Museum of the WHITE MOUNTAINS

PLYMOUTH STATE UNIVERSITY

BEYOND GRANITE

The geology of adventure

A high school geology unit

INTRODUCTION

"Our favorite hikes, climbs, and ski runs are tied to rich geologic histories… there are stories beneath our feet….We often view the mountains as an inert landscape—an environment that we explore and inhabit, a setting for our adventures. But the mountains have their own stories—how the different rock formations came to be, how the mountains have been sculpted through time, sometimes slowly, sometimes very fast, and how they continue to change today. This exhibit allows us to explore the connections between our mountain adventures and the stories of the mountains themselves. It gives you a sense of being connected to a much bigger picture, a much longer tale."

Sarah Garlick, exhibit curator

New Hampshire's White Mountains are home to some of the world's best outdoor recreational opportunities; ice fishing, snowmobiling, snowboarding, skiing, hiking, and rock and ice climbing draw visitors every year to the lakes, rivers and mountains that were formed through a series of geologic events starting more than 400 million years ago. *Beyond Granite: The Geology of Adventure*, explores connections between recreation in and the geological history of the White Mountains.

The essential questions and lessons in this unit have been designed to meet a range of ages and abilities, and are based on the NH Science Frameworks, Next Generation Science Standards, and Common Core State Standards. These questions are foundations that may be modified and changed to meet the needs of educators in their classroom and communities.

The following website contains information and resources for this activity: https://www.plymouth.edu/museum-of-the-white-mountains/exhibitions/beyond-granite-the-geology-of-adventure/

Essential Questions

- What is the connection between the geologic processes that shaped the White Mountains and the adventures people have in them?
- How do different rock types provide for diverse rock climbing experiences?
- How have plate movements caused changes in the positions and shapes of Earth's landscapes?
- How do natural forces shape and reshape the Earth's surface?

Learning Objectives from NH Science Frameworks:
Students will be able to:

- Relate plate movement of crustal plates and volcanic activity, and explain how it results in tectonic uplift and mountain building.
- Provide supporting geologic/geographic evidence that supports the validity of the theory of plate tectonics.
- Describe the processes that transform one type of rock into another, such as lithification, metamorphosis, and mechanical and chemical weathering.

Description of the Unit
The online exhibit focuses on three main areas: *Climbers and Bedrock* (the history of rock climbing in the White Mountains and the influence of different rock types on climbing styles), *Hiking Ancient Mountains* (the story of the 2,180-mile Appalachian Trail that passes through the heart of the White Mountains), and *Adventures Shaped by Climate* (how climate has shaped the winter landscape of the White Mountains and how it will likely dictate our experiences in the future). A special feature of this online exhibit includes three ultra-high resolution panoramic images created through gigapixel photographic technology: Cannon Cliff, Franconia Ridge, and Mt. Washington's

Tuckerman and Huntington ravines. These “gigapans” allow viewers to interact with the images through a deep zooming interface so that geologic features- and even climbers- can be seen up close.

This unit combines the exploration of the online exhibit with appropriate grade-level content and hands-on activities to investigate the geologic processes that created the White Mountains, and to connect these events to the activities we enjoy here. Students will investigate which of the three basic rock types are found in the White Mountains and visually understand how the differences between these rock types provide for varied rock climbing experiences. They will also explore mountain building (through plate convergence and volcanic activity) and erosion (through glaciation and other events). Throughout the unit, they will connect these processes to skiing, snowboarding, hiking, climbing and other recreational activities.

Anticipated Length of the Unit
Estimated class length: 45 minutes
Estimated length of unit: 5 days

- Class time may vary from school to school. The sequence may be modified to fit to a school’s instructional schedule.

Sequence of Daily Lessons
The following is an outline of the possible sequence of procedure for the unit. This foundation may be modified as needed by the instructor.

