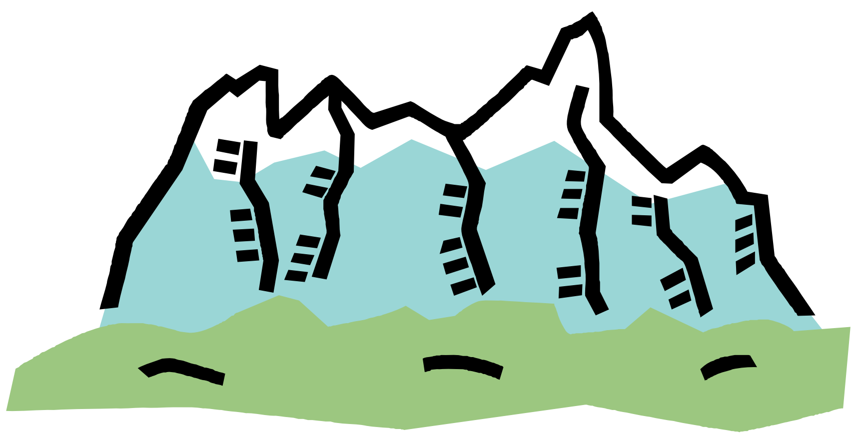
Mountain Building Journal

Teacher's Guide



Name: ______________________________________ Class: _____________________

Table of Contents

Congratulations!

You have just landed a summer internship working for National Geographic magazine. Your assignment is to create an informative photo essay about Mountains. How will you make the story of these mountain come alive for the magazine's readers? What would *they* want to know about these mountains? What kinds of questions do *you* have about mountains? What do you need to know in order to *write* about mountains?

During the course of this unit you will be investigating mountains, including:

- What they look like.
- How they are made.
- What they are made of.
- Where they form.
- Why they form.

You will need to gather all this information on the mountains pictured in the Mountain Photo Archive in order to complete your National Geographic assignment.

Summer Internship Department

National Geographic Society of America

Lesson 1: Why do mountains look the way they do?

Activity 1: What do I know? What do I want to know?

What do I know?

Answers will vary.

What do I want to know?

Answers will vary.

Lesson 2: How to make a mountain

Activity 1: Investigating shape

Think about what mountains look like. What is the difference between a mountain and any other geologic formation? Look at the Mountain Photo Archive and group the mountains into several categories based on shape or size. Mountains can only be listed in one category. In the table below, list your categories in the left column and the mountain photos that you placed in that category in the right column.

Categories	Mountains
Answers will vary.	

What, if anything, was difficult about assigning the mountains to their groups?

Answers will vary.

Activity 2: Folded Mountains

Unfolded Layers (side view)

Folded layers – showing upward and downward folds (side view)

Top cut off to model surface erosion:

Student's choice:

Review and Reflection

Answer the following questions in the space below.

1. How does the model you made illustrate processes at work in the Earth's crust?

   Compression can produce folds in surface rocks

2. What is the name of the force at work in the Earth's crust that makes folded mountains?

   Compression

3. Look at the Mountain Photo Archive. Which, if any, of these mountains look like they are made of folded layers?

   Student answers will vary. Folded mountains are Flat Iron, Zagros

Activity 3: Fault block mountains

Illustrate the formation of Fault Block Mountains using the book model here:

Fault block model before stretching of the crust	Fault block model after stretching of the crust
______________________________ Width of the crust from left to right.	______________________________ Width of the crust from left to right.

Review and Reflection

Answer the following questions in the space below.

1. Look at your "before" and "after" drawings. How did the measurements change? Why do you think this happened?

   The width increased due to expansion of the surface area.

2. Now look at the picture of the Basin and Range Province in Nevada. Based on what you have just learned how do you think these mountains were formed?

   The Basin and Range Province was formed in the same way, by stretching of the earth's crust.

Activity 3 (Optional Extension): Paper fault models

1. Draw and Label each type of paper model fault in a box. Label the hanging wall (A) and the Foot Wall (B), and use arrows to show the relative motion of each side of the fault. Use the line beneath the box to label the type of fault.

Type of Fault ____

Type of Fault ____

Type of Fault ____

Type of Fault ____

Type of Fault ____

Type of Fault ____

Type of Fault ____

Review and Reflection

Answer the following questions in the space below.

