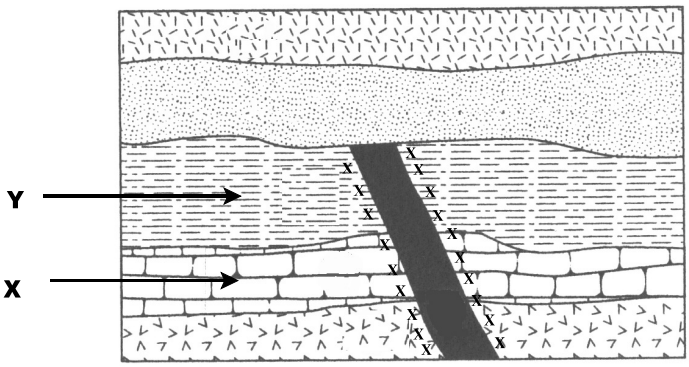
**Earth Systems 3209**
**August 2009**
**Answer Key**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1. | D | | 21. | D | | 41. | C |
| 2. | B | | 22. | D | | 42. | C |
| 3. | C | | 23. | D | | 43. | B |
| 4. | B | | 24. | C | | 44. | A |
| 5. | A | | 25. | A | | 45. | A |
| 6. | B | | 26. | C | | 46. | B |
| 7. | C | | 27. | C | | 47. | D |
| 8. | B | | 28. | D | | 48. | C |
| 9. | A | | 29. | B | | 49. | B |
| 10. | D | | 30. | B | | 50. | D |
| 11. | B | | 31. | A | | 51. | A |
| 12. | C | | 32. | A | | 52. | B |
| 13. | D | | 33. | C | | 53. | C |
| 14. | C | | 34. | C | | 54. | B |
| 15. | B | | 35. | A | | 55. | C |
| 16. | B | | 36. | B | | 56. | A |
| 17. | B | | 37. | B | | 57. | D |
| 18. | C | | 38. | A | | 58. | D |
| 19. | B | | 39. | A | | 59. | A |
| 20. | B | | 40. | B | | 60. | D |

**PART II - Constructed Response Items**
**Total Value: 40%**

Value
2% 61. (a)




(i) Identify the geological principle which can be used to distinguish between the ages of rock layers **X** and **Y**.

**Answer:**

The Principle of Superposition

(ii) Explain your choice.

**Answer:**

The Principle of Superposition states that in a sedimentary rock sequence each layer (or sedimentary bed) is older than the layer above it and younger than the layer below it. As a result of this principle, it can be concluded that layer **X** is older than layer **Y** since layer **X** is below layer **Y** in the sedimentary rock sequence.

2% (b) Using the data below, explain which pair of isotopes could most accurately be used to date an early Precambrian rock sample.

| Isotope Pair | Half-Life |
|---|---|
| Uranium-238 and Lead-206 | 4.5 billion years |
| Uranium-235 and Lead-207 | 713 million years |
| Carbon-14 and Nitrogen-14 | 5,730 years |