Day 1: Introduction: What makes and shapes mountains? Constructive and destructive forces

Objectives- Students will be able to:

- **Describe the processes that transform one type of rock into another…such as lithification…and metamorphosis.**
- **Relate plate movement of crustal plates and volcanic activity, and explain how it results in tectonic uplift and mountain building.**
- **Identify and describe processes that affect features of the Earth's surface (including plate tectonics, erosion and weathering).**

How are mountains and the adventures we have on them connected? Just as we have stories from our adventures in the mountains, the mountains themselves have quite a story to tell about how they came to be.

- Show students the 7-minute *Beyond Granite* video. Afterward,
  - Ask for definitions of geology (not just study of rocks, but processes and history of Earth's formation).
  - Ask which activities were people doing in video? What do these activities have to do with the geology of the area?
- Teacher leads discussion to continue to introduce the central theme of the unit, as well as to ***review*** the three basic types of rock (this knowledge is an important foundation for students to have for this unit):
  - The geology of an area truly influences the recreational activities people do there. For instance, let's look at how rock types influence climbing. The quote above Cannon Cliff in Section 1 states that "Geology is the primary control of the rock climbing experience." What do you think is meant by this?

  - Teacher continues to lead discussion: Investigate Images 7 (Rumney) and 8 (Whitehorse Ledge) in Section 1. Compare and contrast the rock that makes up Whitehorse Ledge with the rock that makes up the cliffs at Rumney:
    - Of what type of rock is each cliff composed (granite, schist)?
    - What is the difference in how these cliffs were formed? What processes formed each cliff? (Think about: igneous rocks/volcanic activity, metamorphic rocks/plate convergence)?
    - Are the processes that created these cliffs related to the style of rock climbing experienced at each cliff? Explain.

- Move focus to constructive and destructive forces in general. As a class, investigate images from Section 1, Section 2, and Section 3 (teacher may wish to pre-select ahead of time). Ask students which image shows an example of a constructive force (any image with mountains) and which image shows an example of a destructive force (any image that shows erosion, whether glacial, landslides, etc). Segue to: we will investigate examples of both types of these forces with images from the exhibit and other activities. Let's start with constructive forces: mountain building.
- "To hike the Appalachian Trail is to hike a seam where an ancient ocean once closed, bringing together all the world's continents into a single landmass." This quote, found in section 3, connects hiking to plate tectonics. Look at the image of the hiker that is next to this quote.
    - Relate the formation of mountains to hikers and their love for hiking. Have any students hiked in the White Mountains? Where? Did you know you were hiking upon land that had been uplifted when two plates came together? Investigate image 7 (section 3) of the Herr family: Sage (age 6), has hiked all forty-eight 4,000 foot mountains in New Hampshire, and Alex, (age 9) has hiked all of them in winter along with their mom, Patricia.
- Use this as an opportunity to teach vocabulary and concepts related to plate tectonics and mountain building. [Three types of mountains (folded, fault block and volcanoes) and how each are formed; White Mtns have folded and volcanic mountains; Folded mountains tend to form near plate boundaries in long ranges that parallel the boundaries; As plates move around over geologic time, plate boundaries change, resulting in modern day mountain belts that are far from present-day plate boundaries. Teachers may wish to show Plate Boundary Map]. Investigate the reconstruction of Pangea found in Section 3.

Day 2: Constructive Forces: Mountain Building

Objectives- Students will be able to:

- **Relate plate movement of crustal plates and volcanic activity, and explain how it results in tectonic uplift and mountain building.**
- **Provide supporting geologic/geographic evidence that supports the validity of the theory of plate tectonics.**

- Revisit vocabulary and concepts from Day 1. Use the *Presidential gigapan* in Section 2 to illustrate a mountain range that is composed of metamorphic rock, formed by the folding of layers of Earth through the convergence of plates. Compare and contrast with mountains shown in the *Franconia gigapan* (Section 3), a mountain range that is composed of igneous rock, formed from volcanic activity.
- Today students will simulate one of the processes that create mountains. They will use playdough to simulate the folding of bedrock that occurs when continental plates converge. Students should understand that this activity only models folding; however, in actual folded mountains both folding and faulting occur.

