blue area). Dashed line is the location of the Columbia river.*

3. Graphic depicting glaciation in the Scablands

ROSEMARY WARDLEY, NG STAFF
SOURCES: USGS;<I> ATLAS OF OREGON</I>

4. Information on Columbian mammoth
https://www.floridamuseum.ufl.edu/100years/columbian-mammoth-exhibit/

Background information:
https://www.pnnl.gov/news/release.aspx?id=247
https://news.nationalgeographic.com/2017/03/channeled-scablands/

Station 4 (weathering and Arches National Park) materials:

1. .stl file of the Grand Canyon on Thingiverse
https://www.thingiverse.com/thing:296704

2. Colored pictures of arches from Arches National Park
https://www.google.com/search?q=arches+national+park&safe=active&source=lnms&tbm=isch&sa=X&ved=0ahUKEwi6nbC14eXbAhVOLKwKHWXGBRAQ_AUICygC&biw=1388&bih=651

Station 5 (Ashfall National Park) materials:

1. Link to Ashfall National Park
http://ashfall.unl.edu/index.html
2. Link to Ashfalls 3D Models (not downloadable): https://sketchfab.com/paleosleuths/models
3. 3D (.stl) files for download or general open-source models that could be substituted for original species:
Sternotherus: https://www.morphosource.org/Search/Index?search=Sternotherus

Pliohippus pernix – Similar Fossil Horse Element: https://sketchfab.com/3d-models/usnm-v-11162-equus-sp-tibia-left-vcu-3d-3459-2f33f1916506456fb1bb9c09bbb8fabc
https://www.floridamuseum.ufl.edu/fhc/plioh.htm
Aepycamelus – Similar Fossil Camel Element https://sketchfab.com/3d-models/camel-jaw-new-mexico-5284cfd3d2a14a1886e1dfd8698a2a24
https://www.floridamuseum.ufl.edu/florida-vertebrate-fossils/species/aepycamelus-major
Hesperotestudo (Giant Tortoise) – Similar Fossil Tortoise Element: https://sketchfab.com/3d-models/imnh-r-885-leopard-tortoise-80de8f59f29f45b8a12ff92b78675eae
Longirostromeryx wellsi (Sabre-Toothed Deer) – Similar Fossil Deer Element: https://sketchfab.com/3d-models/deer-scapula-dd1f396cb0244b42bf196d9c302ea2fb

KEY ACADEMIC AND/OR SCIENTIFIC LANGUAGE

Definitions from National Geologic Society and U.S. Geological Survey

Erosion: breakdown and removal of rock material by flowing water, wind, or moving ice. Not to be confused with weathering!
Deposition: process of settling out of sediment grains from water or wind (usually as flow slows down) or ice (as it melts).
Glacier, glacial erosion: a slowly-moving "river" of ice which rapidly erodes deep valleys because of the rocks embedded in the base and sides of the glacier.
Ice sheet: a mass of ice covering a large land area (as in Greenland or Antarctica at the present day).
Hot spots: An area of concentrated heat in the mantle that produces magma that rises to the Earth's surface to form volcanic islands. The volcanic activity of the Hawaiian Islands is one example. Hot spots generally persist for millions of years.
Lithosphere: outer layer of Earth (uppermost mantle and crust) that behaves as a number of rigid, moving "plates". See also plate tectonics.
Fossils: Mineralized remains or traces of organisms.
Subduction: Process of one crustal plate sliding down and below another crustal plate as the two converge. The **subduction zone** is the area between the two plates, somewhat like a giant reverse fault.
Pangea: The supercontinent which formed at the end of the Paleozoic Era and began breaking up about 200 million years ago to form today's continents.
Plate, Plate Tectonics: plate tectonics describes the slow motion of rigid "plates" of the lithosphere due to movement (convection) of the mantle beneath.
Sediment: material deposited by water, wind or ice. Includes pebbles, sand, mud, organic remains (e.g. shells) and salts left by evaporation.
Strata: layers of rock formed by deposition of sediment (and sometimes lava and pyroclastic material).
Volcanic ash: fragments of rock and pumice thrown out of volcanoes by explosive eruptions, the finest particles are carried long distances by winds.
Volcano, volcanic: cone-shaped (sometimes!) mountain formed by eruptions of lava and/or pyroclastics. Volcanic means "from a volcano".

Weathering: slow breakdown of rock at the Earth's surface, due to climatic and biological processes. See also Physical, Chemical, Biological...

PRIOR KNOWLEDGE

This lesson is structured to be a review of all major geological processes after students have individually learned about each one. Ideally, this lesson could be used as a review before an assessment to review basic science concepts and integrate knowledge.

Students must know the following information to be successful at the stations.

Plate tectonics
https://www.livescience.com/37706-what-is-plate-tectonics.html
https://www.britannica.com/science/plate-tectonics
BrainPop video on plate tectonics: https://www.youtube.com/watch?v=RA2-Vc4PIOY
Movie on plate movement: https://www.youtube.com/watch?v=kwfNGatxUJI
Fossils to prove plate movement: https://www.geolsoc.org.uk/Plate-Tectonics/Chap1-Pioneers-of-Plate-Tectonics/Alfred-Wegener/Fossil-Evidence-from-the-Southern-Hemisphere; http://publish.illinois.edu/alfredwegener/evidence/

Effects of plate tectonics

Earthquakes: https://www.britannica.com/science/earthquake-geology
Volcanoes: https://www.britannica.com/science/volcano
Mountain building: https://www.britannica.com/science/plate-tectonics#ref936127

Basic information on glaciation: https://www.tulane.edu/~sanelson/eens1110/glaciers.htm