CHAPTER 14 GEOLOGY AND EARTH RESOURCES

Chapter Overview

Plate tectonics and the rock cycle shape the Earth and its resources. Mining Earth's resources creates environmental issues. All AP students should know the environmental and economic advantages and disadvantages of mining. Conservation of resources is a fundamental AP topic. Geologic hazards, including earthquakes, tsunamis, and floods have devastating effects on natural ecosystems.

Topics and Key Concepts

Earth Systems and Resources

- Discuss risks and impacts of the various geological hazards.
- Diagram Earth's layers.
- Identify and describe the three types of plate boundaries.
- Differentiate between a mineral and a rock.
- Draw the rock cycle.

Land and Water Use

- Evaluate the environmental effects of resource extraction
- Discuss conservation of geological resources.

Energy Resources and Consumption

- Identify the metallic and fossil fuel non-renewable resources discussed in the chapter.
- Differentiate between the various mining techniques.
- Relate the various types of processing needed to remove the desired metals from ore.

Key Terms

*aesthenosphere
*convergent plate boundary
core
crust
*divergent plate boundary
earthquake
igneous rock
lithosphere
magma
mantle
mass wasting
metamorphic rock
mid-ocean ridge
mineral
mountaintop removal
rock
rock cycle
sedimentary rock
sedimentation
*SMRCA
subduction zone
tectonic plate
*transform plate boundary
tsunami
volcano
weathering

Pacing Guide

In many ways, the geology of Earth, the types of rocks and minerals in an area coupled with its geographic location, determines the type of climate, ecosystem, and population. Many students do not understand the foundations of rocks and soils. Plan to spend 5-7 days on this chapter.

Approach and Tips

The study of geology includes more information than you have time to cover adequately in this course. Therefore, you have to limit your emphasis to basic information dealing with tectonic processes, the rock cycle, and geologic hazards.

The interactions of the rock cycle and tectonic processes are important concepts when discussing minerals and mining. While students are probably aware that metals and minerals are nonrenewable resources that have to be conserved and recycled, linking the information to the common elements and minerals on Earth may make the point more clearly than simply reminding them.

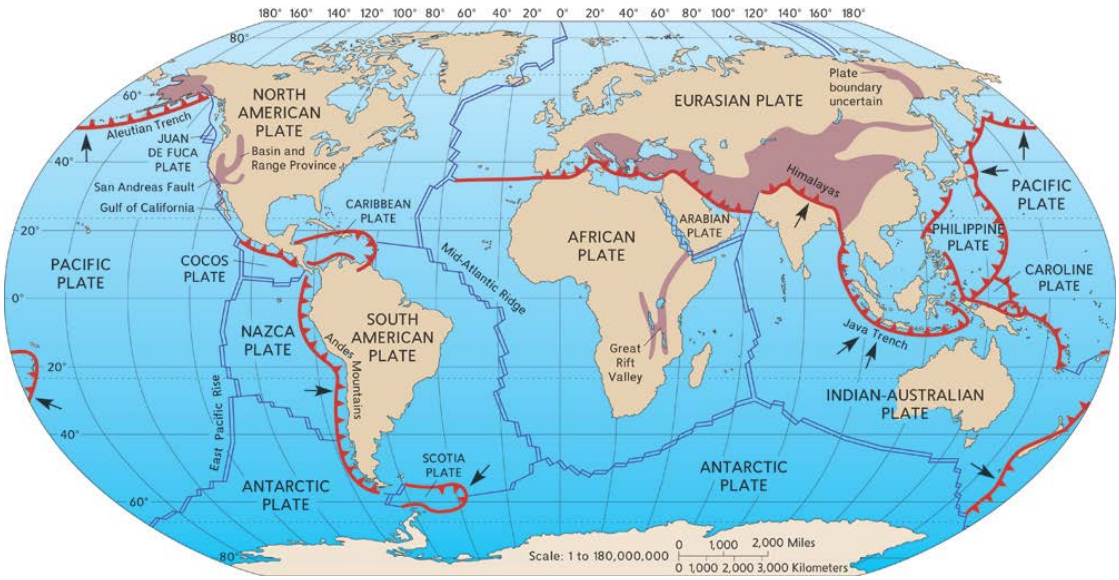
Eight Most Common Chemical Elements (Percent)			
Whole Earth		**Crust**	
Iron	33.3	Oxygen	45.2
Oxygen	29.8	Silicon	27.2
Silicon	15.6	Aluminum	8.2
Magnesium	13.9	Iron	5.8
Nickel	2.0	Calcium	5.1
Calcium	1.8	Magnesium	2.8
Aluminum	1.5	Sodium	2.3
Sodium	0.2	Potassium	1.7

Discuss the uses of silicon, aluminum, iron, and so on in the students' daily lives. Ask them to explain how each one is obtained.

