Everest Education Expedition Curriculum

Lesson 3: Sea Floor To Summit

Created by Montana State University Extended University
and Montana NSF EPSCoR
http://www.montana.edu/everest

Lesson Overview:
Explore the rocks that lie beneath Mount Everest's summit. Simulate the formation of the Himalayan Mountains and Mount Everest while uncovering the dynamic processes of plate tectonics. Study the rocky layers that Dr. David Lageson researched on Mount Everest and investigate the geologic layers that sit below each climber's crampons (ice cleats). Discover how the ancient sea floor now sits on this extreme summit and ponder whether Mount Everest really is the tallest mountain on earth.

Objectives:
Students will be able to:

1. Explain how the Himalayan Mountains formed.
2. Identify the rock layers of Mount Everest.
3. Explain the different ways each of the world's four "tallest" mountains are measured.

Vocabulary:
fault - a crack with offset in the Earth's crust
folding - when rocks or rock layers that were once flat are bent or curved
gneiss (nice) - a high-grade metamorphic rock formed from preexisting granite or sedimentary rock (high grade metamorphism changes the rock so completely that the source rock often cannot be readily identified)

Read more: http://www.answers.com/topic/metamorphism#ixzz1oxKeAZaE

granite - an igneous rock that forms from the slow crystallization of silica-rich magma below Earth's surface
limestone - a sedimentary rock composed mostly of calcium carbonate formed in clear, warm, shallow marine waters
marble - a metamorphic rock formed from limestone mainly composed of calcium carbonate
massif - the compact and connected group of mountains around Mount Everest that includes Everest, Nuptse, Lhotse, and Khumbutse
plate tectonics - a theory that the Earth's outer shell is made up of plates of rock that shift all over the globe causing mountain building and earthquakes
plates - large pieces of rock that make up the Earth's outer shell (lithosphere)
schist (SH-ist) - a metamorphic rock formed from shale
shale - a sedimentary rock with many thin layers formed from mud (clay-rich sediment)
uplift - the tectonic process of land being pushed higher through compressive forces (collision of India with Eurasia)

Background Information:
The Himalayan Mountain Range includes the tallest mountain in the world, Mount Everest. These mountains stretch 1,500 miles (2,415 kilometers) across Asia from the Indus River in Pakistan to the Bramaputra River in India. Usually called the Himalayas for short, these mountains began to rise over 50 million years ago through the collision of the Eurasian and Indian plates. As these two land masses collided, the Indian plate was pushed upwards forming

the Himalayan Mountains. These two tectonic plates continue to collide and are pushing Mount Everest a few millimeters higher each year.

Mount Everest's rock layers tell the geologic story of this mountain's formation through several distinct successions of rock.

- The bottom-most unit, consisting of gneiss, schist and migmatite, is called the Rongbuk Formation. This unit forms the foundation of the mountain and can be found below 23,000 feet (or 7010 meters). The gneiss and schist are locally intruded by white-colored leuco-granite (leuco means white or light colored), which is more prominently exposed on the south face of Nuptse. In other words, magma pushed into cracks and spaces in the gneiss and schist and formed granite.
- Above these rocks, the North Col Formation comprises most of the mountain from 23,000 to 26,900 feet (meters). This formation is a mixture of shale (sedimentary rocks composed of fine fragment, also called pelites), sandstone (quartzite) and yellow-tan marble.
    - The uppermost part of the North Col Formation, near 27,500 feet (8382 m), is limestone.
    - The highest 500 feet of this layer consists of yellow marble known as the Yellow Band. This feature actually slices through Mount Everest at an angle and is most pronounced on the North Face. (On the south side, it's visible around 24,000 feet / 7315 m.)
- Above the Yellow Band is dark grey limestone. It can be seen most prominently in the First and Second Steps of the Northeast Ridge. This soft grey rock comprises the "summit pyramid" and is a special focus of Dr. Dave Lageson's study of the geology of Mount Everest.