1. Which types of faults are produced by tension, compression and shear?

   Tension: Normal Faults

   Compression: Thrust Faults

   Shear: Transverse or Lateral Faults

2. In looking at the paper fault models, which types of faults do you think could contribute to mountain building. Why?

All can. They all move large blocks of the earth and this can result in mountain formation. Typically tension and compression form mountains. Examples: Normal - Sierra Nevada, Thrust - Rocky Mtns,

3. Look at the Mountain Photo Archive. Which, if any, of these mountains look like they could have some faulting associated with them?

Answers will vary. Ruby Mtn. and Franklin Mtn.

Activity 4: How thick is it? Viscosity and Volcanoes

Data Table

Viscosity	Speed of Flow	Area of the Base	Height
High	slow	Comparatively small	Comparatively tall
Medium	Intermediate	Intermediate	intermediate
Low	Fast	Very wide	Very low

Review and Reflection

Use the observations you made during the experiment to answer the following questions.

1. What viscosity of lava produces low, flat volcanic mountains? High viscosity
2. What viscosity of lava produces high, steep-sided volcanic mountains? Low viscosity
3. What viscosity of lava produces volcanic mountains with a wide base? High viscosity
4. What viscosity of lava produces volcanic mountains with a narrower base? Low viscosity
5. Based on your observations, what can you say about how viscosity affects the shape of volcanoes?

High viscosity lava produces narrow, steep-sided volcanoes. Intermediate lava produces large volcanoes with higher, steep-sided, stratovolcanoes, and Low viscosity lava produces very broad, gently sloping volcanic shields

6. Look at the Mountain Photo Archive. Which mountains do you think might be volcanoes? Explain why you think they are volcanoes.

Answers will vary. Volcanoes are Iliamna, Avacha, Mauna Loa, and Frenandina

Lesson 3: Erosion: What goes up must come down

Activity 1: Erosion Drawings

Draw before and after pictures of each of the four kinds of mountains.

Before Erosion	After Erosion
1	
2	
3	
4	

Review and Reflection

Use complete sentences to answer the following questions in the space provided.

1. Did some mountain models erode more easily or more completely than others? Which ones and why?

The ones with more sand erode more easily. Sand is less consolidated and therefore washes away more easily.

2. Real mountains aren't usually made of sand, so how can these models illustrate the erosion and shaping of real mountains?

The sand and other materials can be used to represent how different materials erode at different rates.

3. Look at the Mountain Photo Archive. Do any of these mountains appear to be made by **erosion of surrounding materials** rather than the uplift of new material? Name them and explain your reasoning.

Answers will vary. Mitten Buttes and Hopi Butte

Lesson 4: What are you made of? Composition and the rock cycle

Activity 1: Rock Composition

http://www.geocities.com/RainForest/Canopy/1080/
http://www.windows.ucar.edu/tour/link=/earth/geology/rocks_intro.html
http://www.fi.edu/fellows/fellow1/oct98/create/index.html

Use these websites to research the rocks listed in data table. Information on rock composition is useful when determining how a mountain was made.

Composition Data Table

Rock Name	Rock Type	Description	How it Formed	Erodability
Rhyolite	Extrusive - igneous rock	No crystals to very small crystals usually light in color with lots of quartz and feldspars	Volcanic eruptions, thick lavas that tend to build domes	Medium – moderately erodable
Andesite	Extrusive - igneous rock	Grey groundmass with visible larger crystals of olivine, hornblende, pyroxenes	Volcanic eruption, medium viscosity; forms stratovolcanoes	Medium to hard
Basalt	Extrusive - igneous rock	Black to dark grey; very small crystals may not be visible with the nake eye	Volcanic eruption, low viscosity; forms shield volcanoes	Medium to hard
Granite	Intrusive - igneous	Salt and pepper; large inter-grown crystals of feldspar, quartz, hornblende, and micas	Plutons, crystallize large magma chambers	Hard

Rock Name	Rock Type	Description	How it Formed	Erodability
Conglomerate	Sedimentary	Large pebbles to boulders cemented in lithified sand or mud matrix	Near shore or river environments	Medium to Easy
Sandstone	Sedimentary	All-tends resistant minerals (quartz, feldspars, magnetite)	Near shore, river, lakes	Medium to Easy
Shale	Sedimentary	Fine grains of sediment, cemented together	Continental shelf and lake environments	Easy
Limestone	Sedimentary	White, chalky, soft, can have fossils	Ocean	Variable medium to hared-depends on climate