The geologic time scale and movement of the crustal plates are areas of interest to most students, mainly because they studied dinosaurs and volcanoes in earlier science classes. It is not necessary to go into a great deal of depth on this subject, but do include a review in your discussion (see Figure 14.3).

The use of current earthquakes to mark specific plates can be illustrated. Describe the “ring of fire” as a subduction zone, where the more dense oceanic plates sink into the asthenosphere below the less dense continental plates. This area is also the location of most of the world’s volcanic and earthquake activity.

Explain that geologic forces have shaped our world through millions of years. Massive events of change happen rarely and are referred to as natural disasters. Students should be able to understand that these natural disasters can have several important implications on environmental issues. Floods take the most human lives. Hurricanes and tornadoes cause the greatest property damage. Describe the role of plate tectonics and the occurrences of earthquakes, volcanoes, and tsunamis. Earthquakes cause the most damage in areas with poorly constructed buildings. Tsunamis, which can be generated by earthquakes or volcanic eruptions, cause flooding in coastal areas. Volcanic eruptions release large amounts of dust and gases into the atmosphere, which can block sunlight, reduce air temperature, and produce sulfuric acid rain, which reduces stratospheric ozone. Landslides or mass wasting causes property damage when people ignore the dangers and build homes and roads on unstable ground.



The rock cycle is something with which most students are not familiar. Include a laboratory activity at this point to have students investigate the properties, both physical and chemical, of the different types of rocks. They should be led to the conclusion that the properties are determined by the forces that helped create the specific category of rock they are examining.

This is also a good time to review the soil types and their implications in agriculture that you discussed previously and link the information to the rock cycle.

Understanding the environmental impacts of mineral extraction is very important. Re-visit the topic of restoration, specifically reclamation when discussing mining. Environmental costs and economic benefits should be discussed.

The United States has varied metal and nonmetallic mineral resources and is a principal consumer of metals in the economy. See the USGS National Minerals Information Center to show students which metals are in large supply or lacking in the US: https://minerals.usgs.gov/minerals/ Mining provides many necessary products for modern life, but also has many environmental impacts. Make sure students can explain the mining process and the hazards these operations pose to the environment and human health. Students should also be apprised of the large amount of overburden and waste rock produced by mining mineral resources.

Stress that mining disturbs the surface of the land thus destroying habitat. Surface strip mines, subsurface mines, placer mines, and quarries contaminate groundwater and/or surface waters as well as endangering wildlife. Air is polluted with dust and chemicals. Smelting uses heat to remove a metal from its ore, often releasing sulfur dioxide, heavy metals and GHGs from the energy supply to heat the metal. Water is polluted by chemical and sediment runoff.

Emphasize that recycling metals, such as aluminum and platinum, is often less costly than mining for the metal ore. Using new materials or new technology also helps reduce our need for mining and extraction. Polymers and alloys have helped reduce our need for mineral and metal products while at the same time presents us with other issues.

If you have not already done so, introduce the concepts of “there is no away” and “full cost pricing”, especially in the context of mineral extraction processes.

Common Mistakes and Misconceptions

Students must be able to describe the damage to an ecosystem when mineral extraction takes place. Also, be able to describe environmental damage associated not only with mining of minerals, but of smelting the ores to remove the desired metals. Free response questions often ask the origin of a specific pollutant, and students frequently forget that smelting is one origin of heavy metal and sulfur dioxide emissions.

Emphasize that minerals, particularly certain metals, are important to the economy. The mining, processing, and distribution of these minerals are important to a nation's trade and commerce. While minerals are found everywhere in the world, it is important to find them in concentrations large enough and accessible enough to make mining and processing economically feasible.

Activities

Ore Examination

Students should examine various mineral ores to see that metals cannot be easily viewed in most ore, hence the need for smelting. Students can also conduct mechanical and physical weathering experiments to see how rocks break down to form soil. Additionally, students can conduct mineral studies, such as hardness, specific gravity, and color streaks to see that minerals are quite complex, and the rocks they form can be comprised of myriad minerals or a single mineral.

Cookie Mining Activity

Students will conduct mining activities. Cookie mining will provide a model for surface mining and will include some restoration. The goal is to maximize economic gains while maintaining ecosystem integrity. The worksheet for this activity is found at the end of this teacher's manual chapter.