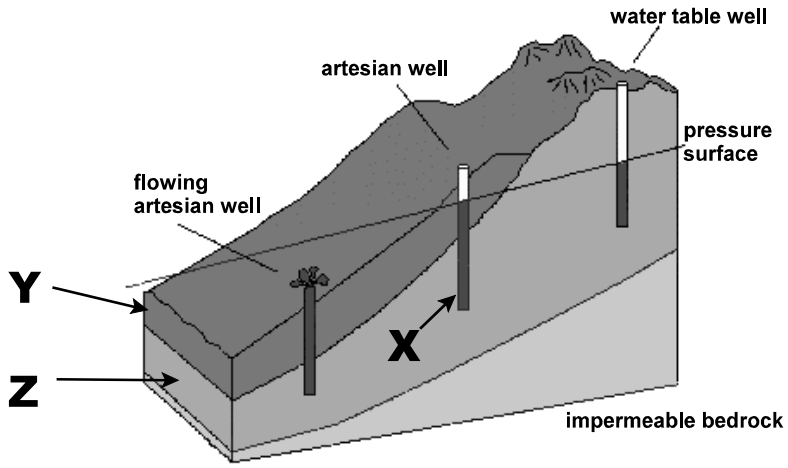
**Answer:**

Since it is known that the rock sample being dated is from the early Precambrian, it is possible to approximate its age as being 4.4 billion years old or slightly younger. The pair of isotopes that could be used to most accurately date this rock sample is Uranium-235 and Lead-207, which has a half-life of 713 million years. Dividing the approximate age of the rock sample by a half-life of 713 million years would result in a small number of half-lives (approximately 6) having occurred. This would result in a significant amount of parent isotopes (i.e. Uranium-235) for dating purposes. As well, as the number of half-lives increase, the fractions (or percentages) of parent and daughter isotopes remaining seem to be closer to theoretical values (i.e. 1/2, 1/4, 1/8, 1/16, 1/32, 1/64).

Carbon-14 and Nitrogen-14 would not prove accurate in terms of dating the rock sample since its half-life is too short (i.e. 5, 730 years). As a result, a large number of half-lives would have occurred in the rock sample (i.e approximately 767, 000), leaving an insignificant amount of parent isotopes (i.e. Carbon-14) remaining for dating purposes.

Uranium-238 and Lead-206 would also not prove accurate in terms of dating the rock sample since its half-life is too long (i.e. 4.5 billion years). This would result in less than one half-life having occurred in the rock sample. Attempting to date the rock sample knowing that less than one half-life had occurred more than likely would involve a significant amount of error and therefore, a highly inaccurate date.

2% 62. (a)




(i) Label rock layers **Y** and **Z**.

**Answer:**

**Y**: Aquitard, aquiclude, or impermeable rock layer. As well, since the question asks to label the rock layer and since shale is an impermeable rock comprising of clay-size particles, then shale is also an acceptable response.

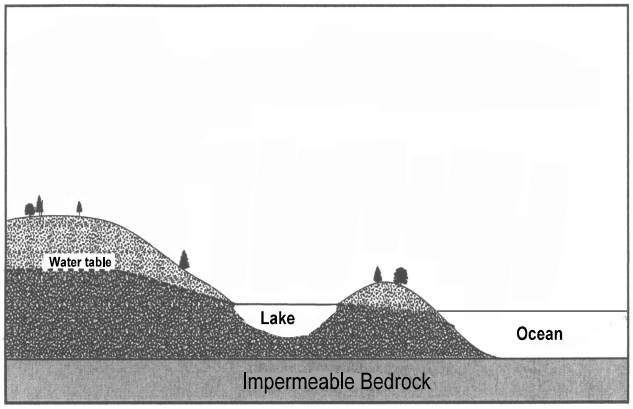
**Z**: Aquifer or permeable rock layer. As well, since the question asks to label the rock layer and since sandstone and breccia are permeable rocks comprising of sand-size particles and gravel-size particles, respectively, then sandstone and conglomerate are also acceptable responses.

(ii) Explain why the artesian well located at **X** is not flowing.

**Answer:**

The artesian well located at **X** will not flow freely because the well opening (i.e. the drill location on Earth's surface) is located above the pressure surface. In this case, the water will only rise to the level of the pressure surface and therefore, is unable to flow freely outwards onto Earth's surface.

2% (b)




During times of drought, the lake in the diagram above becomes salty. Using your knowledge of rock types and the hydrologic cycle, explain why this occurs.

**Answer:**

In the diagram above, the level of the lake is higher than sea level. As water flows "downhill" (i.e. both surface water and ground water) due the force of gravity, the water in the lake will remain fresh since water would flow towards the ocean through the porous and permeable rock layer (i.e. the zone of saturation). In times of drought, the level of the lake will drop lower than the level of the ocean, particularly due to continued evaporation and an insufficient amount of precipitation. In this situation, the salty ocean water would flow inland through the porous and permeable rock, thereby introducing salt into the lake water. Salt can contaminate water to the point where it cannot be used for drinking water.

2% 63. (a) Explain why specific gravity is a better property for identifying an unknown mineral rather than luster.