Rock Name	Rock Type	Description	How it Formed	Erodability
Slate	Metamorphic	Fine grained with the grains aligned to form parallel sheets	Medium depth burial and moderate temperature	Medium
Marble	Metamorphic	White crystalline, can have fossils	Medium depth burial and moderate temperature	Medium
Schist	Metamorphic	Layers of micas, can have secondary minerals like garnet	Medium deep burial and medium to high temperatures	Medium to hard
Gneiss	Metamorphic	Layered with crystals and micas Can have secondary minerals like garnet	Deep burial high temperature	Hard

Activity 2: Rock cycle journey

Background:

The rock cycle is a dynamic process that drives the formation and destruction of mountains and affects entire continents, global weather and ultimately all life on Earth. In this game you will model what can happen to a bit of rock or sediment as it moves through the rock cycle.

Directions:

In this game, rock cycle stages and types of rocks, such as *melting*, *cooling* or *metamorphic*, are located at 11 different stations. Each station has a "die" – a box that is labeled on each of its six sides. The sides of the dice are marked to reflect the relative likelihood of materials actually moving through the stages. For example, rock material may remain in a molten state inside the earth for long periods of time. To show this, the die at station # 10, "Magma," has four sides that say "magma (stay as you are)" and only two sides that say "cooling and hardening." If you roll the "magma (stay as you are)" side of the die, you will stay at station #10 and roll again when it is your turn. If you roll one of the sides that say "cooling and hardening" you would move to station #9, the "Cooling and Hardening (crystallization)" station.

1. Begin by choosing one station to start at. There are 11 stations so there should be two or three students at each station at the beginning of the game. It does not matter where you start; you probably will have a chance to visit most of the other stations during the game.

2. Use you data table to record the # of the station you begin at in the column marked "station #." Record the name of your station in the column marked "station name."

3. Now you get to roll the die. Since this is your first roll, put a 1 in the data column box for "roll #." After rolling the die, record what the die instructed you to do in the "what happened" column of the data table.

4. In reality there is no set formula for how long rocky material spends at each stage of the rock cycle. It may speed through in just 200,000 years or so, or it may stay at the same point in the cycle for millions of years. For the purposes of this game, count each roll of the die as 200,000 years. Even if you end up staying at the same place for multiple turns, every time you roll the die you add another 200,000 years to the age of your rock.

5. Record each of these pieces of information in your data table each time you have a turn. It is important to keep careful records, as you will need the information to complete a "data summary" and answer some questions at the end of the game.

Sample Data Table

ROLL #	STATION #	STATION NAME	WHAT HAPPENED (Stay as _____ or change into ____?)
1	10	Magma	Stay as magma
2	10	Magma	Stay as magma
3	10	Magma	Change to cool and hardened rock
4	9	Cooling and heating	Cool and harden stay crystalline
5	9	Cooling and heating	Change to igneous rock
6	4	Igneous rock	Change! Weathering and erosion
7	11	Weathering and erosion	Weathering and erosion stay here
8	11	Weathering and erosion	Stay as weathering and erosion
9	11	Weathering and erosion	Stay a weathering and erosion
10	11	Weathering and erosion	Change to sediments

Data Table

ROLL #	STATION #	STATION NAME	WHAT HAPPENED (Stay as _____ or change into ____?)

Data Summary

Total Number of Visits to Each Station

Station	**Total # of Visits to this Station** Each time you are told to "go" or "stay" at a station it counts as a visit.
compaction and cementation	
high temperature and pressure	
sediments	
igneous rock	
to the surface	
metamorphic rock	
sedimentary rock	
melting	
cooling and hardening (crystallization)	
magma	
weathering and erosion	

Total number of stations visited altogether: ________________________________

Which station, or stations, did you "visit" more than 3 times?___________________

Total visits to station # 4: ________ What type of rock is this?________________

Total visits to station # 6: ________ What type of rock is this?________________

Total visits to station # 7: ________What type of rock is this?_________________

How many different turns (rolls of the die) did you have?______________________

Review and Reflect

Answer the following questions in the space below.

1. Did you get "stuck" for more than 10 turns at any particular station? Which one and for how long?

Answers will vary

2. How many total rolls of the die did you spend as each rock type ?
   Example: METAMORPHIC: 8
3. If you did not become one of the following rocks, put a zero in that space.