Plate Discovery Activity

Photocopy a map of the world and provide a copy to each student. Provide students with either 2 different colored dot stickers (yellow and red) or 2 different colored markers. Using the internet and the USGS website, students will find research and discover the earthquakes for the last 20 years. Have them place a yellow dot on each location. Students will put a red dot on the map for the locations of volcanic eruptions in the last 20 years. When the students are finished have them compare their maps to Figure 14.3 in the textbook. The students should be able to discuss the similarities and differences of the two maps.

Diagraming Plate Tectonics

Use the Diagram of Plate Tectonics to illustrate the various types of plate boundary movements. Students should color code the lithosphere, crust, and ocean floor to illustrate the types of plates. Diagrams can be found at the end of this chapter.

Earthquake Simulation

Many virtual earthquake simulators exist online. Some of these include www.sciencecourseware.com, Incorporated Research Institutions for Seismology http://ds.iris.edu/edu/10.5/, USGS https://earthquake.usgs.gov/regional/nca/simulations/1906/

Questions for Review

1. What is the 1977 federal Surface Mining Control and Reclamation Act (SMCRA)?
   SMCRA requires better restoration of strip-mined lands, especially where mines replaced prime farmland.

2. How does resource extraction affect water quality? Give a specific example.
   In heap-leach extraction, cyanide is sprayed on a large pile of ore. This cyanide can contaminate ground and surface waters as it runs-off and infiltrates the ground. Mining also results in acid mine drainage which can contaminate groundwater.

3. What are two environmental impacts of mining?
   Examples include habitat alteration/destruction, hazardous run off, air pollution, erosion, and groundwater contamination.

4. How can recycling save energy as well as resources?
   In many cases it takes less energy to recycle a material (such as aluminum) than it does to extract, refine, and produce a new product. Other materials are scarce and the mining process is quite extensive. Recycling saves energy because the first few processes are eliminated in the production of the material.

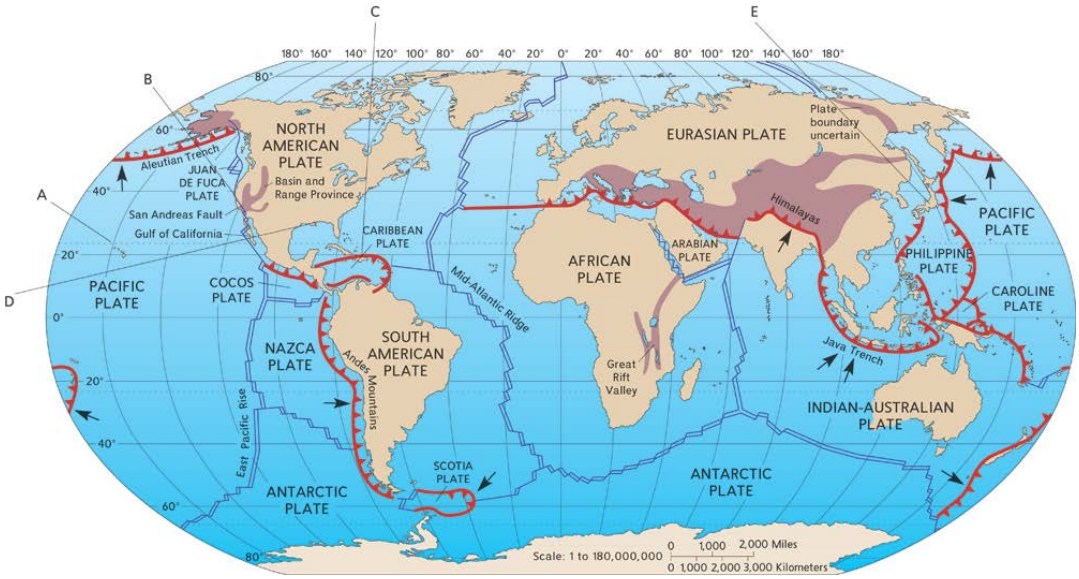
5. Why are floods considered the greatest geological hazard?
   When flooding occurs, it causes more loss of life and more property damage than. People have traditionally settled river and coastal floodplains because these areas were good for agriculture and providing a means of travel for goods to be delivered.

Practice Questions

Multiple Choice:

Directions for questions 1-5: The lettered choices below correspond to the descriptions given in questions 1-5. Select the one lettered choice that best fits each statement. Each choice may be used once, more than once, or not at all.

Several recent geological hazards have occurred during the last 10 years. Use the map below to match the geological hazard.



