

Lecture Tutorials

for Introductory Geoscience

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SAMPLE
NOT FOR RESALE

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What are Lecture Tutorials?¹

Each Lecture Tutorial is a short worksheet that students complete in class, making the lecture more interactive. Research indicates that students learn more when they are actively engaged while learning, and several studies indicate that students who use Lecture Tutorials in the classroom retain more knowledge than students who only listen to a lecture on the same material. After a brief lecture on the subject, students work in small groups to complete the Lecture Tutorial worksheets.

The Lecture Tutorials are designed to address misconceptions and other topics with which students have difficulties. They create an environment where students confront their misconceptions and, through well-designed questioning, guide students to a more scientific way of thinking. This careful design makes Lecture Tutorials unique among most other activities used in the classroom.

By posing questions of increasing conceptual difficulty to the students, Lecture Tutorials help students construct correct scientific ideas. The first questions help the students think about what they do and do not know. The Lecture Tutorial then guides the students by asking them questions focused on underdeveloped or misunderstood concepts and slowly steps them through thinking about more difficult questions. The final questions on the Lecture Tutorial help to indicate whether the students understand the material.

Lecture Tutorials can be used in any size classroom. Students should speak with each other and teach each other while the instructor acts as a facilitator. The questions on the Lecture Tutorials require no technology and are written so the conceptual steps for each question are manageable.

Guidelines for Use

Step-By-Step Implementation for the Instructor

1. Lecture on the material as usual. You can also provide an introduction of the background information that students need to know before beginning the Lecture Tutorial.
2. Optional: Pose a well-designed, multiple-choice question for you and the students to gauge their understanding of the material.
3. Have the students split into groups of 2 or 3 and work on the Lecture Tutorial. Walk around the room and answer their questions. Lecture Tutorials take 10–15 minutes for most students to complete.
4. Review some of the main points of the Lecture Tutorial.
5. Optional: Pose a new multiple-choice question to check if the students have the expected understanding of the information.
6. Continue with the lecture.

¹ Revised from On the Cutting Edge – Teaching Methods – Lecture Tutorials (http://serc.carleton.edu/NAGTWorkshops/teaching_methods/lecture_tutorials/index.html).

Directions for the Student

You are using Lecture Tutorials in your class because they help to improve your understanding of the material. They require you to actively think through questions instead of listening passively to the lecture. Lecture Tutorials allow you to gauge how well you understand the material and ask any necessary questions. They also address different learning styles, so you can use your strengths while learning the material. Surveys have shown that an overwhelming majority of students feel that Lecture Tutorials are a useful part of their learning experience.

However, in order for you to get maximum benefits from the Lecture Tutorials, you need to put effort into completing them. Think about the answers as you are working through them, and be sure to write down your logic. Nothing is more frustrating than reviewing the Lecture Tutorials and not remembering how you solved the problems! You will be asked to work in groups to complete the Lecture Tutorials. Take advantage of working with your fellow students by both learning from them and teaching them.

Acknowledgements

We wish to credit Scott Clark for his original research on misconceptions addressed in parts of five Lecture Tutorials (Tectonic Plates and Boundaries, Subduction Features, Movement at Convergent Boundaries, Plate Boundaries in Oceans, Melting Rocks and Plate Tectonics). Many of the figures and lines of questioning in these Lecture Tutorials are adapted from his unpublished research instruments. Initial findings were presented in Clark, S.K., Libarkin, J.C. (2008) Post-Instruction Alternative Conceptions about Plate Tectonics Held by Non-Science Majors (Abstract 248-14 at the Geological Society of America Meeting in 2008).

We would like to thank Ed Prather and Timothy F. Slater for their guidance and encouragement. We learned of the Lecture Tutorial teaching method through the Lecture Tutorials for Introductory Astronomy they co-wrote and promoted, and after discussions with them, we created our own geoscience Lecture Tutorials.

We appreciate the enthusiasm and hard work done by Anthony Palmiotto, Anthony Petrites, Jodi Isman, Christine Buese, Amy Thorne, Scott Guile, Randi Rossignol, Clancy Marshall, and the rest of the team at W. H. Freeman.