**Answer:**

Specific gravity would be a better property for identifying an unknown mineral rather than luster. This is because specific gravity is consistent for each mineral regardless of the size and shape of the sample as well as its location of discovery on Earth's surface. In contrast, many minerals can have the same luster (e.g., metallic, non-metallic, earthy, pearly, dull), thereby making this property much less effective for identifying individual minerals and much more effective for simply grouping minerals. As an example, the minerals pyrite and chalcopyrite both have a yellowish, metallic luster; however, pyrite has a specific gravity of 5.2 and chalcopyrite has a specific gravity of 4.2.

2% (b) Explain the difference between a rock and a mineral. Provide an example of each.

**Answer:**

A mineral is any Earth material that possesses the following characteristics:
1. solid;
2. inorganic;
3. naturally-occurring;
4. definite chemical composition; and
5. definite chemical structure.

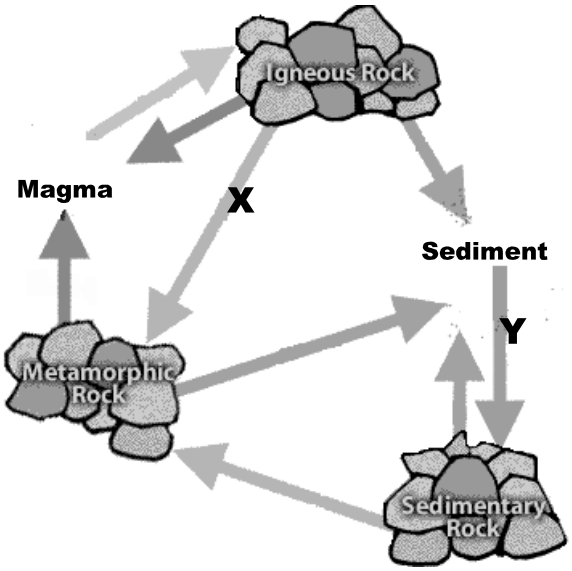
A rock is any Earth material that is solid and is a consolidated mixture of minerals. It is significant to note that the definition of a rock is not "perfect" and somewhat problematic since it is possible for a pure mineral to be a rock.

In relation to rocks that are comprised of a mixture of minerals, there are two main differences between such rocks and a mineral, which include: chemical composition; and chemical structure. A minerals has a specific chemical composition while the chemical composition of a rock can vary since it is comprised of more than one mineral. As well, a mineral has a characteristic chemical structure while the chemical composition of a rock can vary since it is comprised of more than one mineral. Since rocks often contain more than one type of mineral, they will not have a characteristic crystal structure.

For example, a mineral such as potassium feldspar is a solid, naturally-occurring, inorganic, crystalline material with a unique chemical composition and structure, whereas a rock such as granite is a consolidated mixture of minerals (e.g., potassium feldspar, quartz, mica).

It can be concluded that a mineral's chemical composition and structure is always unique and constant; however, in a rock, the chemical composition and structure varies depending on the number of different minerals present.

4% (c) Explain one process that occurs at location **X** and one process at location **Y.**




**Location X:**

**Answer:**

At location **X**, igneous rock is undergoing the process of metamorphism due to three metamorphic agents: heat, pressure, and chemically-active fluids.

Heat and pressure could be the result of regional metamorphism, for example, as two tectonic plates collide. Pressure, but predominantly heat, could also be caused by an intrusion of molten, which would "bake" or contact metamorphose the surrounding igneous rock.

Chemically-active fluids would be required in relation to both regional metamorphism and contact metamorphism since they are fundamental in relation to the process of recrystallization of new minerals.

**Location Y:**

**Answer:**

Sediment is undergoing the process of lithification, which involves converting unconsolidated sediment into solid sedimentary rock. There are two sub-processes that are involved in the process of lithification, which include compaction and cementation. As sediment and its associated weight increases, the particles (or grains) experience compaction, which results in decreasing pore space between the particles. Water that comprises of elements and/or ions permeates through the pore space and the end result is the precipitation of cements that hold the particles together. A clastic sedimentary rock is essentially composed of the particles as well as the cements.

2% (d) Explain the difference between igneous rocks that are extrusive and those that are intrusive. Provide an example of each.