1. earthquake that lead to an outbreak of cholera

2. nuclear plant meltdown as a result of a tsunami

3. flooding as the result of a hurricane

4. volcanic eruptions currently occurring

5. mass wasting as a result of drought and then torrential rainfall

6. Which of the following geologic hazards can produce an acidic aerosol?
   (A) Volcanic eruption
   (B) Earthquake
   (C) Tsunami
   (D) Landslide
   (E) Flooding

7. This process removes gold from ore by spraying a large pile of ore with cyanide.
   (A) gold removal process
   (B) placer process
   (C) cyanidification
   (D) ore separation process
   (E) heap-leach process

8. In the automobile industry, steel and iron are being replaced by _____.
   (A) polymers
   (B) copper
   (C) stainless steel
   (D) titanium
   (E) vanadium

9. To reach coal deposits, mountaintop removal is used primarily in this region of the United States.
   (A) The upper mid-west
   (B) The Rocky mountains
   (C) The Appalachian mountains
   (D) The Cascades
   (E) The Sierra Nevada mountains

10. The ancient supercontinent was called _____.
   (A) Laurasia
   (B) Pangaea
   (C) Gondwana
   (D) Pagonaland
   (E) Eurasamafric

Free-Response Question:

Directions: Answer all parts of the following question. Where explanation or discussion is required, support your answers with relevant information and/or specific examples. When a calculation is required, be sure to show how you arrived at your answer.

1. The Knightland Mining Company is currently mining coal in Western Kentucky.

   (a) Describe TWO techniques used to mine coal.

   (b) For each of the techniques you named in part (a), explain one environmental consequence of that technique. You may not use the same consequence twice.

   (c) Explain TWO methods to reduce the amount of coal used as a power source.

   (d) A local power company is using the mined coal to produce electricity. If the local coal fired plant produces 10 million kwh of electricity a day and it takes an input of 5,000 BTUs for 1 kwh, and 1 pound of coal produces 2,500 BTUs, calculate the following:

      (i) How many BTUs does the power plant need each day?
      (ii) How many pounds of coal does the power plant use each day?

Answers to Practice Questions

Multiple Choice:

1. C
2. E
3. D
4. A
5. B
6. A
7. E
8. A
9. C
10. B

Free-Response Question:

This question is based on 10 points.

1. (a) 2 points total. One point for each technique given. Only the first two will be scored. Acceptable techniques include: strip mining, open pit mining, mountaintop removal and underground mining.

   (b) 2 points total. One point for each environmental effect, including: acid mine drainage, habitat destruction, loss of biodiversity

   (c) 2 points total. One point for each method. Methods include: conservation, educate people to turn off lights, lower thermostats.

   (d) 4 points total. 2 points for (i) and 2 points for (ii).

      (i) 2 points, 1 point for the correct set-up (must use dimensional analysis) and 1 point for the correct answer.

$$\left(\frac{1\,\text{x}\,10^{7}\ \text{kwh}}{\text{day}}\right)\left(\frac{5\,\text{x}\,10^{3}\ \text{BTU}}{1\,\text{kwh}}\right)=\frac{5\,\text{x}\,10^{10}\ \text{BTU}}{\text{day}}$$

      (ii) 2 points total, 1 point for the correct set-up (must use dimensional analysis) and 1 point for the correct answer.

$$\left(\frac{5\,\text{x}\,10^{10}\ \text{BTU}}{\text{day}}\right)\left(\frac{1\,\text{lb}}{2.5\,\text{x}\,10^{3}\ \text{BTU}}\right)=\frac{2\,\text{x}\,10^{7}\ \text{lbs}}{\text{day}}$$

Answers to questions in the Student Edition:

Case Study AP Document-Based Question (p. 302)

(A) Traditional coal mining methods involve digging in coal seams between rock layers. Deep mineshafts are created and coals is collected and brought to the surface. Blasting and scraping rock with heavy machinery is also common. Production of coal is labor-intensive and more expansive than modern technologies like fracking. Fracking, or hydraulic fracturing, is a modern type of drilling technique for extracting oil and gas from shale rock. Fracking is done by drilling a deep vertical hole in shale rock, then once the hole is a mile or more deep the hole is then dug horizontally. Holes are drilled into the horizontal portion of the pipe, and a mixture of water, sand, and chemicals are pushed out of the holes at high pressure. This slurry produces fissures in the shale, held open by the sand in the mixture, which allows natural gas to freely flow to the top of the well. The environmental impacts include the use of large amounts of water, water contamination by harmful chemicals, risk of earthquakes, air emissions, and wildlife habitat destruction. The resulting natural gas from fracking is, however cheaper and relatively clean-burning when compared to coal.