The summit of Mount Everest was the seafloor 470 million years ago. The rock that comprises the "summit pyramid," or uppermost part of Mount Everest, is gray limestone that was deposited in the Tethys Ocean to the north of India during the early to middle Ordovician Period of the Paleozoic Era, long before India began its northward journey towards Eurasia and the eventual collision of tectonic plates that uplifted the Himalaya and Tibetan Plateau. Called the "Qomolangma Limestone" by geologists, the summit rocks are limestone (grainstone) with fragments of common Ordovician marine invertebrate shells, such as trilobites, brachiopods, ostracods and crinoids. The Qomolangma Limestone has been altered by heat, pressure and fluids that have altered the original limestone, so it is now a low-grade metamorphic rock (low-grade metamorphism takes place at much lower temperatures and pressure than high-grade metamorphism, and low-grade metamorphic rocks are characterized by an abundance of minerals that contain water in their crystal structure). These rocks have been brought to the *roof of the world* through continual uplift caused by the collision of India and Eurasia (which is still on-going today), deep erosion of the Greater Himalaya, and fault displacement along the South Tibetan detachment (Qomolangma detachment fault) that has tectonically placed the summit rocks over higher-grade metamorphic rocks below.

The Everest Education Expedition conducted scientific research on the geology of Mount Everest including gaining a better idea of the age of Mount Everest and rocks that comprise the **massif** (the compact and connected group of mountains around Mount Everest that includes Everest, Nuptse, Lhotse, and Khumbutse); collecting a suite of samples to better date and describe the fossil-bearing marine limestones that form the summit pyramid of Everest; and studying the major faults that cut through Mount Everest to better understand how and when they formed (in particular, the Qomolangma and Lhotse detachment faults).

If your class needs to go over some basic points such as what is a rock, what is a mineral, and what the three classifications of rocks are, refer to this *MSU Science Zone #31* What is a rock? *worksheet.* *http://eu.montana.edu/pdf/outreach/msuscizone31.pdf*

Activity 1: Himalaya Mountain Formation

Activity Length: 20 minutes (more if your class needs to be introduced to plate tectonics)

Materials:

- *Piece of paper, does not have to be blank (one per student)*
- *Hand towels (two for demonstration, or more for student use)*
- *Himalayan Mountain formation flip-book (one per student)* *http://www.montana.edu/everest/resources/pdf/Lesson_03_Everest_Flip_Book.pdf*
- *Colored pencils*

1. Review **plate tectonics** with your students. (If your class has not yet covered plate tectonics, please see the "Taking it Further" section for an activity that briefly introduced this concept.) Remind your students that the earth's surface is covered in tectonic plates that move and collide, helping to create landforms.
2. Ask your students to think back to the previous lesson and recall that Mount Everest is in the Himalaya Mountains. Tell your students that these mountains were formed when two **plates** (India and Eurasia) collided. Explain to your students that they will be using different objects to help them model how the Himalayas formed.
3. Have your students model mountain building with their hands.
    a. Have your students hold their hands out in front of them with their palms facing downward and their fingertips touching. One of their hands now represents the Indian plate; the other the Eurasian plate.
    b. Instruct your students to slowly add pressure and push their fingertips together. This pressure will force their fingers to bend upward as the pads of their fingers (and eventually their palms) press together.
    c. Explain to your class that this model shows in a very simple way that two colliding continental plates push land masses upward and build mountains. (Note: This model does not accurately represent how these two continental plates layered as they formed mountains.)
4. Now have each of your students set a piece of paper on their desk. (It does not have to be blank.)
    a. Have students gently but steadily push from both ends of the sheet of paper (or towel if available) toward the center. Ripples and bumps of many shapes will push up along the surface. (Once the folds in your students papers are too big, they fall over.)
    b. Demonstrate this folding for your classing using one hand towel folded in quarters.
    c. Tell your class that as the Indian plate pushes into the rest of Asia, it is causing the Eurasian plate to **fold** and make mountains, just like your paper did.
    d. Explain to your students that this was the first step of the formation of the Himalayan Mountains. (Note: Unlike the model where students used their hands, the paper and towels show how the Himalaya's rock layers folded as they were pushed upward.)
5. Explain to your students that it is not just the folding rock layers that make Mount Everest so tall. Once the rock layers are folded too much, the rocks break along their fold, creating a **fault**. Have your students watch your demonstration using two hand towels (or follow along if they have towels of their own).

    a. Push two different colored hand towels folded in quarters into each other along a flat surface with the folded edges leading and touching.
    b. The towels will both fold at first, then one towel will be forced under the other. The towel on top is being **uplifted** to form mountains. Tell your students that this is the mountain building process that formed the Himalayas.
    c. The towel that ended up on top was lighter and represents the Asian plate.
    d. The towel that ended up on the bottom after folding is the Indian plate.
6. Show your students the pictures from the Flip Book and walk them through this process again referring to the towels.
7. Have your students color and assemble the Flip Book demonstrating the formation of the Himalayas and Mount Everest.

