Answers to Section K: Internal Processes and Structures (Plate Tectonics)

1. Outline evidence for lithospheric plate motion and continental drift.

   The continental coastlines fit together well. Similar fossils, glacial deposits and rock formations found on different continents. When these continents are fitted together the fossil remains, glacial deposits and rock formations are contiguous.

2. Describe convergent, divergent, and transform types of plate boundaries.

   Divergent plate boundaries *are those in which two plates are separating. A rift occurs here and magma rises. Rifts occur in both oceanic and continental crust (but more often in oceanic since they are thinner.) The Mid-Atlantic Ridge and the rest of the mid-ocean ridge all over the globe on the ocean floor are divergent plate boundaries. Examples of a continental rift zones are the Stikine Volcanic Belt in NW BC and the East African Rift zone.*

   A ***convergent plate boundary*** *occurs when two plates collide. If one plate of oceanic crust collides with a plate of continental crust the more dense oceanic crust will subduct beneath the continental crust, a chain of continental composite volcanoes will form. Examples are the Cascade Mountains, and the Andes Mountains (South America.) If two plates of continental crust collide, neither can subduct and a mountain chain will form (i.e. the Rockies and Himalayans.) If two plates of oceanic crust collide the older, cooler and more dense oceanic crust will subduct beneath the other to form an island arc. The Aleutian Islands in Alaska is an example.*

   A ***transform plate boundary*** *is where two plates slide past each other. The San Andreas Fault in California is an example.*

3. Suggest possible causes for the movements of the plates.

   Mantle convection *can explain plate movement. Hot rock rises within the upper mantle, it reaches the top of the asthenosphere and moves along pulling the lithospheric plates. As the hot rock cools it sinks back into the mantle.*

   Gravity: *Another proposal to explain plate movement suggests that the plates slide downhill from the higher altitude mid-ocean ridges.*

4. Describe the origin of magma formed during plate tectonic processes.

In a subduction zone	*Friction raises the temperature* *Adding water lowers the melting point* *Reducing pressure melts the rock as it rises*
At a spreading centre	*Reducing pressure melts the rock as it rises*
At a hot spot, or mantle plume	*Reducing pressure melts the rock as it rises*

5. Relate volcanic activities and features to convergent, divergent, and intraplate settings.

Convergent	*Continental crust and continental crust*	*Both are floating on top of the asthenosphere and rocks deform to form mountains*
	Continental crust and oceanic crust	*More dense oceanic crust subducts below to form volcanic mountains, cinder cones, composite volcanoes and mountain ranges*
	Ocean crust with oceanic crust	*Both are dense, the older slab of oceanic crust that is more dense will subduct below the other and form an island arc. Ex: the Aleutian islands in Alaska, Japan.*

Divergent	*Continental crust and continental crust*	*A rift valley is formed and volcanoes of basalt may form. Ex: the Red Sea which has since filled up with water*
	Oceanic crust and oceanic crust	*A mid-ocean ridge forms and basaltic lava wells up. Ex: the Mid-Atlantic Ridge; the Juan de Fuca Ridge off our coast.*
Intraplate	*Over a hot spot*	*Basaltic magma can rise. The Hawaiian Islands sit on top of a mantle plume, or hot spot. This plume has been stationary for millions of years, and as the Pacific Plate has moved over top it has created a chain of islands. The islands to the northwest are the oldest.*

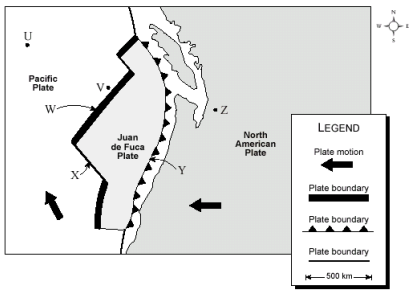
6. Describe the geologic activities that occur at lithospheric plate boundaries.
   *The majority of **volcanoes** and **earthquakes** occur at or near plate boundaries. **Mountain ranges** are formed due to the collision of lithospheric plates. There are many **mineral deposits** near lithospheric plate boundaries. This is because there is a heat source due to the presence of magma to heat water. Water in the crust will heat up near a magma source, and water will be hotter far down into the crust even far from an active volcano. Hot water can dissolve minerals and other ores more readily than cool water. This water will rise through a magma vent, or a fault, and as it cools the minerals precipitate out of solution.(=Hydrothermal ore deposits.)*