Each of these Lecture Tutorials has gone through many revisions, and we would like to thank all of the students who gave us feedback and comments on the previous versions of these Lecture Tutorials.

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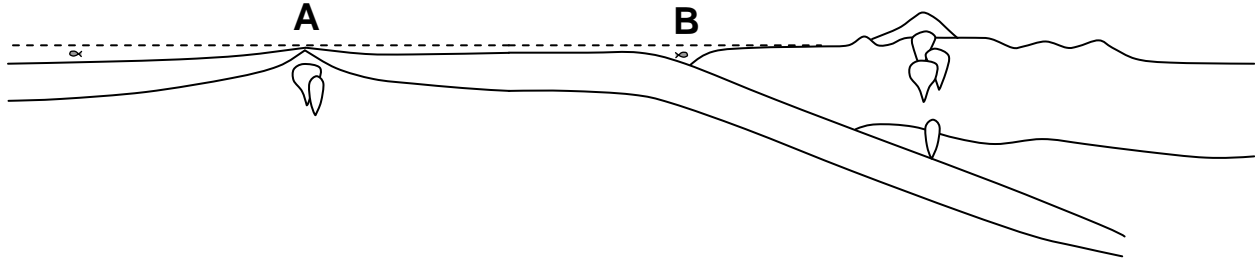
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Plate Boundaries in Oceans

Part 1: Features

The cross section below shows the tectonic plates beneath an ocean and a nearby continent. Sea level is indicated by the dashed line.



- 1) Use arrows to show the directions the plates are moving near Locations A and B.
- 2) Two students are discussing the directions the plates are moving.

Student 1: *I drew the arrows moving apart at Location A because magma is pushing the plates up as it rises to fill in the gap as the plates move apart.*

Student 2: *I drew the arrows moving together at Location A because as the plates are moving toward each other, they get pushed up.*

With which student do you agree? Why?

- 3) What seafloor feature is found at Location A? ridge trench abyssal plain island
- 4) What seafloor feature is found at Location B? ridge trench abyssal plain island
- 5) What type of plate boundary is at A? divergent convergent transform
- 6) What type of plate boundary is at B? divergent convergent transform
- 7) Check that your answers for Questions 5 and 6 match the arrows you drew at Locations A and B in Question 1.

8) If you find a plate boundary in the middle of an ocean away from the edge, what type of plate boundary is it most likely to be?

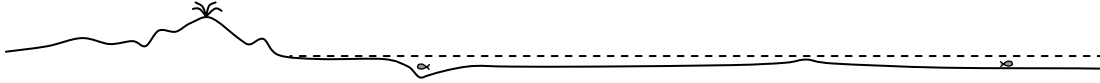
divergent convergent with subduction convergent without subduction

9) If you find a plate boundary along the edge of an ocean next to a continent, what type of plate boundary is it most likely to be?

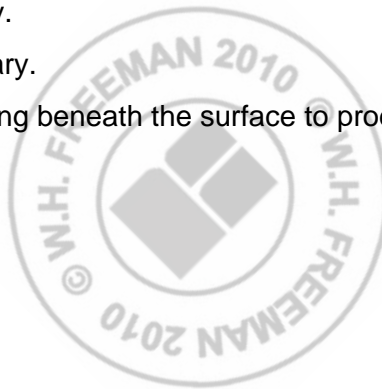
divergent convergent with subduction convergent without subduction

Plate Boundaries in Oceans

Below is a cross section of the ocean floor and nearby land showing the surface features. Sea level is indicated by the dashed line.



- 10) Label the ocean ridge.
- 11) Label the ocean trench.
- 12) Label the mountains/volcanoes on land.
- 13) Label the divergent boundary.
- 14) Label the convergent boundary.
- 15) Draw what the plates are doing beneath the surface to produce the surface features.

