Science Unit: ***Geology and Plate Tectonics***

Lesson 5: ***Plate Tectonics***

School Year:	2011/2012
Developed for:	Laura Secord Elementary School, Vancouver School District
Developed by:	Linda (Hanson) Herbert (scientist); Lesley Chambers and Phil Green (teachers)
Grade level:	Presented to grade 6/7; appropriate for grades 2 – 7 with age appropriate modifications
Duration of lesson:	1 hour and 20 minutes
Notes:	This lesson was delivered to students who already had a basic understanding of the structure of the Earth and plate tectonics. It could be modified to be delivered to students unfamiliar with plate tectonics but additional time would likely be required.

Objectives

1. Discover how plate tectonics influence other geologic processes.
2. Learn about local tectonic plates and processes.
3. Practice classifying and identifying local rocks.

Background Information

The Earth's crust can be thought of as a giant jigsaw puzzle made up of many interlocking pieces (i.e. plates). However, unlike a jigsaw puzzle these plates are in constant motion due to the geologic processes occurring within the Earth's mantle. Plate tectonics explains the dynamic nature of the Earth's crust, including how it is continually forming and being destroyed, and how this dynamic nature influences virtually all geologic processes. The area where two plates meet is termed a plate boundary or fault. The relative motion of adjacent plates determines the geologic nature of each fault; i.e. the geologic processes and events that will occur there and the geologic features that will be observed. Geologic processes/events associated with tectonic faults include earthquakes and volcanoes which can result in a variety of geological features: mountain ranges, trenches, chasms, mid-ocean ridges/rifts, rift valleys.

Vocabulary

Crust:	The outermost layer of the Earth it consists of a thin layer of (hard and rigid) rock. Continental crust has continents on it (thicker) while the oceanic crust has ocean floor (thinner).
Mantle:	Thick, taffy like layer of solid and partially melted rock. Very hot (~1000C).
Core:	The centre of the Earth; can be divided into the outer core and the inner core. A very hot region of molten iron and nickel.
Fault:	The boundary where two tectonic plates meet.
Convergent fault:	A tectonic plate boundary where two plates are moving towards each other.
Divergent fault:	A tectonic plate boundary where two plates are moving away from one another.
Transform fault:	A tectonic plate boundary where two plates are moving alongside each other.

Rift valley: A valley or trench that occurs at a divergent fault as the result of two continental tectonic plates moving apart.

Mid-ocean ridge: An undersea ridge or mountain range with a valley/trench at its peak (i.e. a rift) that occurs at a divergent fault between two tectonic plates.

Materials

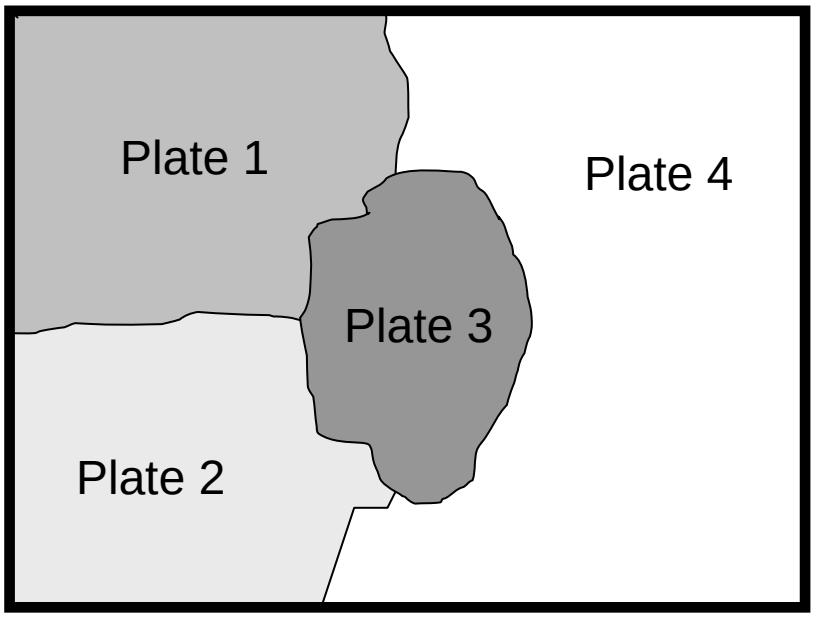
- Worksheets
- pencils
- LCD projector
- Slideshow (see notes throughout lesson)
- Pencil crayons (optional)
- Plastercine or modeling clay
- Wax paper
- Pebble identification pamphlets (see references)
- Rock and mineral kits
- Ceramic tiles or streak plates
- Magnifiers
- Additional rock and mineral identification books/resources