(B) MTR mining permanently changes the ecosystem of the area. MTR mining involves clear cutting forests, removing entire tops of mountains and pushing them downhill to fill valleys and streams. This process is almost always irreversible and always very destructive. It also causes large amounts of pollution from the toxic chemicals it releases from the ground. The economic costs associated include the time, labor, and energy required to extract the coal (which is much higher than with natural gas extraction through fracking) and the costs associated with re-creation (constructing a new ecosystem on the former mountaintops), mitigation (purchasing or creating habitat elsewhere), and reclamation/remediation (cleaning of contaminants).

Use the Math (p. 313)

$70,000,000,000 / 550,000 mines = $127,273 per mine, on average.
$70,000,000,000 /300,000,000 = about $233 per person.

AP Connections Review Answers (pages 320-321)

Multiple-Choice Questions

1. d. Iron is the most prevalent element in the earth's core.

2. e. If rain dissolves portions of a rock, then the rock is undergoing chemical weathering. The other examples are mechanical weathering.

3. a. Depletion of ore resources is an economic impact of mining.

4. a. The San Andreas Fault is found at a transform boundary.

5. e. oxygen is a major component of the crust (45.2%). Potassium is the only other element present in a large quantity in the curst, at 1.7%.

6. d. No volcanoes have erupted in the continental United States since 1920 when Mt. St. Helens erupted. Lava is not always emitted during an eruption, sulfur dioxide makes up the greatest proportion of gases, and hot, dense, toxic gases are what causes most human deaths. Volcanic eruptions contribute to global cooling through the formation of sulfuric acid (which interferes with solar radiation reaching earth) and the presence of ash (providing a shading effect).

7. c. Floods result in the most human deaths, followed by earthquakes.

Data Analysis & Free-Response Questions

1a The measured sea level increased by 11 m from 0° to 3°N or 3.67m/degree latitude. The model's predictions did not accurately predict the rate of increase. The model did well in predicting extremes of sea height, but did not hold up in predicting the distance experiencing this drop or rise. The model anticipated a drop in sea level rise further south (1°S), matching actual sea level measurements experienced at 0°, but expected a sharper rate of increase (5.5m/degree). The model's anticipated rise in sea level rise was 0.4m which didn't quite meet peak measurements. It also did not predict this peak to occur for several degrees latitude.

1b The percent error 97.5% (0.01-0.4/0.4*100)

1c Answers will vary but could include winds, or physical barriers under or above water.

2a Earthquakes are the result of sudden shifts in tectonic plates, due to a buildup in friction. These sudden jerks of crust displace water with force. Water rushes to fill gaps and sets off a ripple effect, like when a stone is thrown into the water. These ripples may seem smooth in deep water, but as they approach the shallow coastline, the force and water are driven upward causing tall waves.

2b Earthquakes are particularly dangerous because they can cause the collapse of buildings and they can trigger tsunamis.

2c Three strategies to reduce the loss of life from earthquakes and tsunamis include early detection systems for earthquakes that are of a strength that can trigger tsunamis, evacuations from affected areas, and building buildings that can withstand tremors or are located further from the coast.

Cookie Mining Activity

*Student:*_____

Procedure:

1. Make a data table to keep track of all mining costs and all monies gained while mining. Do this in the form of a ledger sheet with total profit or loss at the bottom. You can present this information in any format; just make sure that all information is included in your ledger sheet.

2. Cookie mines for sale:
    a. Chips Ahoy $ 5.00
    b. Chips Deluxe $10.00
    c. Generic Store Brand $ 2.00

3. Place the cookie on the graph paper and trace the outline of the cookie. You will have to reclaim the land to the original shape after the chips (ore) have been removed. So, any cookie crumb that falls outside of the original circle must be put back into the circle, or you will be charged for damage to the environment.

4. Mass your cookie using a triple beam balance or digital scale. Record this mass on your ledger sheet.

5. You are not allowed to touch the cookie with anything other than the mining equipment.

6. Mining equipment for rental
    a. Flat toothpick $2.00
    b. Round toothpick $5.00
    c. Paper clip $6.00
    d. If any of the above is returned broken, extra fees of double the rental price will be charged, so make your purchase carefully.

7. Mining and Reclamation time costs: $5.00/minute with a maximum time allowed of 5 minutes to mine and 5 minutes to reclaim.

8. Have your lab partner time you while you mine. Put the chips aside as you get them out of the cookie. You have a maximum of 5 minutes to mine, but you can use less that that if you wish.

9. When mining is completed, count and mass the chips. Whole chips will be bought at $5.00 per chip. Take partial chips and put them together to make a whole chip.

10. After mining, the remaining rock (chip) must be placed back into the circled area on the graph paper. This can only be done using the mining tools. No fingers or hands may touch the cookie. You will be charged $5.00 per minute to cleanup (reclamation).