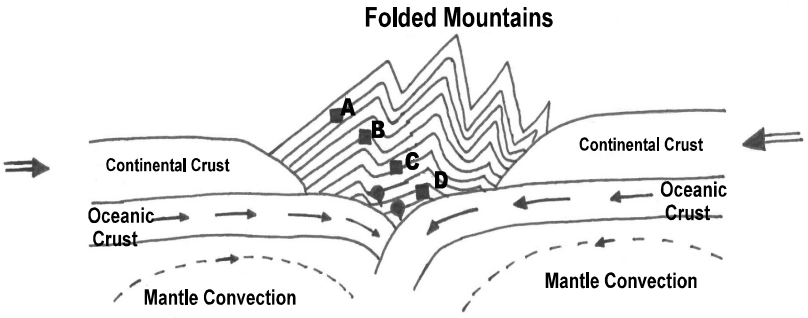
**Answer:**

The most noticeable difference between extrusive and intrusive igneous rocks is their texture. Extrusive igneous rocks will be fine-grained (i.e. contain small crystals) and therefore, possess what is called an aphanitic texture; whereas, intrusive igneous rocks will be coarse-grained (i.e. contain large crystals) and therefore, possess what is called a phaneritic texture.

Extrusive rocks such as rhyolite, andesite, and basalt result from volcanic activity whereby molten breaks through the crust as lava and solidifies (via crystallization) quickly on Earth's surface. In this situation, crystals will be very small or even absent (e.g. obsidian) due to the rapid cooling time. The more rapid the cooling time, the smaller the crystals since they have less time to grow.

Intrusive rocks such as granite, diorite, and gabbro form below Earth's surface in magma chambers (or plutons). The long cooling time of the molten magma allows for crystal growth. Therefore, large crystals will be present in intrusive rocks. The longer the cooling time, the larger the crystals since they have more time to grow.

3% (e) Explain the sequence from **A** through **D** that will occur in shale as it is buried deeper within the folded mountains at a continent to continent plate collision.




**Answer:**

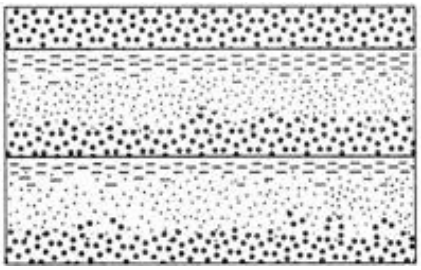
Shale is a clastic sedimentary rock that is capable of being metamorphosed. As shale is buried deeper and deeper in Earth's crust (e.g. within the folded mountains at a continent to continent plate collision), heat and pressure increase. Consequently, the degree of metamorphism will also increase (i.e. low grade through to high grade), producing a predictable sequence of rocks as follows:

Low grade metamorphism will occur at locations **A** and **B**. Shale is metamorphosed into slate at location **A** due to low heat and pressure as well as the presence of hot chemical fluids. Slate is metamorphosed into phyllite at location **B** due to increasing heat and pressure as well as the presence of hot chemical fluids. Medium (or intermediate) metamorphism will occur at location **C** due to increasing burial. With such increasing burial comes increasing heat and pressure in association with hot chemical fluids. Such agents of metamorphism serve to change phyllite into the metamorphic rock called schist. High grade metamorphism will occur at location **D** due to the converging of plates as well as increasing burial. The result will be extremely high amounts of heat and pressure that, combined with hot chemical fluids, will lead to the metamorphism of schist into gneiss.

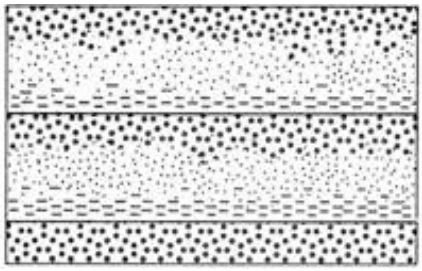
2% (f) With the aid of diagrams, explain two sedimentary features which can be used to determine if a rock outcrop has overturned.