7. Relate the rock cycle to plate tectonics
   The rock cycle explains the transformation among igneous, sedimentary and metamorphic rocks. The rock transformation includes weathering and erosion to eventually form sedimentary rocks. Heat and pressure alter rocks to form metamorphic rocks. Melting and solidification form igneous rocks. The role of plate tectonic in this process is to provide a mechanism. Hotspots, subduction and rifting all provide a source of heat to melt rock or undergo metamorphism. Dynamic movements including uplifting and faulting contribute to metamorphic changes due to pressure. Mountains formed by tectonic activity allow water and rivers to erode rock. Rifting and trenching create basins for sedimentary rocks to form.

8. Compare oceanic crust and continental crust in terms of composition, thickness, age, etc.
   Oceanic crust is denser, less thick, and on average newer than continental crust.

Use the map below to answer questions 9 to 13. The map shows an area of western
North America and the sea floor off that coast. Several plate boundaries are shown.

9. The feature labelled **W** is a(n)
   a) island arc.
   b) ocean trench.
   c) oceanic ridge
   d) transform fault.



10. The relative plate motion at feature **X** is best shown as

A.

B.

C.

D.

11. An earthquake along feature **X** would **most likely** have a(n)
    a) shallow focus (depth less than 100 km).
    b) deep focus (depth greater than 400 km).
    c) intermediate focus depth (from 100 - 400 km).
    d) wide range of possible focus depths (from 0 - 700 km).

Transform faults have shallow earthquake foci since there is no down-going plate.

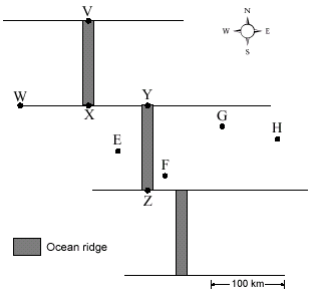
12. Composite (strata) volcanoes would **most likely** be found at
    a) U
    b) W
    c) Y
    d) Z

13. A rock sample taken at feature **V** is found to have an age of 2 000 000 years. Feature **V** is located 80 km away from the centre of feature W. (Note: 1 km = 100 000 cm.) The rate of plate motion in this area is
    a) 0.25 cm/y
    b) 2.0 cm/y.
    c) 4.0 cm/y.
    d) 8.0 cm/y.

14. The most common igneous rock type found at a divergent plate boundary is
    a) basalt.
    b) granite.
    c) rhyolite.
    d) andesite.

Use the following map of plate boundaries in oceanic lithosphere to answer questions 15 to 17.

15. The type of plate boundary shown between **X** and **Y** is
    a) diverging.
    b) transform.
    c) subduction.
    d) converging.



16. Which of the following rock types is **most likely** found at the centre of the ridges?
    a) rhyolite tuff
    b) organic shale
    c) basalt pillows
    d) organic limestone

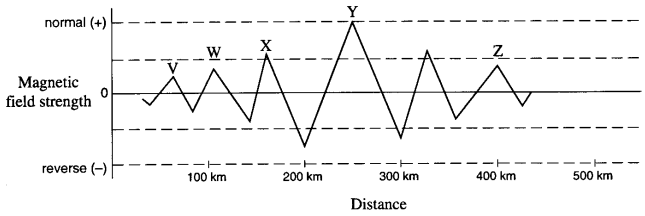
17. Ocean floor sediments have been drill-sampled down to bedrock at locations E, F, G and H. The **most likely** location to have the **thickest sediment** deposit is
    a) E
    b) F
    c) G
    d) H

    Because H is the furthest from the ridge. The rocks are the oldest and have had the most time to accumulate sediment.

18. Some of the world's mountain belts, such as the Rockies, are not along active earthquake belts. This observation seems to contradict the idea that plate collisions can create mountains. A likely explanation of this observation is that these mountains
    a) are thick deposits of basalt.
    b) were formed by layers of sediment.
    c) are the sites of ancient collision boundaries.
    d) are points where new plate boundaries are forming.

Use the following graph of magnetic field strength and distance across an ocean basin to answer questions 19 to 22.