11. Go to another lab group that bought a different cookie and record the type of cookie they bought, the mass of the cookie and the mass of the chips. Continue this until you have information for each of the three types of cookies.

Questions:

1. Did you leave any chips behind in the cookie? Why or why not?

2. Were you able to restore the land? Why or why not?

3. What did the costs of mining represent?

4. What did the cost of reclamation represent?

5. Which type of cookie mine had the best chips to cookie mass ratio?

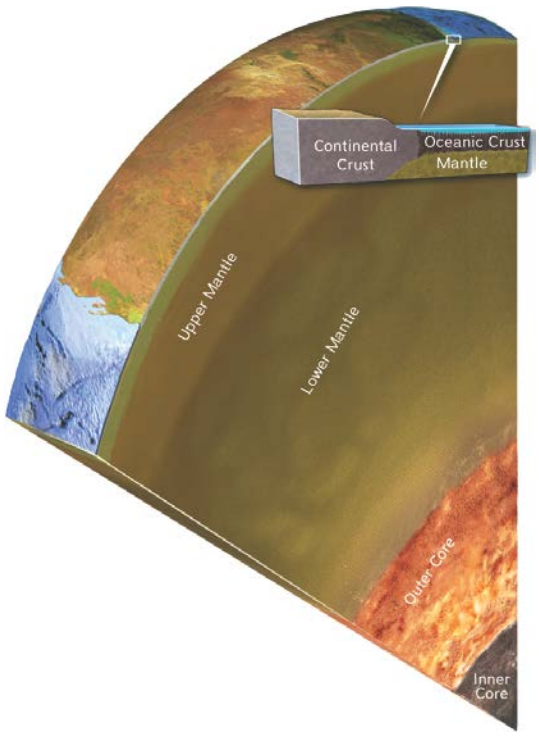
6. Why must a mining company reclaim a mine, and what is the law that makes this so?

7. What environmental costs are associated with mining?

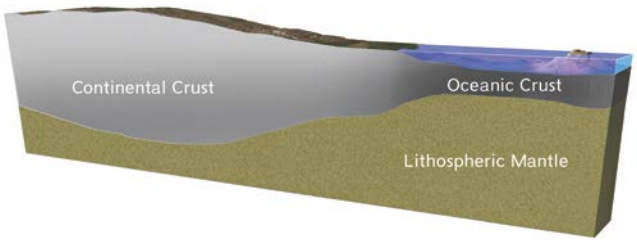
8. What would have made this lab a better representation of the mining procedures? (include both mining and reclamation)

9. How can recycling save energy as well as materials?

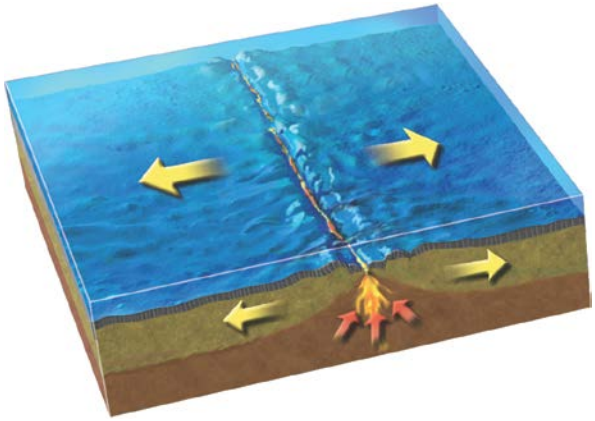
Diagramming Plate Tectonics



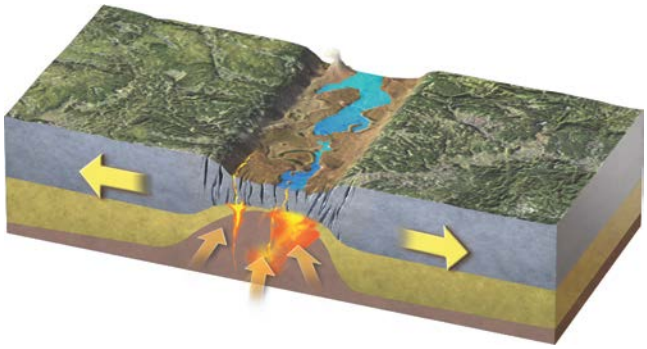
A. Cut out the diagram to the left. Glue it to the top of a piece of paper.
B. Draw in the divisions between the upper and lower mantle.
C. Label the lithosphere and the asthenosphere
D. Draw a convection current and label it in the appropriate place on your diagram.