**Answer:**

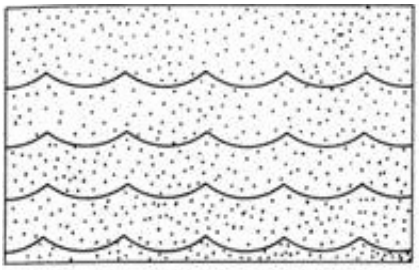
**Graded Bedding**



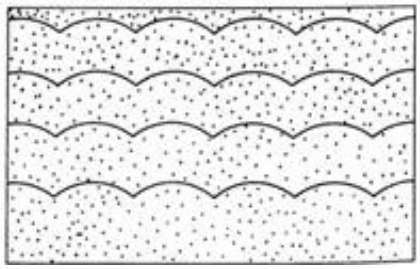
**Inverted Graded Bedding**



**Ripple Marks**



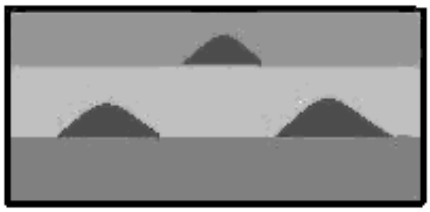
**Inverted Ripple Marks**



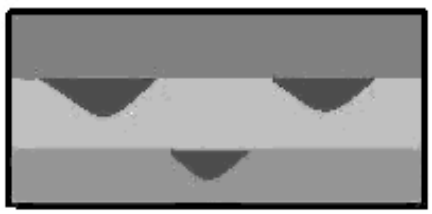
**Mud Cracks**

**Inverted Mud Cracks**

**Shell Fossils**



**Inverted Shell Fossils**



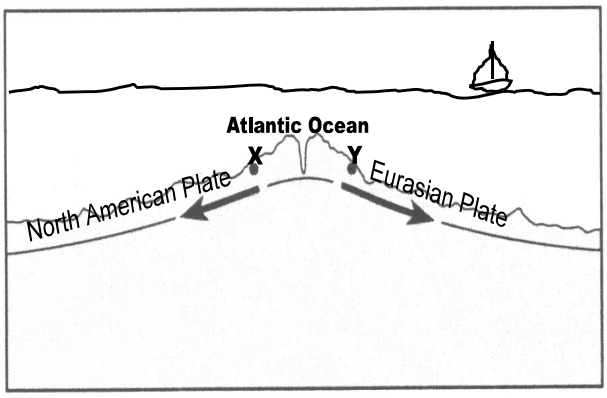
**Answer:**

The sedimentary features in any dipping (i.e. non-horizontal) sedimentary sequence should be examined carefully because the sedimentary rocks could be overturned by tectonic forces. The sedimentary layers that are on top appear to be younger; however, they could be the oldest if they had been overturned in the geological past.

Some sedimentary features that could be used to determine if a sedimentary layer has been overturned include: graded bedding; ripple marks (i.e. current or oscillation); mud cracks; and fossil shell orientation. If either of these sedimentary features appear as inverted in contrast to the normal orientation, then it should be concluded that the sedimentary layers have been overturned by tectonic forces.

With inverted graded bedding, grain size will decrease rather than increase with increasing depth below Earth's surface. With inverted ripple marks, the peaks (or high points) of the ripple marks will point downwards instead of upwards. As well in relation to oscillation ripple marks, they will appear as concave downwards instead of concave upwards. With inverted mud cracks, the peaks will point upwards instead of downwards. It could also be said that the mud cracks appear as "upside down V's". Inverted shell fossils imply that the sequence of sedimentary rocks has been overturned. Inverted shell fossils means that they will be facing upwards (i.e. their open end facing or pointing upwards). In an undisturbed sequence of sedimentary rocks, the shell fossils will be facing downwards (i.e. their open end facing or pointing downwards). This is because moving water will typically flip them over, causing sediment to be deposited on top.

2% (g)




(i) Name the type of plate boundary.