   METAMORPHIC:________ IGNEOUS:________ SEDIMENTARY:________

Answers will vary

4. How long did it take your rock to move through the rock cycle? Each roll of the dice is a turn and each turn is equal to 200,000 years of geologic time. Find the age of your rock by multiplying your total number of turns 200,000. Write the answer below.

Answers will vary

Compare your journey through the rock cycle with at least two other students. Is there only one path through the rock cycle? Explain.

Answers will vary

Optional extension: Cartoon Challenge

Use this sheet as a kind of journey log to help plan your cartoon strip. Record your steps as you traveled to new stations during your rock cycle journey. Describe your experience at each station and say what kind of rock or material you were (igneous, sediments, magma, etc.). It is okay if you did not actually go to new stations 12 times; just fill out what you did.

1. I began my adventure as ____ at this station:

____. 2. The next station I went to after that was

____ where I became ___________________________.

3. After that station, I became ____at station:

____. 4. Next, I went to this station_________________

_________________________________ and turned into ______________________________________.

After that, I found myself at station: ______________________________________ where I became

____.

Next, I went to ____ and turned into

____. 8. The next station I went to after that was

_____________________________________ where I became __________________________________.

9. After my experiences there, I became ____at this

station ____.

10. Next, I went to ____ and turned into

____. 11. Following that, I went to

_______________________________________ where I became _______________________________.

12. Finally, after that last station I ended up as ____

at this station____.

Cartoon Strip

Create a comic strip story of your journey through the rock cycle.

Lesson 5: Location and setting: Plate tectonics and mountains

Activity 1: Map it!

Mountain Information Table

Use this data to locate each mountain on the map on the next page. Since the map is small, you can just use the number of each mountain for labeling.

	Latitude	Longitude
1. Avacha	53.25 N	158.83 E
2. El Capitan	37.73 N	119.64 W
3. Fernandina	0.37 S	91.55 W
4. Flat Irons	39.99 N	105.29 W
5. Franklin Mountains*	31.9 N	106.49 W
6. Hopi Butte**	35.50 N	111.00 W
7. Iliamna	60.03 N	153.09 W
8. Mauna Loa	19.48 N	155.6 W
9. Mitten Buttes	36.92 N	110.07 W
10. Ruby Mountains*	45.31 N	122.23 W
11. Torres Del Paine*	53.0 S	72.5 W
12. Zagros Mountains*	27.3 N	54.5 W