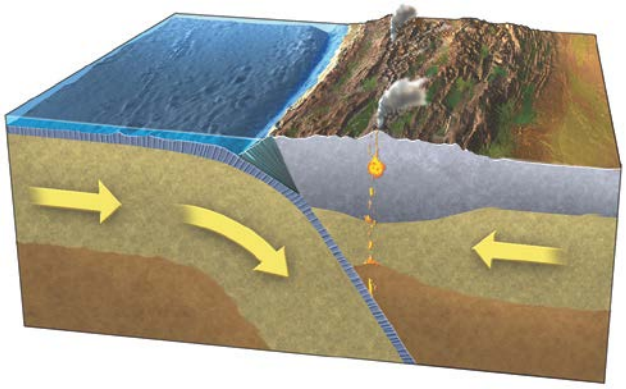
A. Cut out the diagram to the left.
B. Glue it onto your sheet of paper beside the lithospheric plate diagram.
C. Label: basalt, granite, more dense, less dense, newer, older



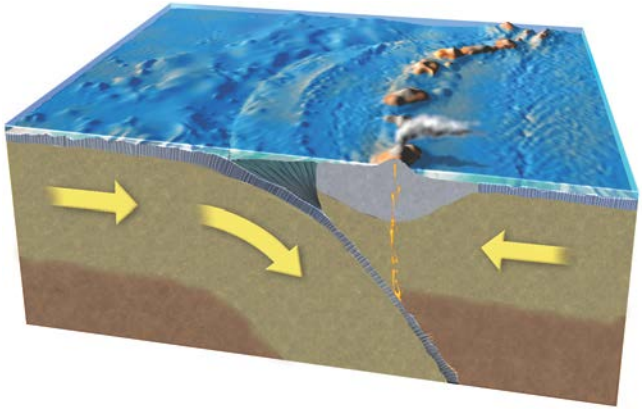
A. Cut out the diagram to the left. Glue it below your other two diagrams, so that it sits on the left half of the page.
B. Label the following: **ridge**



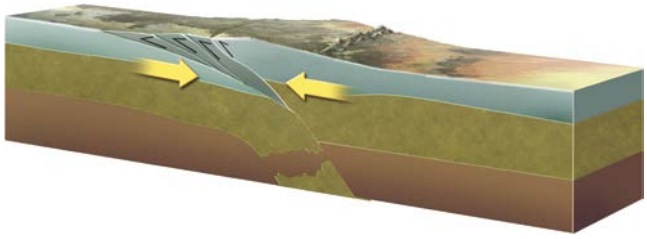
A. Cut out the diagram to the left. Glue it on the right hand side of the previous diagram.
B. Label the following: **ridge**



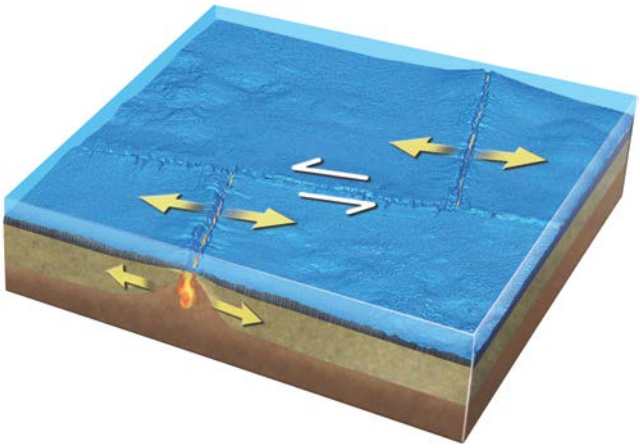
A. Cut out the diagram to the left. Glue it below your other two diagrams, so that it sits on the left half of the page.
B. Label the following: **subduction zone, trench, volcano.**



A. Cut out the diagram to the left. Glue it on the right hand side of the previous diagram.
B. Label the following: **subduction zone, trench, volcanic island**



A. Cut out the diagram to the left. Glue it on the right hand side of the previous diagram.
B. Label the following: **subduction zone, trench. volcano**
C. Draw a volcano where it might appear.



A. Cut out the diagram to the left. Glue it on the right hand side of the previous diagram.
B. Label the following: **divergent boundary, transform boundary, ridge**

Cut out the large world map diagram, and fill out the information below. Glue it onto the back of your sheet of paper.