**Answer:**

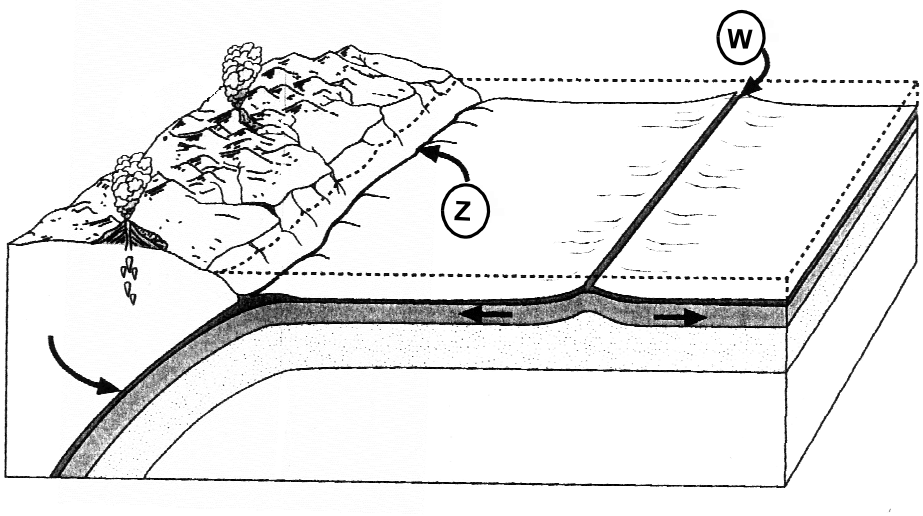
Divergent Plate Boundary

(ii) Explain why the rocks at locations X and Y would be the same age.

**Answer:**

Originally, the rocks located at **X** and **Y** were formed simultaneously from the same body of upwelling molten material that escaped through the Mid-Atlantic Ridge. Diverging convection currents located in the asthenosphere created tensional (i.e. pull-apart) forces, thereby pulling the North American and European plates in opposite directions, each carrying rocks that were formed at the ridge. Consequently, as distance from the Mid-Atlantic Ridge increases so does the age of the rocks. Since locations **X** and **Y** are at the same distance away from the Mid-Atlantic Ridge, but in opposite directions, it should be concluded that rocks at both locations are the same age.

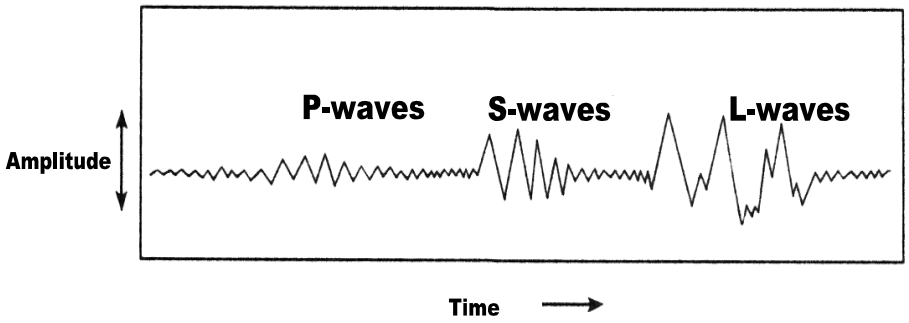
3% (h) Explain how the processes occurring at W and Z are related.




**Answer:**

**W** is located at a divergent plate boundary. New oceanic crust is being formed at this plate boundary due to the upwelling of molten material caused by the diverging convection currents in the asthenosphere, thereby making the two adjacent plates travel in opposite directions. The oceanic plate on the left side of the diagram and to the left of the divergent plate boundary is forced to travel to a convergent plate boundary, which is located at **Z**. At location **Z**, dense oceanic crust is forced to subduct beneath the continental crust, which is less dense, where it is destroyed due to melting. This process is cyclical in that oceanic crust is continuously being created at divergent plate boundaries (e.g. location **W**) and being destroyed at convergent plate boundaries (e.g. location **Z**).

2% 63 (i)




(i) Which seismic wave would cause the most destruction at Earth's surface?