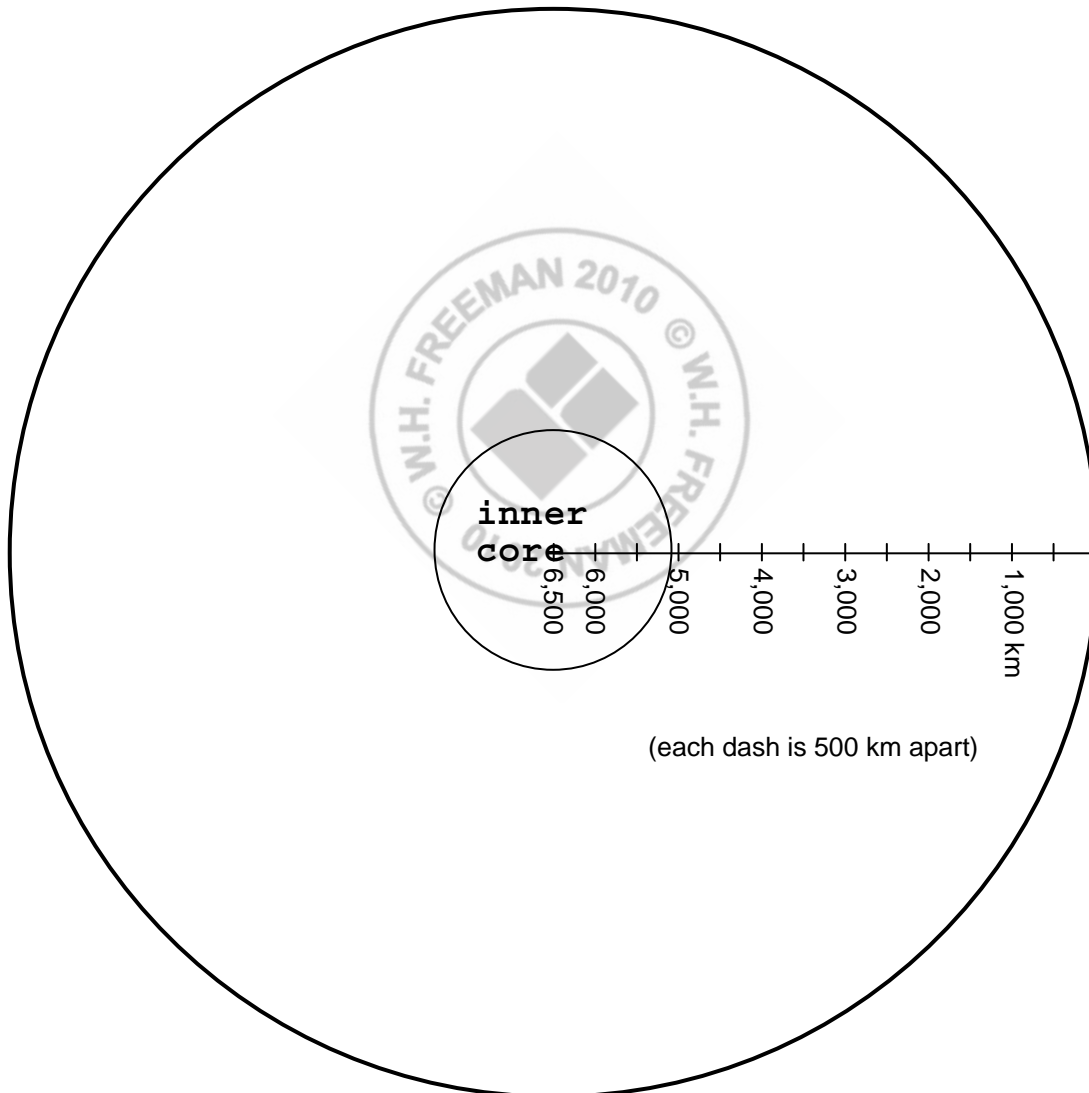


Part 1: Earth's Layers

Earth can be divided into three layers based on composition (what it is made of): the crust, mantle, and core. The core can be divided into two layers based on phase: the liquid outer core and the solid inner core. The depths in the chart below are approximate and vary with location.

Layer	Depth of top	Depth of bottom	Phase and composition
Crust	surface of Earth	30 km	solid, rock
Mantle	30 km	2900 km	mostly solid, rock
Outer core	2900 km	5100 km	liquid, metal
Inner core	5100 km	center of Earth	solid, metal

- 1) Sketch and label the four layers of the Earth on the diagram below. The inner core has been drawn and labeled for you.



- 2) What is the best comparison for the thickness of the crust?
- The crust has the same relative thickness as the skin of an apple.
 - The crust has the same relative thickness as the peel of an orange.