19. At which location is new rock being formed?
    a) W
    b) X
    c) Y
    d) Z



20. Rock with the same age as rock at Z would also be found at
    a) V
    b) W
    c) X
    d) Y

21. If the difference in the ages of rocks at W and X is 2 000 000 years, and locations W and X are 60 km apart, the rate of sea floor spreading is
    a) 1 cm/y
    b) 3 cm/y
    c) 6 cm/y
    d) 9 cm/y

22. Which of the following best records magnetic field direction on the ocean floor?
    a) Igneous rock
    b) Sedimentary rock
    c) Metamorphic rock
    d) Sea floor sediments

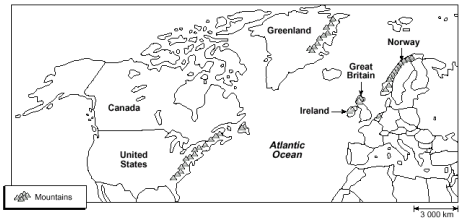
    When molten the iron with the igneous rock can align with the Earth's magnetic field.

23. The most likely energy source driving plate tectonics is
    a) friction
    b) ocean heat
    c) magnetism
    d) radioactivity

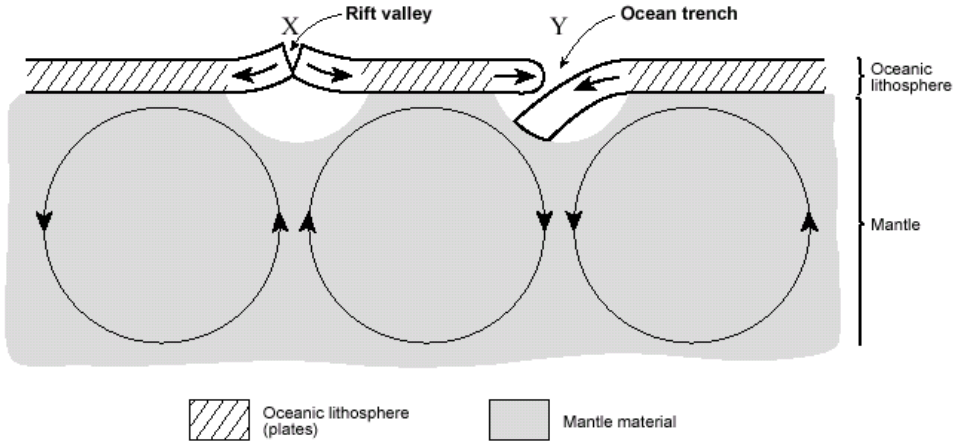
24. The large scale apparent wandering of the Earth's magnetic north pole as recorded in continental volcanic rocks is a result of changes in the
    a) tilt of the Earth's axis
    b) location of the pole star
    c) positions of the continents
    d) position of the geographic north pole

Use the following map to answer question 25.

25. The Appalachian Mountains in North America and the Caledonian Mountains in Europe contain very similar rock types, structures and fossils. This observation suggests that North America and Europe
    a) were once together.
    b) are moving closer together.
    c) are on the same lithospheric plate.
    d) were joined by mountains extending across the Atlantic Ocean.



Use the following cross section of three mantle convection currents and part of the oceanic lithosphere to answer question 26.



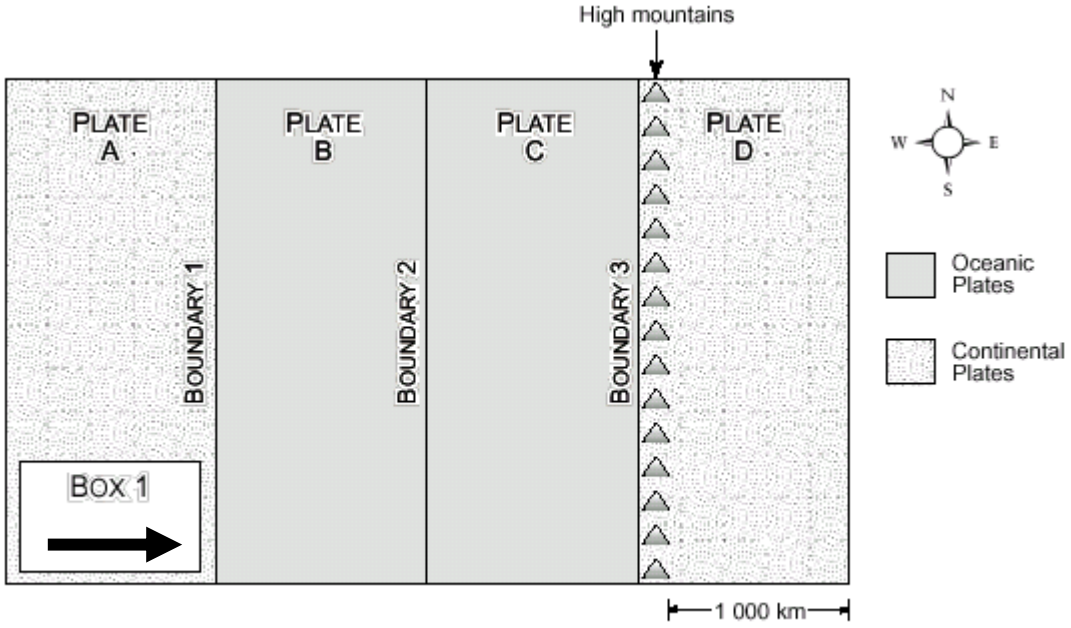
26. a) Explain what causes the mantle convection currents to rise and then fall.