Folded mountains activity

(adapted from the Digital Library for Earth System Education Teaching Boxes)

Materials Each group of students will need:

- 2 oz. each of four different colors of play dough
- One butter knife

Procedure

1. Tell students that they will be building some mountains made up of layers.
   a. Have students roll each color of play dough, forming a flattened pancake about 15 cm. (or 6 inches) in diameter and 1 cm (or 1/3 inch) thick. The greater the diameter and the thinner the layers, the more easily the model can be folded.
   b. Have the students stack the layers on top of each other. It doesn't matter in which order the colors are stacked.
   c. Ask students to observe the layers from the side; the layers should look flat.
   d. Have students draw and label a side view of this model of unfolded layers in their science notebooks.
2. Now students will simulate compression: Have them place their hands, one on either end of the play dough layers so that they can squeeze it along its longer

axis. Tell them to gently push their hands together causing the play dough layers to fold and buckle. Try to make at least one upward fold (anticline) and one downward fold (syncline). Ask students to draw and label the folded model in their science notebooks.

3. Students should answer the following questions in their science notebooks:

- What actually might cause similar compression to occur to the earth's crust? (Answer: plates moving toward one another)
- Where might this occur: (Answer: at convergent plate boundaries)
- Do you think a person can observe mountains being formed (plates moving)?

Teacher may want to go into greater depth with plate tectonics. A plate boundary map can be found at Plate Boundary Map].

Teacher should highlight Section 3 text to help explain plate movement: "When continents collide it is analogous to a head-on collision of automobiles…."

Continue to answer questions:

- How does the model you made illustrate the processes at work in the Earth's crust?
- How is this model different from the actual process?
- How many years ago did the main mountain building event for the Presidential Range in the White Mountains occur? Refer to quote at top of Section 3. (Answer: over 400 million years ago)
- Look at the image of Jeremy Johnson on *Man Overboard* at Rumney (section 1, image 7). Can students see the folded layers in the rock of the cliff?
- Look at the geologic cross section showing the "anatomy of the Presidential Range" in section 3. (Teacher should explain how to view a cross-section: similar to the side view of layers of play dough.) Can you see evidence for the folding of metamorphic rock in the illustration?
- Were all of the mountains in the White Mountains formed in the same way as the Presidentials? Refer to the quote at the top of Section 3 to help you. (Answer: No. Other areas of the Whites, including the Franconia Ridge, formed later when large volcanoes erupted across the region.

Conclude activity: Students should understand that while this activity only models folding; however, in actual folded mountains both folding and faulting occur. Ask students what they think would happen if they had rocks that were less squishy and more brittle than play dough? When the rocks got squeezed, they might actually break instead of just bend. Tell them that natural mountains do both. Sometimes they bend and sometimes they break. The breaks are called faults, and faults that move because of compression are called "thrust faults." We therefore call this type of mountains "fold-thrust mountains" – the mountains both fold and have breaks called thrust faults.

Wrap up: In addition to mountain building, are there other geologic processes that have shaped/influenced human activities in the mountains? Brainstorm ideas. No right or wrong answers, but teacher should summarize with “geologic forces that form and shape mountains are both constructive and destructive… and tomorrow we will investigate destructive forces.”

Day 3- Destructive Forces: Erosion via Glaciers

Objective- Students will be able to:

- **Identify and describe processes that affect features of the Earth's surface (including plate tectonics, erosion and weathering).**

- Start class with discussion: have the White Mountains remained exactly the same since they were formed, whether from volcanic activity or collision of plates? What else has shaped them? Students will intuitively know that the mountains have not stayed the same, and some will likely mention erosion, glaciers, or the Ice Age as something that shaped the White Mountains. Basically, erosion (of various types) and weathering are destructive forces that shape terrain. Introduce vocabulary words such as glacier, erosion and weathering. (Erosion is a destructive force that sculpts and shapes all mountains. Mountains are usually made up of many types of rock, and some rock types erode more easily than others, producing differential rates of erosion in neighboring rocks.)
- Students will investigate one such force today: glacial activity, and how it shapes mountains. First, show image of reconstruction of the ice sheet covering North America (section 2, image 12). Identify NH on this map. Did glaciers once cover NH?
- When did glaciers last visit the White Mountains? Refer to the quote at the top of Section 2 to help you with this question. (Answer: 11,700 years ago)
- Supplement with additional content, if desired (types of glacial action, etc.)