**Answer:**

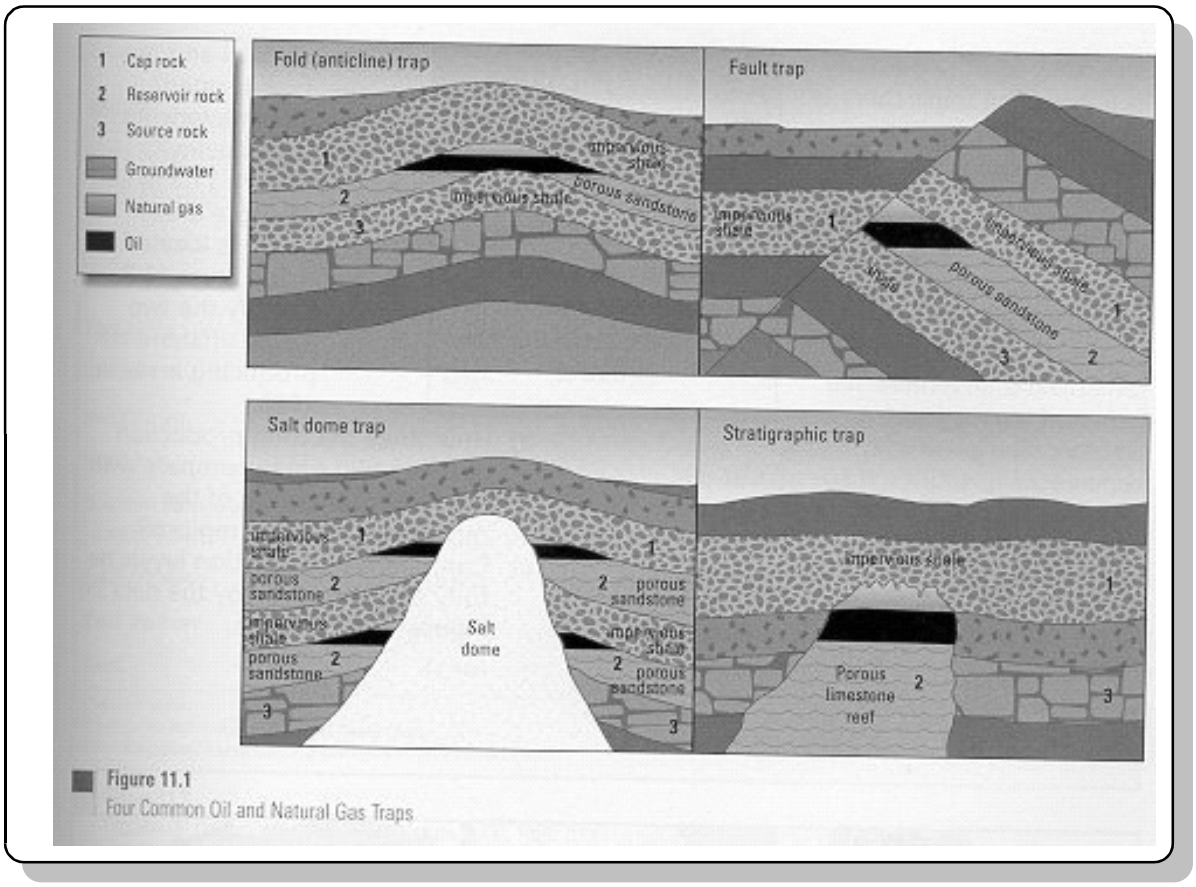
The L-waves would cause the most destruction at Earth's surface, particularly since L-waves are a type of surface waves.

(ii) Explain your choice.

**Answer:**

When comparing surface waves (e.g. L-waves), P-waves, and S-waves, the L-waves have the highest amplitude, therefore causing the most damage. Additionally, L-waves are confined to a narrow region just beneath Earth's surface and they maintain their amplitude longer. As a result, the energy is dissipated over a smaller area, thereby making them much more destructive. The motion of an L-wave is essentially that of a S-wave in that there is no vertical displacement. L-waves move through the ground from side to side in a horizontal plane, but at right angles to the direction of propagation. The horizontal shaking of L-waves is particularly damaging to the foundations of man-made structures.

4% (j) With the aid of a labeled diagram, explain the conditions needed to form an oil trap.




**Source: <u>World Georaphy</u>, Oxford, page 183**

**Answer:**

An oil trap will form when a hydrocarbon-rich source rock (e.g. shale) is "covered" by a porous and permeable reservoir rock (e.g. sandstone). The reservoir rock must be buried by non-permeable cap rock (e.g. shale).