Mantle convection currents rise where they are hottest and consequently least dense. When the mantle material cools, it becomes denser again and sinks toward the bottom of the mantle.

b) Complete the oceanic plates appropriately in the gaps below X and Y. Label with arrows showing the direction of movement.
See diagram above.

c) On the completed diagram, label an ocean trench and a rift valley.
See diagram above.

Use the following diagram of four lithospheric plates to answer question 27. All the plates are moving.



27. a) Boundary 1 is a convergent boundary. Indicate with an arrow in Box 1 on the diagram the direction that Plate A must be moving relative to Plate B.
Direction of Plate A: See diagram. Plate A must be moving east relative to plate B.

b) A chain of high mountains lies on Plate D. Name two geologic processes which could contribute to the formation of this mountain chain on Plate D.

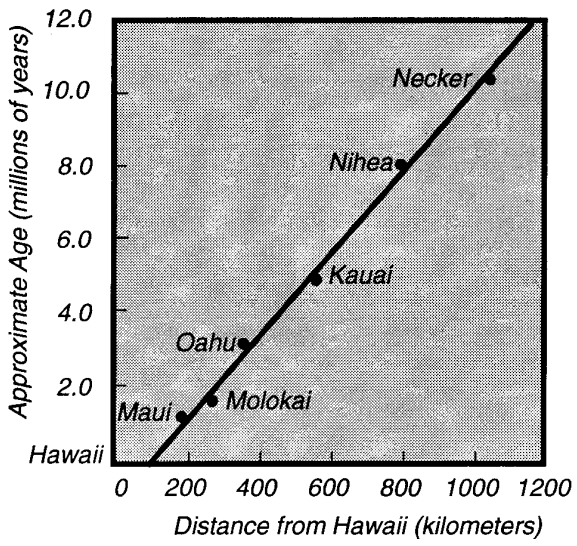
Geologic Process 1: *Subduction causing volcanism.*

Geologic Process 2: *Convergence causing uplifting, folding.*

c) What geologic feature would need to be located at Boundary 2 to account for the relative motion of these four plates?
Spreading centre / spreading ridge / rift zone.

Use the following graph to answer question 28.

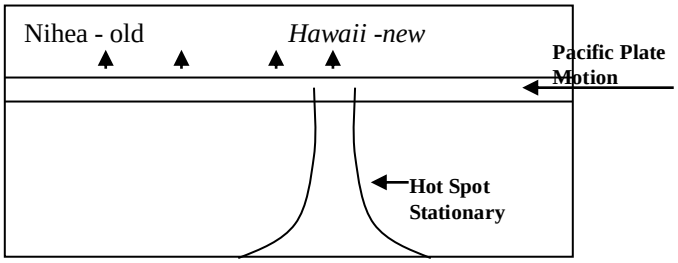
28. The graph shows some of the Hawaiian Island chain. The vertical axis of the graph gives the approximate age of the volcanic rocks found on each island, and the horizontal axis shows the distance of each island from Hawaii.



a) Assuming an age of 8.0 million years for the rocks of Nihea, determine the rate of motion in centimetres per year, of the Pacific Plate in this region.

$$\frac{800\,km}{8000000\ yr} = 10\,\frac{cm}{yr}$$

b) With reference to the concept of mantle hot spots, explain the relationship between age and distance from Hawaii for the islands in the Hawaiian chain. Draw a cross-sectional diagram to help illustrate your answer.