Students will investigate one such force today: glacial activity, and how it shapes mountains.
There are several activities teachers might choose from to communicate the ways in which glaciers shape land. One recommendation is:

- *Explaining Glaciers, Accurately* (free NSTA *Science and Children* journal article, April/May 2009). Describes two activities that help students develop correct understanding of how glaciers change the earth's surface: water, ice cubes, small rocks and dirt are used to demonstrate plucking; and pieces of wood, sandpaper, ice, and various types of rocks are used to demonstrate abrasion.
- After completing the activity, students should use the exhibit to answer the following questions in their science notebooks:
    1. After completing one of the above activities, have student look at the Mount Washington panoramic in section 2. Ideally, students should do this independently or in pairs. Teacher should help students understand

navigation so they can zoom in on Tuckerman Ravine. Can they spot the areas that were channeled, or rounded out by glaciers? The two deepest "bowls" just to the left and right of the center are Tuckerman and Huntington Ravines. Tuckerman Ravine is famous for spring skiing. What is it about the shape of a ravine that makes it a better place to ski than other parts of the mountain? (Answer: ravines collect more snow.)

2. What other images show evidence that glaciers once moved over the White Mountains? Students should select an image from the exhibit, and through discussion or in science notebooks, describe the shapes of the mountains seen in the photograph. How can they tell that glaciers shaped them?
3. Can students find evidence for other types of erosion in the images? (They should be able to spot landslides, eroded dykes, etc.) Select an image and describe to partner or to entire class.
4. Can we see glaciers moving? Can we see rocks eroding? Which types of erosion might people actually witness? (Any images with talus or gullies are examples of erosion, which is largely a very slow process. Any images with landslides, such as Hillman's Highway, image 8 (section 2, are examples of fast processes.)

Day 4: Destructive Forces: Erosion and Weathering

Objective- Students will be able to:

- **Identify and describe processes that affect features of the Earth's surface (including plate tectonics, erosion and weathering).**

- Review that on Day 3 students investigated one type of erosion, glacial activity. Today we will explore other types of erosion and also another type of destructive force called weathering. Begin with: some geologic processes happen very slowly, over a long period of time, while other processes happen quickly. Students should find an example of each- a slow process, and a fast process- in the exhibit images. Select volunteers to describe the features in the images they chose, the geologic processes that shaped each feature, and the effect each process had upon the land to create each feature. (Teacher should use this as an opportunity to reiterate that some changes happen slowly and others happen quickly.)
- Teach content: Define erosion, weathering, chemical weathering, and mechanical weathering. Be sure to help students understand difference between erosion and weathering, and be sure to discuss factors that contribute to both, such as freeze-thaw, gravity, and differential rates of weathering of different rock types. Teacher may wish to show images from exhibit as examples (Images 1, 2 and 15 of Old Man in section 1; talus seen in Cannon gigapan of section 1; or any images that show features such as the movement of talus down slope due to gravity, dyke erosion, etc.)

Content from the USGS National Park Service:

"Weathering involves two processes that often work in concert to decompose rocks. Both processes occur in place. No movement is involved in weathering. **Chemical weathering** involves a chemical change in at least some of the minerals within a rock. **Mechanical weathering** involves physically breaking rocks into fragments without changing the chemical make-up of the minerals within it. It's important to keep in mind that weathering is a surface or near-surface process. As you know, metamorphism also produces chemical changes in rocks, but metamorphic chemical changes occur at depth where either the temperature and/or pressure are significantly higher than conditions found on the Earth's surface.

As soon as a rock particle (loosened by one of the two weathering processes) moves, we call it erosion or mass wasting.. Rock falls, slumps, and debris flows are all examples of mass wasting. We call it erosion if the rock particle is moved by some flowing agent such as air, water or ice. So, here it is: if a particle is loosened, chemically or mechanically, but stays put, call it weathering. Once the particle starts moving, call it erosion."