In the Classroom

Introductory Discussion

The worksheet and introductory discussion will be integrated with a slide show illustrating the concepts being investigated. Details of the slides used will be indicated throughout the lesson plan. A multitude of images freely available for educational use can be found on the internet.

1. Today we are going to learn about plate tectonics, earthquakes and volcanoes.
    - What causes earthquakes? (movements of the Earth's crust)
    - Let's review the structure of the Earth and discuss how the Earth's crust moves.
    - Draw a model of the Earth on the board, or have a slide prepared of the diagram on the worksheet. Have students offer up the names of the various layers and use questions to prompt discussion/suggestions of their characteristics. The focus should be on the crust and mantle for this lesson. Ask for names of each layer, characteristics, etc. Discuss the relative thicknesses of each layer etc.
    - How hot is the mantle? What is the mantle comprised of? (molten and partially melted rock) Is it soft? Hard? (taffy-like)
    - What is the crust made of? (rock, soil etc.) What consistency does it have, is it soft? Hard? (hard, rigid). How thick is the crust? (average ~50 km, this is equivalent to driving from the school to Maple Ridge or Aldergrove or Porteau Cove campground.)
    - Show a slide illustrating the tectonic plates of the Earth. Point out and name the ones in close proximity to BC. Define a fault. Discuss the relative movements of the plates and the speed at which they move.
    - How do the Earth's tectonic plates (i.e. Earth's crust) move? (The movement of molten rock results in the mantle acting like a series of conveyor belts; however the conveyor belts aren't all pointing in the same direction.
    - With this in mind, in what ways can two adjacent plates interact? Use the diagram below (in slide form or draw on the board) to prompt student answers.



- (To students) Look at the diagram on the board and think about how the plates can interact: What if plate 2 was moving upwards and Plate 1 was moving downwards? This kind of fault is called a convergent fault. (Two plates are converging or coming together).
- What about if plate 1 was moving up and plate 2 was moving down? This is called a divergent fault (two plates are diverging). The point where the plates split is called a ridge. What do you think causes this kind of fault? (hint, what is causing the plates to move – the mantle).
- At a divergent fault the surface of the Earth is pulling apart and molten rock from the Earth's mantle forces its way up towards the surface and creates new crust. This kind of fault is common in the ocean (show example near BC; Juan de Fuca ridge).
- Think about plate 1 moving upwards still, how does this affect plate 3? This type of fault is called a transform fault.
- The BC coast is one of only a few areas in the world where all three types of faults occur. (Show slide of tectonic plates off the coast of BC – Pacific plate, Juan de Fuca plate, North American plate). Prompt students to fill out their worksheets as needed.
- To assist you in completing the table on your worksheet, we will discuss the table as a class and complete it while looking at a slideshow. Optional: you can have students use the modeling clay to simulate the three different types of faults as each are discussed. Wax paper should be placed under the clay to keep desks clean.
- The first type of fault we are going to study is the convergent fault (show diagram of convergent fault). The type of fault occurs where the Juan de Fuca plate and the North American plate meet. How do these two plates move relative to each other? What happens when they push into each other? Try it with your clay. Remember, the North American plate is thick while the Juan de Fuca plate is much thinner. (Juan de Fuca subducts under the North American)
- Let's think about what geologic features or events we would expect to find here. If one tectonic plate is subducting under another where does it go? (mantle) What happens there? (it melts into

magma). Where do we see magma? (volcanoes) Do we have volcanoes in BC? (YES!!) Show a map of BC's volcanoes. (See volcanoes in Canada handout referenced at end of this lesson plan.)