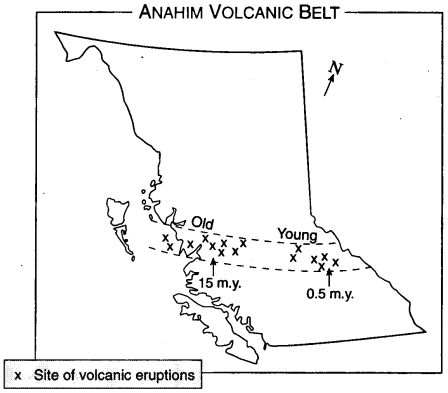
The Pacific plate is moving over a hot, stationary mantle plume. The magma penetrates the Pacific plate and creates the Hawaiian chain shield volcanoes. There must be an episodic extrusion of magma because otherwise there would be a continuous chain of volcanoes rather than isolated islands. (Magma plume finds weak spots in plate to break through.)

c) The oldest islands in the Hawaiian chain are also the lowest in elevation and the smallest. Give two geologically reasonable explanations why this is so.

1) Over time erosion cuts the volcanoes down.

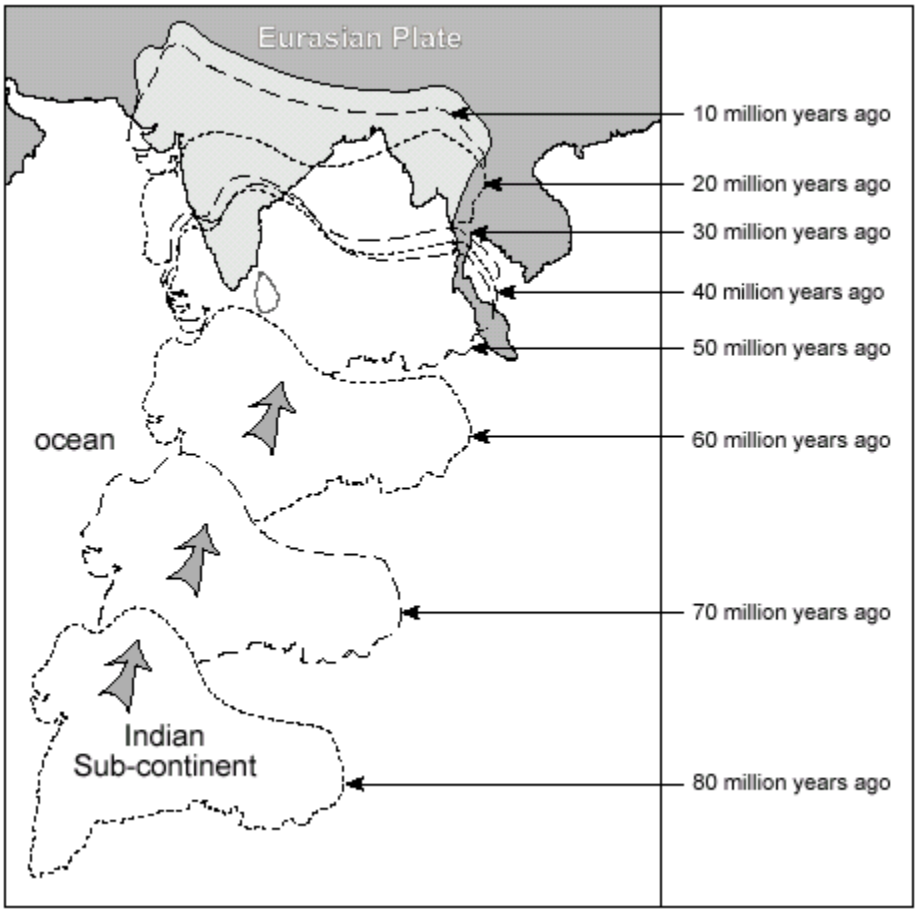
2) The mantle plume raises the land directly above it. When the plate has moved away from the plume, the land then subsides at that location again.

29. Observe the diagram to the right. Use your knowledge of plate tectonics to explain the occurrence of the volcanic belt.



A mantle plume is beneath the area. As the North American plate moves toward the west the plume remains stationary and intrudes into a new part of British Columbia further east. This is an identical pattern to that of the Hawaiian volcanic chain.