With the proper combination of heat, pressure, and time, hydrocarbons located in the source rock will mature and be squeezed out into the reservoir rock due to increased burial. As a result of density and buoyancy, the hydrocarbons will migrate upward through the porous and permeable reservoir rock. The hydrocarbons will continue their upward journey until they encounter the non-permeable cap rock, which will trap them.

Common oil traps include: anticline; fault; salt dome; and stratigraphic. Pinch-out, unconformity, and limestone reef are three types of stratigraphic oil traps. Despite having an appropriate source rock, reservoir rock, and cap rock, oil will not be produced if a trap of one type is not present.

3% 64. (a) Describe three pieces of evidence to contrast the Theory of Continental Drift and the Theory of Plate Tectonics.

**Answer:**

The Theory of Continental Drift cites observable evidence that would suggest that the continents have changed their location over time; however, the theory has failed to propose a mechanism for causing plate movement. In contrast, the Theory of Plate Tectonics addresses this issue by suggesting the presence of convection cells (or currents) in the asthenosphere that drives plate movement.

**Evidence suggested by the Theory of Continental Drift could include:**

1. A puzzle-like fit of the continents, which would suggest that they were once together but have since drifted apart. Additionally, the continental shelves seem to line up even closer than the continents when they are brought back together.

2. Rocks of similar composition and age, particularly in mountain chains, can be found on different continents. These rocks and the associated mountain chains line up closely when the continents are brought back together.

3. Fossils of the same species (e.g. mesosaurus) are found in certain areas on different continents. These areas line up when the continents are brought back together.

4. Glaciers and their related features serve as paleoclimatic evidence. For example, ground moraines, terminal moraines, and eskers are found in certain areas on different continents. These and other features line up when the continents are brought back together.

**Evidence suggested by the Theory of Plate Tectonics could include:**

1. **Seafloor spreading:** New oceanic crust is being formed at divergent plate boundaries as plates are being pulled in opposite directions by diverging convection currents that are deep within the asthenosphere. The volcanism as well as the earthquakes that occur in these areas serve as evidence that plates and plate boundaries exist.

2. **Magnetic reversals on the ocean floor**: Symmetric patterns of normal and reverse polarity can be observed on the ocean floor in relation to mid-oceanic ridges, which suggest that plate movement as well as sea-floor spreading is occurring.

3. **Age of ocean floor:** Dated drill core samples from the ocean floor show that as distance from the mid-oceanic ridges increase, so does the age of rocks, which suggest that plate movement as well as sea-floor spreading is occurring.

4. **Hotspot (or intraplate) volcanism:** Volcanic activity occurs in the middle of both oceanic and continental plates at some locations on Earth's surface. As plates move over hotspots, which are stationary plumes of up-welling molten, volcanoes are the result. In the case of oceanic plates, such volcanoes can lead to the establishment of islands (e.g. Hawaii). As the plates move over the stationary hotspots, chains of volcanoes are the result, which can be analyzed for the purpose of determining the direction of plate movement.

5. **Wadati-Benioff Zones**: In areas that are characterized by convergent plate boundaries, shallow-, intermediate-, and deep-focus earthquakes may occur. This supports the concept of plate movement and related subduction along deep-ocean trenches where oceanic plates descend and are melted. Moving molten below Earth's surface results in earthquakes.

6. **Polar wandering:** The orientation (or direction) of a rocks acquired magnetic field can be compared to other rocks of different ages on different continents. When sample paths of polar wander from two continents are compared, such as North America and Europe, they coincide as if the two continents were once joined.

3% (b) With reference to plate tectonics, explain why Newfoundland has three major geological zones.

**Answer:**

Newfoundland has three major geological zones, which include: Western; Central; and Eastern. As the plates moved due the underlying convection currents in the asthenosphere, a collision occurred between the North American plate (i.e. Western Zone) and the African plate (i.e. Eastern Zone). During this period of convergence, the Central Zone was created by the uplift of the ancient Iapetus ocean floor as well as volcanism. These three zones remained together as the supercontinent called Pangea broke apart, forming Newfoundland.