Part 2: Origins of Magma

Materials melt with a combination of high temperature and low pressure. If the temperature is too low or the pressure is too high, rocks will not melt.

The outer core has the right combination of temperature and pressure for metal to be molten. At 15 to 100 km below the surface, the temperature and pressure are potentially just right to partially melt rock. This depth is where pockets of most volcanic magma are formed.

- 3) On the diagram of Earth, draw a star at the depth of the source of magma.
- 4) What layers melt to form magma?
- | | | | | |
|-------|----------------------|----------------------|------------|------------|
| Crust | Upper (outer) mantle | Lower (inner) mantle | Outer core | Inner core |
|-------|----------------------|----------------------|------------|------------|
- 5) Overall, how much of the mantle is liquid? very little to none about half most to all
- 6) According to your diagram, estimate how far the molten metal from the outer core would have to travel to erupt as a volcano. For comparison, New York and Los Angeles are ~4000 km apart.
- 7) What is the composition of the outer core? What is the composition of erupted lava from a volcano?
- 8) Two students are debating whether the molten outer core erupts as volcanoes.
- Student 1:** *I don't think the molten outer core erupts as volcanoes because the magma would have to travel thousands of kilometers through the mantle to reach the surface, and I don't think it could go that far through the mostly solid mantle.*
- Student 2:** *If the outer core erupted as volcanoes, then we would have pure metal erupting out of Earth's surface. Volcanoes erupt molten rock, so the molten source cannot be the outer core.*

Do you agree with one or both students? Why?

- 9) You are the science advisor to a movie. The screenwriters come to you with the following scenario: A mad scientist threatens to detonate a bomb in the center of Earth, triggering volcanoes around the world to erupt, unless world leaders pay him a large ransom. Explain to the screenwriters why their story is or is not scientifically accurate. (*Note: Atomic bombs at Earth's surface can cause damage up to 20 km away.*)

Igneous Rock Mineral Size

Part 1: Forming Minerals

The size of minerals in an igneous rock is determined by how long the magma takes to cool. To illustrate, everyone should stand up and scatter throughout the room.

- 1) You have two seconds to form groups as big as possible. How many per group? _____
- 2) Scatter again. Now you have 10 seconds. How many per group? _____
- 3) Two students are debating about how this activity relates to mineral size in rocks.

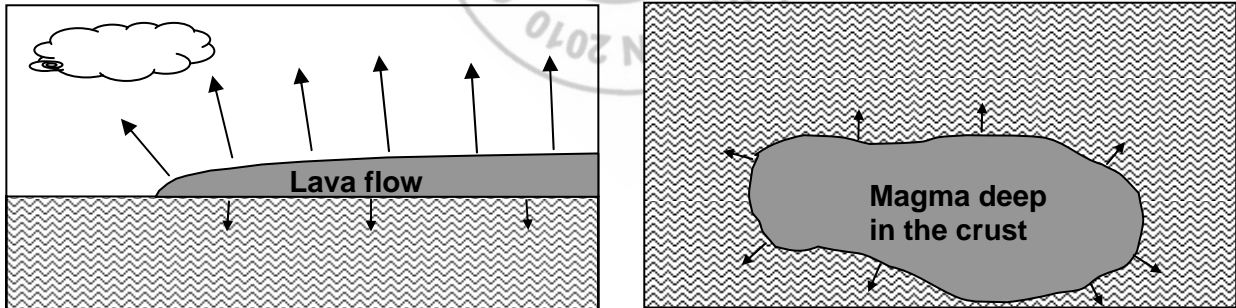
Student 1: *It seems to me that with a longer amount of time, it is possible for all the atoms to form really large minerals.*

Student 2: *I don't know, I would think that more time means that more minerals will form, and only a little bit of time means only a few big minerals will form.*

With which student do you agree? Why?

Part 2: Mineral Formation Location

Two bodies of magma are shown in cross section below. One is above ground and the other is deep within the crust. The length of the arrows represents the rate at which heat is escaping from the molten rock as it cools.