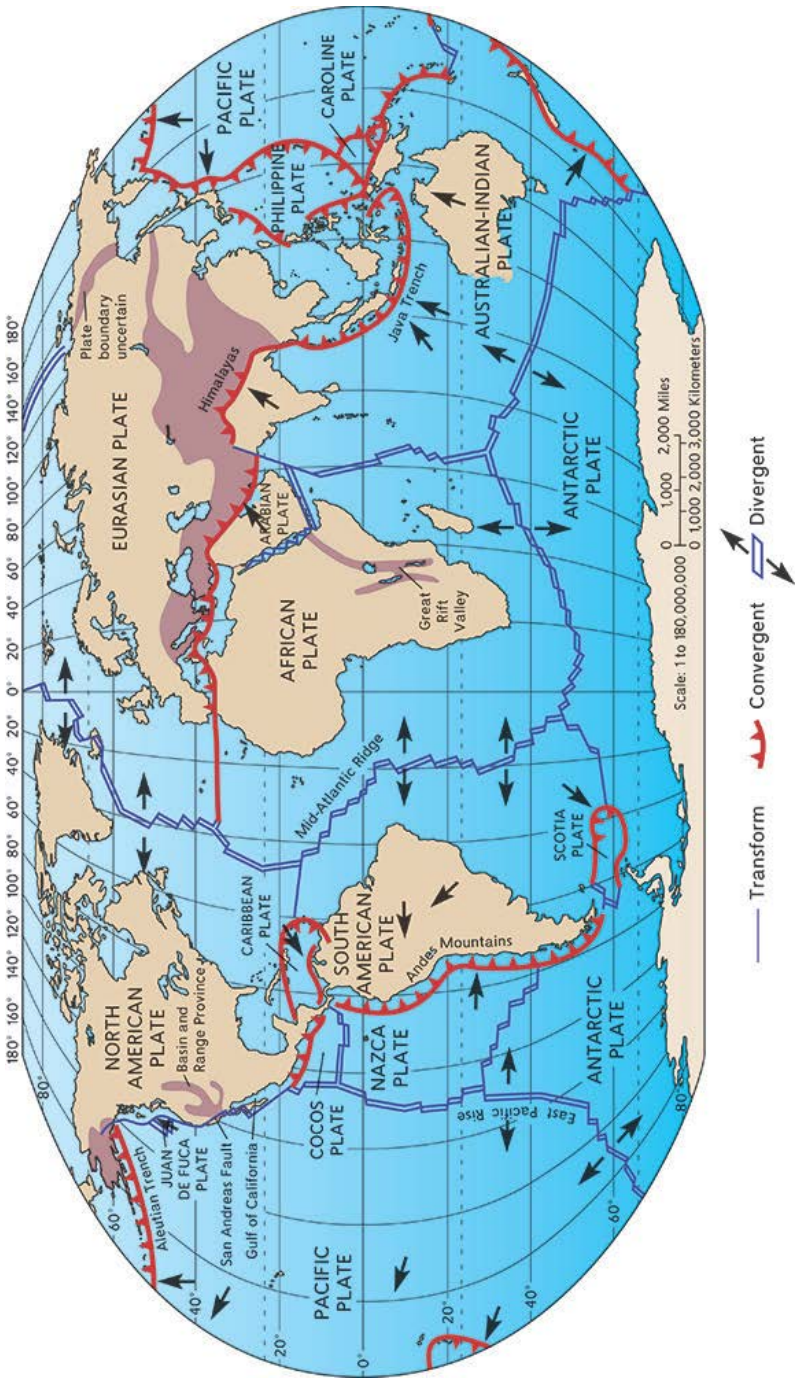
A. Using red, outline the Ring of Fire

B. Using green, trace or circle the divergent plate boundaries.

C. Using blue, trace or circle the convergent plate boundaries.

D. Using purple, trace or circle the transform plate boundaries

E. Circle the two areas outside of the United States, where the ocean ridges are cutting through a body of land.


PACIFIC PLATE
CAROLINE PLATE
PHILIPPINE PLATE
AUSTRALIAN-INDIAN PLATE
Plate boundary uncertain
Himalayas
Java Trench
EURASIAN PLATE
ARABIAN PLATE
ANTARCTIC PLATE
AFRICAN PLATE
Great Rift Valley
Mid-Atlantic Ridge
SCOTIA PLATE
CARIBBEAN PLATE
SOUTH AMERICAN PLATE
Andes Mountains
NORTH AMERICAN PLATE
Basin and Range Province
NAZCA PLATE
ANTARCTIC PLATE
East Pacific Rise
COCOS PLATE
Aleutian Trench
JUAN DE FUCA PLATE
San Andreas Fault
Gulf of California
PACIFIC PLATE
Scale: 1 to 180,000,000
0 1,000 2,000 Miles
0 1,000 2,000 3,000 Kilometers
Transform
Convergent
Divergent