Activity 2: Rock Layers of Everest

Lesson Length: 20 minutes

Materials:

Mount Everest Geology Profile (one per student)
http://www.montana.edu/everest/resources/worksheets/Worksheet_Everest-geology-student.pdf
http://www.montana.edu/everest/resources/worksheets/Worksheet_Everest-geology-teacher.pdf

- *Colored pencils*

1. Tell your students that Mount Everest is composed of different types of rocks that are stacked in four layers like a cake because of how the rocks were arranged as the Indian plate collided with the Eurasian plate.
2. Using the Mount Everest Geology Profile, tell your students about each of the four layers of rock (from the base of the mountain to the summit) including their properties and how they formed.
    a. Have your students locate the bottom-most layer of rock on the Profile.
    b. Tell your students about this rock.
    c. Then, have your students color this layer according to the key.
    d. Repeat this process for each of the four layers. (See the background information below for more detailed descriptions of these layers.)

Rongbuk Formation
(Color in light grey to symbolize the light color of the granite that is part of this layer.)
    a. forms the base of Mount Everest below 7,000 m (23,000 ft)
    b. **schist**, **gneiss** and migmatite
    c. leuco**granite** (light colored granite) that intruded the Rongbuk Formation visible on the North Face

North Col Formation
(Color in brown to symbolize the mud and sand that created these rocks.)
    a. 7,000 to 8,200m (23,000 to 26,900 ft)
    b. **Shale** (pelites), quartzite and marble
    c. the base of it is a detachment normal fault called the Lhotse detachment

Yellow Band
(Color in yellow to symbolize the name of the formation and its color.)
    a. 8,200 -8,600 m (26,900 to 28,000 ft)
    b. **marble** made from metamorphosed limestone with fossils

c. the top is marked by a major “detachment normal fault” called the Qomolangma detachment

Summit Pyramid (also called the Qomolangma Formation)
(Color in blue to symbolize this rock was formed in warm, shallow water.)

a. 8,600m (28,000 ft) to the summit
b. Ordovician **limestone** (470 million years old) with ostracods, trilobites, crinoids and other fossils of marine invertebrate animals

(continued from above)

e. After each of the four layers are colored in, review the rocks as a class revisiting each layer’s unique characteristics.
f. You may also wish to view a geologic map of your state to see where similar rocks can be found near you. Visit http://geology.about.com/library/bl/maps/n_statemap_MT1600.htm for a geologic map of Montana or to find geologic maps of all 50 states visit http://geology.about.com/od/maps/ig/stategeomaps.
g. If possible show your students the following two films of Dr. Dave Lageson discussing the geology of Mount Everest: Detecting Limestone *http://youtu.be/bDSDtkGWNEE* and Summit Limestone *http://youtu.be/1GPztdqmJdk*

Activity 3: Is Everest Really the Tallest?

Lesson Length: 10 minutes
Materials:

- *MSU Science Zone #29* What is the World’s Tallest Mountain? *worksheet (one per student) http://eu.montana.edu/pdf/outreach/msuscizone29.pdf*
- *Access to a computer for the students or simply provide them with the altitude of the place you live*

1. Have your students read MSU Science Zone sheet.
2. Require students to complete the questions in the “Try This!” section.

Tying it All Together:

Use the following ongoing activities to check for student understanding of each lesson’s concepts. Grade for completion, management of data collection, effort and participation throughout unit.

1. **“Mount Everest and Me” Worksheet**
   http://www.montana.edu/everest/resources/worksheets/Worksheet_EverestandMe.pdf

   This worksheet will be an ongoing activity for your students. In a table format, the “Mount Everest and Me” Worksheet compares Mount Everest, Granite Peak (the highest peak in Montana), and your hometown. Using comparisons, the worksheet reinforces the lesson’s content while helping students put this knowledge into perspective by comparing their home state and hometown. Have your students fill in the correlating rows of the table after completing each lesson. This can be completed as a class or individually.
2. **Everest Education Expedition Vocabulary Crossword Puzzle**
   http://www.montana.edu/everest/resources/worksheets/Worksheet_Lesson3Crossword.pdf

This crossword puzzle reinforces vocabulary presented in each lesson. Have your students fill in the correlating vocabulary words for each lesson's puzzle after each lesson.