4) Which will cool faster? Lava erupted onto the surface Magma deep underground

5) The igneous rocks granite and gabbro have large minerals. In which location would they have formed?

on the surface deep in the crust

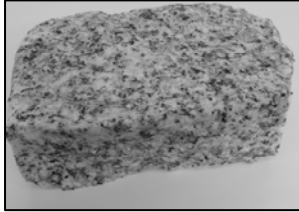
6) The igneous rocks rhyolite and basalt have minerals so small it is difficult to distinguish them with the naked eye. In which location would they have formed?

on the surface deep in the crust

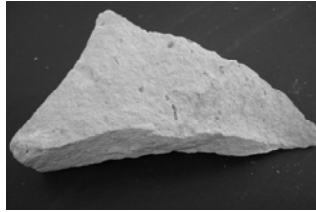
Igneous Rock Mineral Size

7) Circle the two rocks that formed deep in the crust.

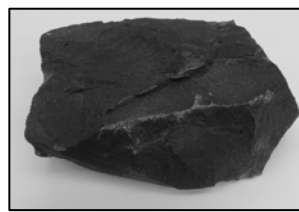
Granite



Rhyolite



Basalt



Gabbro

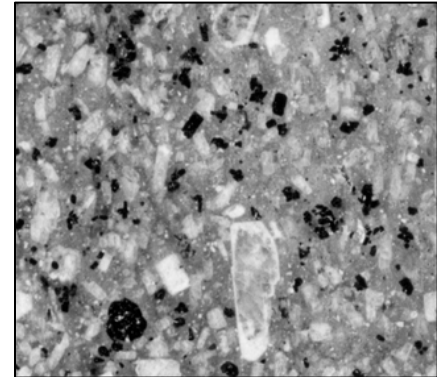


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Check your answer with your answers for Questions 5 and 6.

Part 3: Porphyry

8) The igneous rock to the right has large, black-and-white colored minerals and many small, gray minerals. You can tell it is an igneous rock because the minerals are rectangular and not rounded like sediments. How might the igneous rock shown to the right have formed?



C. B. Hunt/U.S. Geological Survey

Porphyry

9) Two students are debating about the cooling rate of this rock and the formation of the large minerals.

Student 1: *The magma must have gotten large pieces of sediments that we can see trapped in it, and the sediments didn't melt, even though they were in the magma. So, this rock formed because large pieces of sediment got picked up by lava, and then that lava cooled quickly.*

Student 2: *This is an igneous rock, so everything started off as magma. The large minerals must have formed deep underground when the magma was cooling slowly, like in a magma chamber. But the rest of the rock has very small minerals, so they cooled quickly at the surface.*

With which of these students do you agree? Why?

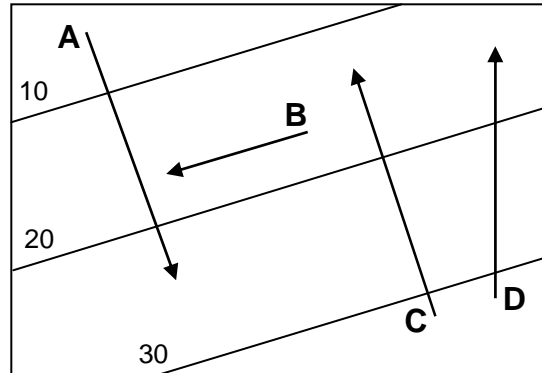
10) Student 2 said that the large minerals formed deep underground, like in a magma chamber, and the small minerals formed at the surface. Describe what actually happened to form the rock. In other words, what story does the appearance of this rock tell us about its history?

(Hint for Question 10: In what situation is magma in a magma chamber moved to the surface?)

Groundwater Contamination

The contamination within groundwater flows along with the groundwater. As a result, by determining the flow of groundwater, you can determine the flow of the contamination.

- 1) The contours on the map to the right show the water table elevation above sea level. Why is Arrow C better than the other arrows at showing the direction groundwater will flow?



Arrow A:

Arrow B:

Arrow D:

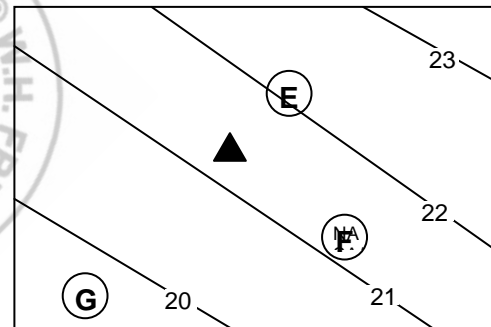
- 2) Which arrow shows the direction the contamination in the groundwater will flow?