- Show slides of the nearest BC volcanoes and discuss each (state of activity, last eruption, any memorable/significant eruptions, expected rock composition etc.) The slides used were Mt. Garibaldi (granite, adenosite, breccia, quartz, tuff), Mt. Meager (basalt; responsible for one of Canada's largest eruptions ~2.5K years ago), Mt Baker (located nearby in Washington state), Mt. St. Helens (basalt, adenosite, lava flows etc.). For Mt St Helens pictures were shown both before and after the 1980 eruption and the scientist and teacher shared stories of when it erupted (news accounts can be used if no personal stories are available).
- What if two oceanic plates meet at a convergent fault? What do we see? Show slides of island arcs (Aleutian Islands, Hawaii) and ask students to think of other island arcs (Philippines, Indonesia, Japan etc.)
- What if two continental plates meet at a convergent fault? Have students try this with their clay. Then we will see mountain ranges. Show slide(s) of the movement of the Indian plate into the Eurasian plate to form the Himalayas. Show an aerial view that illustrates how the shape/curve of mountain ranges delineates the boundaries of the two plates (Isn't it amazing how the Earth's surface can give us clues to events that occurred millions of years ago!). Show a picture of Mt Everest.
- What other geologic activates happen at convergent plate boundaries? Do you think the plates move smoothly past each other? Are the edges and surfaces of the plates all nice and smooth? What happens when they move – try this with your hands. Sometimes they stick, what happens when tectonic plates get "stuck" and then suddenly release? (earthquakes)
- Show slide of earthquakes off the BC coast for the past year. Can generate maps at http://www.earthquakescanada.nrcan.gc.ca/recent/index-eng.php.
- What might we see when earthquakes happen near the BC coast? (tsunamis) Can discuss and/or show pictures of the 2011 Tōhoku earthquake and tsunami if students are old enough to remember it.
- Let's move onto divergent tectonic plates. How are the plates moving? What geologic feature would you expect to see if two continental plates were pulling apart? (volcanoes, rift valleys, sinkholes etc.)
- Show a slide illustrating the divergent fault that runs across Iceland between the Eurasian and North American plates. Show a map with all of the Icelandic volcanoes indicated. Discuss the May 2011 eruption of the Icelandic volcano Grimsvotn if students are old enough to remember it.
- Show pictures of the rift valley between the Eurasian and North American plates. Show pictures of the Danakil Depression and Great Rift Valley in Africa.
- What would you expect to see at a divergent fault between two oceanic plates? Use the Juan de Fuca ridge (boundary between the Juan de Fuca plate and Pacific plate) as an example. Show pictures of the mid-ocean ridge and discuss underwater volcanoes, black smokers etc. Can also discuss and show pictures of the Mariana/Marianas trench.
- Let's finish up our table with the third type of tectonic plate boundary, the transform fault. The North American plate and the Pacific plate meet at a transform boundary just a little south of us. Who has ever heard of the San Andreas Fault? What is it famous for? (earthquakes) Show a picture of the San Andreas Fault and a map indicating the earthquakes over the last week or month. Maps can be generated at http://earthquake.usgs.gov/earthquakes/map/

Example Worksheet Answers

Fault Type	Convergent	Divergent	Transform
Relative direction that plates move	Towards each other	Away from each other	Alongside each other
Illustration of how plates move	→ ←	← →	↑ ↓
Geologic features or events that occur at this type of fault	Volcanoes, earthquakes, tsunamis, mountains, trenches	Mid-ocean ridges, rift valleys, volcanoes	Earthquakes

- Review the three fault type that occur in the BC area and ask students what families/types of rock they would expect to find in the local environment. Have them base their answers on geologic processes and events.
- Introduce the local rock identification activity.

2. Short description of other items to discuss or review.
   - Students should be familiar with the concept of plate tectonics prior to the lesson.
   - Remind students to fill out their worksheets WHILE they are viewing the slideshow.
3. Briefly describe science experiment/activity.
   - Students will complete the first half of their worksheet (pages 1-2) while viewing and discussing the slideshow.
   - Students will sit in groups (to share materials and discuss observations) for the rock identification activity.
4. Briefly describe the processes of science that the students will focus on: For the rock identification activity students will focus on making observations, integrating their knowledge and using their knowledge and observations to draw conclusions.
5. Briefly describe safety guidelines.
   - Do not touch your face or mouth while handling the rock specimens. Wash your hands with soap at the conclusion of the experiment and especially before eating.