Taking it Further:

Testing for Limestone
Lesson Length: 20 minutes
Description: Either have a teacher demo or let your students explore how to test rocks to see if they are limestone. Limestone will gently bubble when exposed to an acid such as vinegar.
Materials:

- *Several samples of rock with one piece of limestone included (either a single group for the teacher to use as a demo, or multiple sets for students to share and experiment with)*
- *Goggles*
- *Gloves*
- *Eye dropper bottles full of vinegar*
- *Paper towels*

Background Information:
Limestone is a kind of calcium carbonate ($CaCO_3$). It is a common chemical compound found in rocks around the world. Limestone is largely made up of tiny shells of sea creatures. Eggshells also have calcium carbonate in them and other carbonate minerals include chalk, marble and travertine. Calcium carbonate is also a key ingredient of cement and often used as a dietary supplement for calcium. Calcium carbonate can preserve fossils through permineralization (a process of fossilization in which mineral deposits form internal casts of organisms), which has occurred in the rocks on the summit pyramid of Mount Everest. There may be places in your state where this has happened. In Montana for example, most of the vertebrate fossils of the Two Medicine Formation (known for its duck-billed dinosaur eggs) are preserved by calcium carbonate permineralization.

Calcium carbonate + acetic acid → Calcium acetate + carbon dioxide + water
formula C2H4O2. (One hydrogen atom is lost when the acid ionizes.) The reaction is:
$2\ C_2H_4O_2 + CaCO_3 = Ca(C_2H_3O_2)_2 + CO_2$ (gas) $+ H_2O$.

Here is what happens if you add a much stronger acid to the calcium carbonate.

Calcium carbonate + hydrochloric acid → calcium chloride + carbon dioxide + water
$CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O$

Note that both reactions are producing carbon dioxide. Reactions similar to these are happening in the oceans right now. As greenhouse gas (such as carbon dioxide) emissions increase, the gases dissolve and react with water to make oceans more acidic. Increased acidity in the oceans is, in turn, damaging the production of shells and plates (made out of calcium carbonate) by sea creatures. Therefore we are seeing massive damage to reefs and invertebrate life, which affects many other ocean organisms.

1. Provide your students with samples of rocks, some of which are limestone and others that are not, or just demonstrate this reaction for them.

2. Provide anyone conducting the experiment with safety goggles, paper towels, and a eye dropper bottle full of vinegar.
3. Supervise the students as they place a few drops of vinegar onto each rock. Ask them if they notice any strange reactions.
4. Once they have identified which of their rocks bubbles when exposed to the vinegar, ask them if they have any ideas about what is happening.
5. Use the background information above to explain the reaction to them and its relationship to global climate change.

Extension:
Vinegar reacts with the calcium carbonate in limestone as well as the calcium carbonate found in eggshells. Have your students soak a hard boiled egg in vinegar for a few days and watch the shell disappear.
http://www.edinformatics.com/math_science/science_of_cooking/naked_egg_experiment.htm

Activity: Plate Tectonics
Explain to your students what the term plate tectonics means. Have your students peel an orange without the use of a knife and in as few pieces as possible. Tell the students to replace the peel on the orange. (You can have students secure the peel with toothpicks.) This orange peel is similar to the earth's crust because the earth's crust is in pieces just like the orange peel. The cracks are called faults. The Himalayan Mountains were formed when two of these pieces collided.

Activity: Rock Layers
As a class, examine pictures of local mountains, landforms, and rock outcrops or well-known landforms (ex. Grand Canyon) and identify the presence of rock layers. Compare and contrast these rocks with those found on Mount Everest.
Ask your students:

- Are the layers flat, or tilted like Mount Everest indicating folding?
- Can you see any individual small folds? What do you think caused this folding?
- Are the layers different colors? What colors do they see?
- How many distinct layers are there? Is this more or less than the layers they learned Mount Everest has?