Arrow A Arrow B Arrow C Arrow D

- 3) The contours on the map to the right show the water table elevation above sea level. The black triangle represents a septic tank. If this septic tank is improperly installed, which location would detect contamination first?

E F G

Explain your answer.



- 4) Three students are debating which location will first detect the contamination.

Student 1: *I think that E will detect the contamination first because it is closest to the septic tank.*

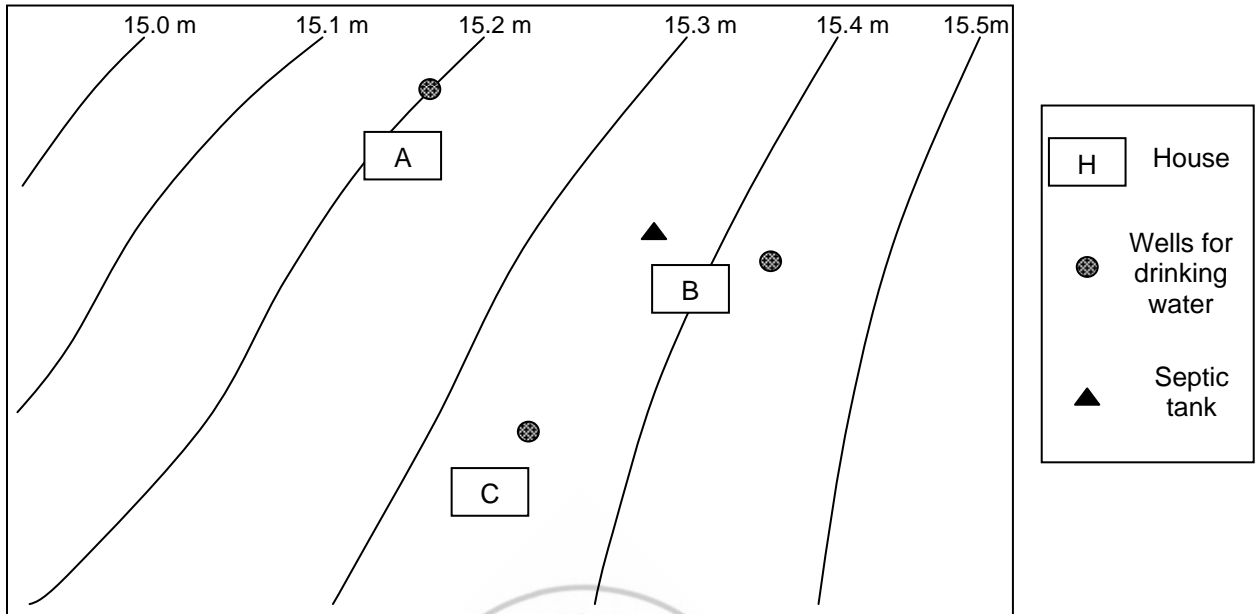
Student 2: *But you need to consider what direction the water will flow. I think that F will first detect the contamination because the contamination will flow along the lines down toward F.*

Student 3: *The lowest elevation is toward G where the elevation is less than 20, so the water will flow from 21 to 20, and G will detect contamination first.*

With which student do you agree? Why?

Groundwater Contamination

The figure below shows the water table elevation, three houses, three wells, and a septic tank.



- 5) Draw at least three arrows on the map showing the direction of ground water movement. Keep in mind your answer to Question 1 when drawing the arrows.
- 6) The triangle is a proposed location of septic tank for House B. Septic tanks may release contaminants in the water if constructed without the proper considerations. Draw an arrow showing the direction of the contaminant plume which may be released from the septic tank.
- 7) The wells of which houses, if any, could be affected by the septic tank? A B C
- 8) Put a star on the map where you think would be a better place for a septic tank for House B. The tank, to be useful to the inhabitants of the house, needs to be located near the house. Explain your decision in the space below.