* mountain ranges
** volcanic field

Blank map with plate boundaries

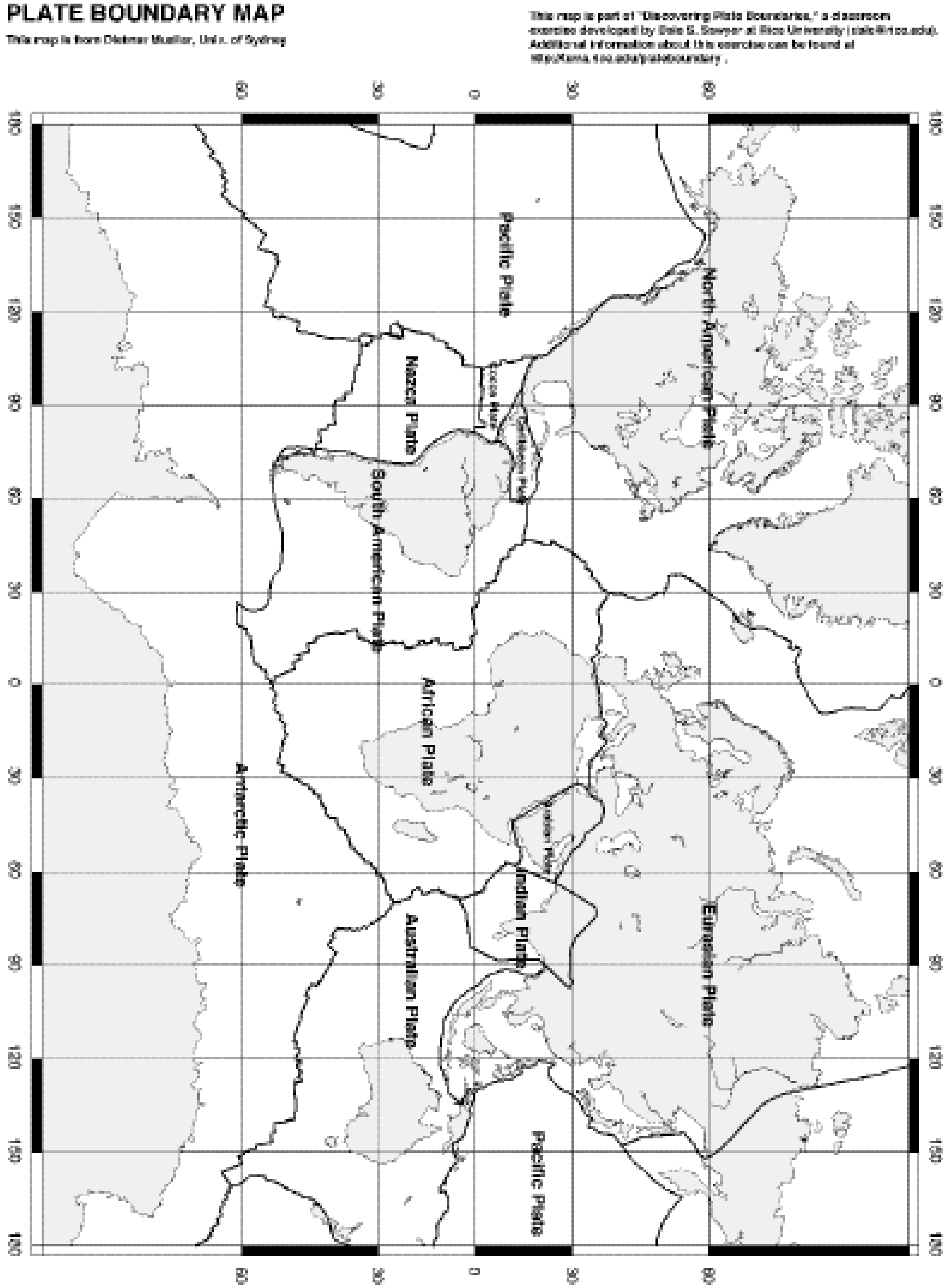


Plate Boundary Proximity Data Table

Mountain	Proximity to Plate Boundary (near or far)
1. Avacha	Near
3. El Capitan	Near
4. Fernandina	Near
5. Flat Irons	Far
12. Franklin Mountains	Far
6. Hopi Butte	Far
7. Iliamna	Near
8. Mauna Loa	Far
9. Mitten Buttes	Far
2. Ruby Mountains	Far
10. Torres Del Paine	Near
11. Zagros Mountains	Near

Review and Reflect

Based on your completed map answer the following questions.

1. Name the mountains (or their numbers) that are located on a convergent plate boundary.

   Avacha, Ilimna, El Capitan, Torres Del Paine, Zagros

2. What kinds of mountains are created at or near convergent plate boundaries?

   Folded, volcanic, batholiths

3. Name the mountains (or their numbers) that are located on a divergent plate boundary.

   Fernandina, Ruby Mtns and Franklin Mtns

4. What kinds of mountains form at divergent boundaries?

   Fault block mountains

5. Name the mountains (or their numbers) that are not located near a plate boundary.

   Mauna Loa, Mitten Buttes, and Hopi Butte, Flat Irons

6. What could explain the presence of mountains that are far away from plate boundary?

   Plate tectonics; the plates move over time and mountains that formed near a boundary can carried far from their origin.

Optional:

7. What do you notice about the relationship between plate boundaries, volcanoes, and mountains?

   Mountains and volcanoes form at or near plate boundaries.

Batholiths

Using what you know about rock composition and the appearance of the mountains in the Mountain Photo Archives, do you think any of them could be batholiths? If so, which ones? You know that El Capitan is a batholith but there is one other. Describe what it is about the appearance of these two mountains that characterize them as batholiths.

Notes on batholiths:

Comparison:

	El Capitan	?: Torres Del Paine
Rock type	Granite	Granite
Appearance **(Massive or Layered)**	Massive	Massive
Proximity to Boundary	Near	Near
Type of Boundary	Convergent	Convergent
Other	Boundary type has changed from convergent to transform and moved west.	Boundary has not changed over time nor has it moved over time.

Mesas and Buttes

Can you tell if any of the mountains in the Mountain Photo Archives are mesas or buttes? If so, which one(s)? Mitten Buttes is one of them. Can you find the other? Describe what it is about the appearance of these two mountains that characterize them as a mesa or a butte.