- Investigate Diagram of Old Man Collapse from Union Leader (section 1, image 1). NH lost its state symbol, the Old Man of the Mountains, in 2003. In science notebooks, students should use new vocabulary to describe the processes that caused the Old Man to fall.

Day 5: Stories of mountains, stories of adventure

Objective- Students will be able to:

- **Give an example that illustrates the connection between the geologic processes that shaped the White Mountains and the adventures people have in them.**

Many people snowshoe, ice fish, snowmobile, snowboard, ski, hike, rock and ice climb in the White Mountains each year. The White Mountain Visitors' Center and the Museum of the White Mountains want more people to come here to do these activities! Pick one activity. Create a story board that the Visitors Center will use as advertising to inspire people to come do this activity in the White Mountains!

- Find an image from the exhibit of a person performing your chosen activity.
- Create a 4-panel storyboard. Each panel should include text and illustrations.
    - Panel 1 should begin with the exhibit image (or draw one of your own that shows that same type of geologic feature- mountain, cliff- as the exhibit image. Be sure to include a person doing their activity!). Include a tagline to describe what the person is doing.
    - Panel 2 should use vocabulary and concepts learned in this unit to describe how the feature (mountain, cliff, etc.) was *formed*.
    - Panel 3 should use vocabulary and concepts learned in this unit to describe how the feature (mountain, cliff, etc.) was *shaped*.
    - Panel 4 should explain the connection between the activity and the characteristics of the landscape that make this activity possible. Include a sentence that states why the White Mountains are *the perfect* place to come do this activity!

Instructional resources
An Abecedary of Rocks and Ice: An alphabetical introduction to the geology of the White Mountains

Roadside Geology of Vermont and New Hampshire (Roadside Geology Series) by Bradford B. Van Diver

NH Department of Environmental Services: Hot Topics

- 2013 Highway Geology Symposium Field Trip Guide:
  Introduction
  History
  Field Trip Overview
  Stop Descriptions
- Madison Boulder Natural Area brochure

PhysicalGeography.net

- Intro to the Lithosphere
- Composition of Rocks
- Plate tectonics
- Mountain Building

Digital Library for Earth System Education

- Evidence for Plate Tectonics
- Mountain Building

Glaciers, Climate and Society

- *Compendium of excellent* glacier education resources *for all grade levels*

NeoK-12

- Collection of online educational videos about glaciers

Assessment
Teachers may use diagrams in students' science notebooks and activity discussion questions as formative assessment. The final question on Day 5 may be used as a summative assessment. Additional assessments, tailored to specific student needs and learning styles, may be designed by the teacher. Assessments by should be guided by the essential questions. Did students explore, engage with, address and interpret the essential questions during the unit?

NH Science Curriculum Frameworks

S:ESS1:11:5.2 Relate plate movement of crustal plates and volcanic activity, and explain how it results in tectonic uplift and mountain building.
S:ESS1:11:5.4 Provide supporting geologic/geographic evidence that supports the validity of the theory of plate tectonics.
S:ESS1:12:6.1 Describe the processes that transform one type of rock into another, such as lithification, metamorphosis, and weathering on a chemical level.

Common Core State Standards

- ELA-Literacy.RST.11-12.9. Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

Next Generation Science Standards

Disciplinary Core Ideas

- ESS1c. The History of Planet Earth
  The rock record resulting from tectonic and other geoscience processes as well as objects from the solar system can provide evidence of Earth's early history and the relative major geologic formations.

- ESS2.B Plate tectonics and large-scale system interactions
  Plate tectonics is the unifying theory that explains movements of rocks at Earth's surface and geological history. Maps are used to display evidence of plate movement.

- ESS2.C The roles of water in Earth's surface processes
  Water movement causes weathering and erosion, changing landscape features.

Cross Cutting Concepts

- Patterns
- Cause and effect
- Scale, Proportion and Quantity
- Stability and Change

Science and Engineering Practices

- Developing and using models
- Constructing explanations
- Engaging in argument from evidence