Science Activity

Activity Title: Local Rock Identification

Purpose of Activity: Students will integrate their previous knowledge to identify a local rock sample.

Methods and Instructions:
Set-up prior to experiment: The teacher and/or scientist should obtain a sufficient number of local rocks that each student will have one to identify. When this activity was originally performed the students were allowed to select their rock from a collection of interesting rocks obtained by the scientist. Students were able to keep their rocks at the end of the lesson. Students could also be asked to collect a local rock sample and bring their rock sample to use in this lesson.

Brief description of how students will work in groups or pairs: students will sit in groups to share materials and discuss observations but they will characterize and identify their rocks individually.

1. See worksheet for detailed instructions.
2. Students will use the resources available to help them characterize and identify their rock samples. Depending on the length of time that has passed since the earlier lessons you may wish to review the procedures for streak tests and hardness tests and have the class brainstorm characteristics of the three rock families prior to starting the activity.
3. Available materials can include some or all of the following:
    - Pebble identification guides
    - Rock identification pamphlets and books
    - Ceramic tiles or streak plates
    - Labeled rock and mineral kits to use for comparisons
    - Notes form previous lessons
    - Magnifiers and/or microscopes

Closure Discussion

1. Discuss students' observations and results of the local rock identification activity.
2. What family of rock was most prevalent? Why you think that is?
3. Where on Earth would you expect to find the youngest/newest rocks? The oldest? Why?
4. Given the relative movement of the tectonic plates off the coast of BC what will eventually happen to the Juan de Fuca plate? Given the positions of San Francisco and Los Angels on opposite sides of the San Andreas Fault, how will the geographic relationship between them change in the distant future? (i.e. will they be located closer together etc. – Los Angeles which is east of the fault will eventually end up north of San Francisco which is west of the fault!)
5. How will the position of the continents change? Can you predict what the Earth might look like in another 10-20 million years?

References

1. Chapman, Anita, David Barnum, Carmen Dawkins and William Shaw. 2005. BC Science Probe 7. Nelson.
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3. Roney Sattler, Helen and Giulio Maestro. 1989. Our Patchwork Planet. Lothrop, Lee and Shepard Books.
4. Storad, Conrad. 2007. Earth's Crust. Lerner Publications Company.
5. Van der Flier-Keller, Eileen. 2006. A Field Guide to the Identification of Pebbles. Harbour Publishing. [available from the Geological Survey of Canada or available to order online from Chapters/Indigo.]
6. West, Krista. 2009. Layers of the Earth. Chelsea House Publishers.

7. Zim, Herbert and Paul Shaffer. 1957. Rocks and Minerals: A Guide to Familiar Minerals, Gems, Ores and Rocks. Golden Press.

8. <http://earthquake.usgs.gov/earthquakes/map/> Real Time Earthquake Map. United States Geological Survey. [Can generate maps of recent earthquakes in the US or any global region] Accessed June 12, 2012.

9. <http://www.earthquakescanada.nrcan.gc.ca/recent/index-eng.php> Recent Earthquakes Near/In Canada. Natural Resources Canada. [Can generate maps or lists of recent earthquakes for any region in Canada] Accessed June 12, 2012.

10. <http://www.nrcan.gc.ca/earth-sciences/org/vancouver/geotour/7811> Sea to Sky Earth Sciences. Natural Resources Canada. [Geological information on the Sea to Sky highway region] Accessed April 30, 2012.