Notes on Mesas and Buttes:

Comparison:

	Mitten Buttes	?: Hopi Butte
Rock type	Sandstone	Sandstone capped by a lava flow
Appearance (Massive or Layered)	Layered	Layered
Proximity to Boundary	Far	Far
Type of Boundary	None	None
Other	Arid climate	Arid climate

Mountain Data Table

Name of Mountain	Topography (Shape)	Composition	Type of Mountain	Latitude	Longitude	Type of Plate Boundary	Proximity to Active Boundary	Geologic Origin
Avacha	Cone	Andesite	volcano	53.25 N	158.83 E	Convergent.	Near	Subduction
El Capitan	Massive.	Granite.	Batholith.	37.73 N	119.64 W	Convergent.	Near	Subduction
Fernandina	Shield shaped; low dome	Basalt.	Volcano.	0.37 S	91.55 W	Divergent.	Near	Hot spot
Flat Irons	Tipped layers.	Sandstone.	Folded and faulted	39.99 N	105.29 W	None.	Far	Compression
Franklin	Irregular, blocky	Sedimentary.	Fault block.	31.9 N	106.49 W	None.	Far	Tension or extension
Hopi Butte	Lava-capped column..	Basalt over sandstone.	Butte.	35.5 N	111 W	None.	Far	Erosion
Iliamna	Cone.	Andesite.	Volcano.	60.03 N	153.09 W	Convergent.	Near	Subduction
Mauna Loa	Low, flat shiled.	Basalt.	Volcano.	19.48 N	155.6 W	None.	Far	Hot spot
Mitten Buttes	Flat-topped column.	Sandstone.	Butte.	36.92 N	110.07 W	None.	Far	Erosion
Ruby Mountains	Irregular; blocky.	Metamorphic rocks.	Fault block.	45.31 N	122.23 W	None.	Far	Tension or extension
Torres del Paine	Massive.	Granite.	Batholith.	53.0 S	72.5 W	Convergent.	Near	Subduction
Zagros Mountains	Folded.	Sedimentary.	Folded.	27.3 N	54.5 W	Convergent.	Near	Compression

Mountain Diagnostic Table

Type of Mountain	Batholiths	Mesas & Buttes	Fault Block Mountains	Folded Mountains	Volcanoes
Topography/ Shape	Craggy, steep-sided mountains	Flat topped with steep sides	Relatively triangular	Can have many shapes	Either shield shaped or cone shaped
Layer Description	No layers	Horizontal layers	Tilted layers	Folded layers	No layers
Type of Plate Boundary	Near ancient convergent plate boundaries	Does not need to be near plate boundary	Divergent	Convergent	Any, or at hotspot

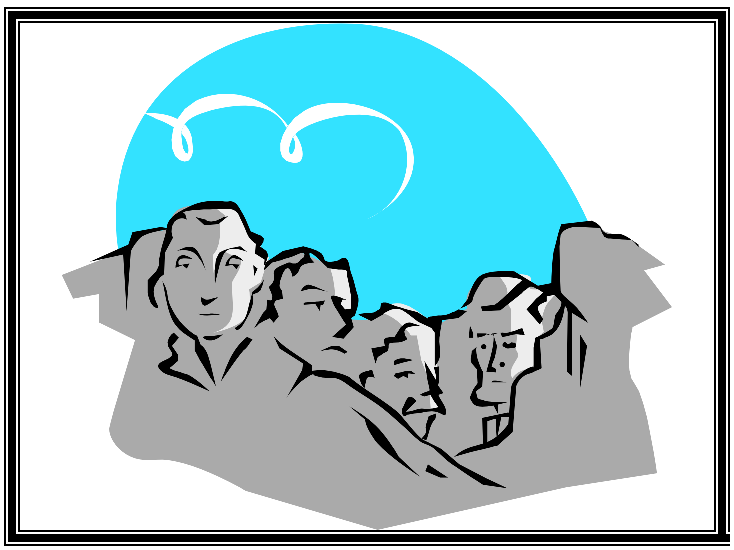
Lesson 6: Mountain histories: National Geographic Photo Journal

Write your photo captions in the space provided. Be sure to include all of the details shown below when writing your captions for each mountain. You will need to use your Mountain Building Journal and you will need to do some research on-line or in the library.