11. Handouts available from the Natural Resources Canada Bookstore (625 Robson Street, Vancouver B.C.; Tel: 604-666-0271) and some are available at http://www.earthquakescanada.nrcan.gc.ca/info-gen/teachers-enseignants-eng.php.

    a. Her Majesty the Queen in Right of Canada. 2011. Earthquakes in Southwestern British Columbia. Natural Resources Canada.

    b. Her Majesty the Queen in Right of Canada. 2011. Episodic Tremor and Slip. Natural Resources Canada.

    c. Her Majesty the Queen in Right of Canada. 2011. Plate Tectonics Shape (and Shake) British Columbia. Natural Resources Canada.

    d. Her Majesty the Queen in Right of Canada. 2010. Sea to Sky Story: Making of Mountains. Natural Resources Canada.

    e. Her Majesty the Queen in Right of Canada. 2010. Sea to Sky Story: Volcanoes. Natural Resources Canada.

    f. Her Majesty the Queen in Right of Canada. 2008. Seismographs in Canada. Natural Resources Canada.

    g. Her Majesty the Queen in Right of Canada. 2008. Volcanoes in Canada. Natural Resources Canada.

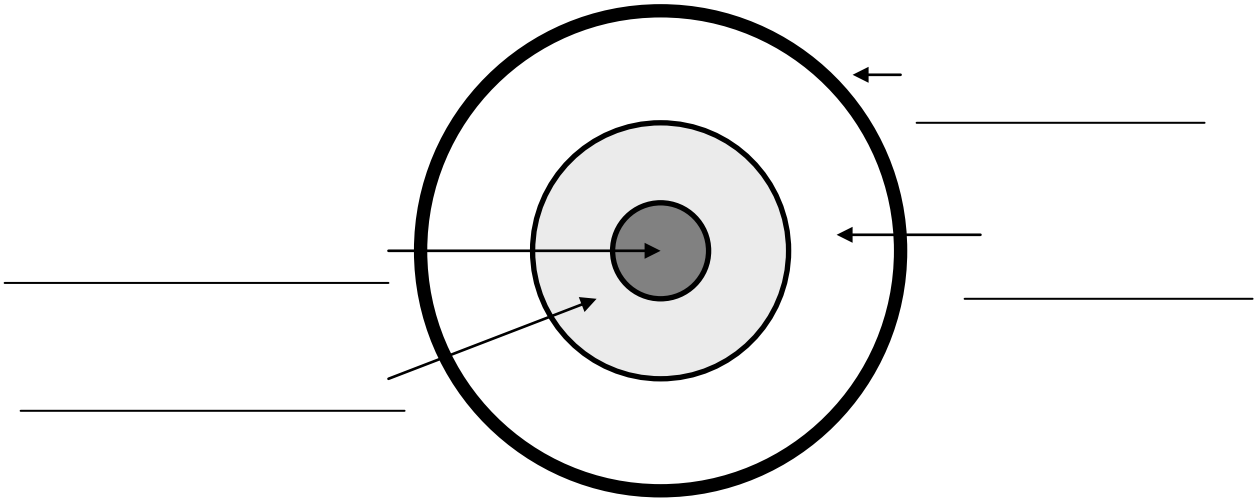
SCIENTIST IN RESIDENCE PROGRAM

Scientist: _____

Date: _____

PLATE TECTONICS & LOCAL GEOLOGY

Label the 4 main layers of the earth (outer core, inner core, crust, mantle):



Name the three tectonic plates located near British Columbia

_____

_____

_____

SCIENTIST IN RESIDENCE PROGRAM

Scientist: _____

Date: _____

Fault Type			
Relative direction that plates move			
Illustration of how plates move			
Geologic features or events that occur at this type of fault			

SCIENTIST IN RESIDENCE PROGRAM

Scientist: _____

Date: _____

LOCAL ROCK IDENTIFICATION

Use your observations and the questions below to help you identify and describe your rock sample.

Use the pebble identification guides and your knowledge of rock properties from previous lessons to help you determine which rock family your sample belongs to.

Questions to consider:

- What colour(s) is it?
- Does it have layers / patterns?
- Does it have foliation lines?
- How hard is it?
- Is the lustre dull or shiny?
- Are there visible crystals?
- Does it have any special features?

I think my sample is in the _____ rock family.

Why? _____

_____

Use the available resources to try to determine the identification of your sample (i.e. its name). _____

Can you identify any minerals in your rock?

_____

_____

Draw a detailed picture of your sample in the box below.

Bonus question: The Juan de Fuca plate moves approximately 2.5 cm each year, how far has it moved since you were born? (Show your work below.)

_____ cm