Details, Details!

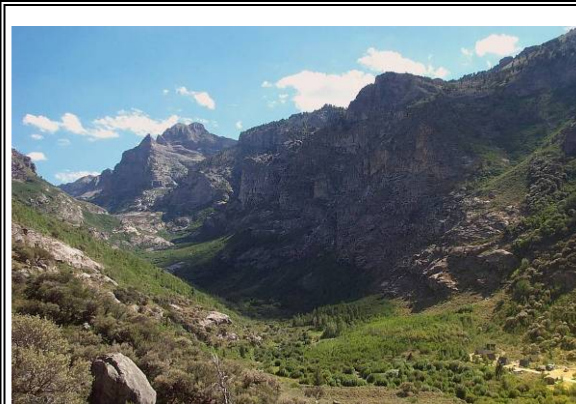
- name
- location (country, state, latitude and longitude)
- elevation
- geologic origin (faulting, folding, volcanism)
- composition (layered, basalt, etc.)
- shape (low and rounded, jagged, etc.)

EXAMPLE



Mount Rushmore

Mt. Rushmore is located in the Black Hills of South Dakota (43°52’N, 103°28’W). The Black Hills were formed approximately 1.5 billion years ago by folding and thrust faulting. The mountains were originally as high as 15,000 ft. Mt. Rushmore now stands at 5725 ft. Mount Rushmore is a massive body of granite and is part of the Harney Peak Batholith. Mount Rushmore is not currently on an active plate boundary. It was formed by compression of the North American Plate.



Avacha

Ruby Mountains

Photo courtesy of Tatyana Rashidova

Photo courtesy of Larry Morales

El Capitan

Fernandina

Photo credit: copyright © Bryan Law;
Image courtesy Earth Science World Image Bank
http://www.earthscienceworld.org/images

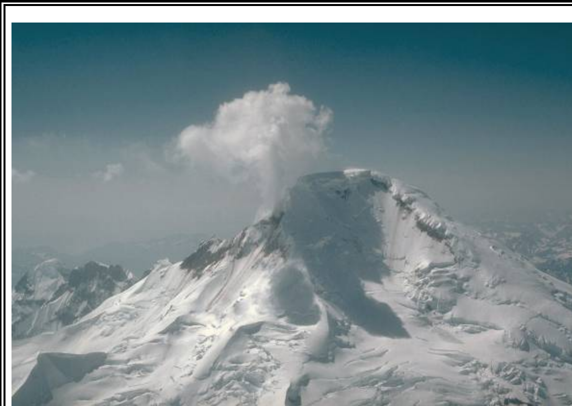
Photo courtesy of Chuck Wood, 1979

Flat Irons

Franklin Mountains

Photo courtesy of Deborah Trimble

Photo courtesy of Scott M. Cutler,9 Mar, 1998

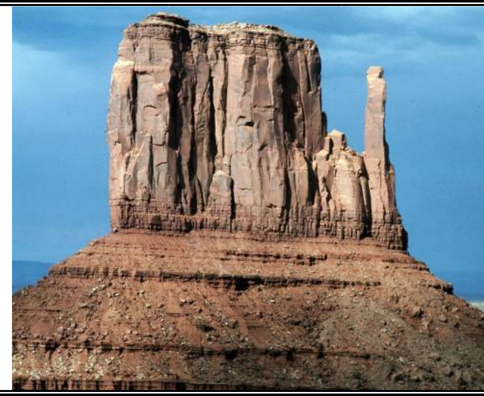


Hopi Butte

Iliamna

Photo credit: copyright © [Louis Maher](); Image courtesy Earth Science World Image Bank http://www.earthscienceworld.org/images

Photo courtesy of R. G. McGimsey, Alaska Volcano Observatory/U.S. Geological Survey, May 6, 1986



Mauna Loa

Mitten Buttes

Photo courtesy of J.D. Griggs, Hawaiian Volcano Observatory, U.S. Geological Survey, January 10, 1985

Photo credit: copyright Bruce Molnia, Terra Photographics; Image courtesy Earth Science World Image Bank http://www.earthscienceworld.org/images

Torres Del Paine

Zagros Mountains

Photo credit: copyright Louis Maher, University of Wisconsin; Image courtesy Earth Science World Image Bank http://www.earthscienceworld.org/images

Photo courtesy of U.S. Geological Survey