Use the following diagram to answer question 30 to 32.



30. What geologic feature resulted from the collision of the Indian sub-continent with the Eurasian plate?
The Himalayan Mountains

31. Describe the process within the Earth's interior to explain the motion of the Indian sub-continent.
Convection currents in the mantle carry and push the plates around the surface of the Earth. It has resulted in the Indo-Australian plate colliding with the Eurasian plate and forming the Himalayan Mountains.

32. Jurassic ammonites (ancient sea creatures) have been found high in the mountains. Using your knowledge of plate tectonics, give a possible geological explanation.
On the south coast of the old Eurasian plate during the Jurassic period there were ammonites. These became buried and fossilized off the coast. Along the coast sedimentary rocks were formed that included many fossils. When the Indo-Australian plate collided with the Eurasian plate the resulting collision pushed and folded the sedimentary rocks into huge mountains. In fact, the summit of Mt. Everest is marine limestone.

Answers to Section L: Internal Processes and Structures (Seismology)

1. Describe fault creep and elastic rebound as they relate to seismic activity

   Tectonic plate movement is responsible for subduction, rifting and compression. This can cause the rocks to move or to stretch. ***Fault creep*** *occurs when the rocks move gradually and smoothly; it causes broken curbstones and offset fences etc. Or the rocks do not move and this causes the rocks to stretch, or be compressed. Rocks can stretch, and when they do they store energy.*
   When stresses that move the tectonic plates are strong enough the rocks can no longer hold and suddenly move. This sudden movement is a large release of energy, which is an earthquake. The stressed rocks snap back elastically; this is referred to as ***elastic rebound***
   Earthquakes usually occur along fault lines where the lithosphere is the weakest. It is easier for the rocks to move along a fault.

2. Distinguish between magnitude and intensity

   The amount of vertical shaking is related to the magnitude of the earthquake, whereas intensity is a measure of the effects of an earthquake. Intensity is not a precise measurement unlike magnitude which uses instruments to measure vertical motion and energy released. Intensity is based on direct observations of individuals based on the extent of the damage that varies due to the local geology.

3. Compare and contrast the Richter and Mercalli scales

   The ***Mercalli*** *scale measures* ***relative intensity*** *and the effects of an earthquake. It is qualitative and subjective to those who describe the earthquake. It is measured on a scale from I to XII. The* ***Richter*** *scale measures the* ***magnitude*** *based on the amplitude of the earthquake wave. The Richter scale is a quantitative measure of an earthquake that does not rely on someone's opinion. It is measured on a scale from 1 to 9; each increase in magnitude of one the earthquake is 10 times stronger.*

4. a) Describe in detail how to locate the epicenter of an earthquake using seismograph data.

   Seismologists use the fact that P waves travel faster than S waves to determine how far away the epicentre is located. Three seismographs are required. At each seismograph location the difference in arrival time is measured. The greater the difference in arrival times the further away the epicentre, because S waves get further and further behind. This difference in time determines how far away the epicentre is. A circle is plotted around that seismograph location, since the earthquake could have occurred anywhere on that circle. The seismograph tells nothing about the direction from which the waves came. The data from three seismographs are plotted on the same map, and because three circles will intersect only at one point, the epicentre location can be determined.
   The magnitude of the earthquake would be calculated from the amplitude of the wave as measured on the seismograph and corrected for distance from the epicentre. The magnitude decreases away from the epicenter.

   b) What represents magnitude on a seismograph?

   The amplitude of the waves (size of the squiggley lines) on the seismogram paper is what seismologists use to determine the magnitude.

5. Assess the seismic risks for a particular area using:
   - geographic location

     An increased risk of experiencing earthquakes occurs for those people who live near plate boundaries and active fault lines. There are densely populated locations around the world that experience frequent large earthquake, ex: Chile, Peru, Southern California, Japan, and Italy

   - topography

     Adding to their risk is those people who live near mountains because these regions have a lot of landslides, mudslides and other hazards. People near the shore may experience tsunamis; however, these unfortunate people may be thousands of miles from the epicentre.

- ground strength
  Solid bedrock such as granite resists shaking more so than softer rock. Building on sediment is risky because of the threat of liquefaction. Landslides can be a serious danger in hilly areas because an earthquake can loosen rock on a slope.

- rock types
  Buildings built on solid bedrock resist ground shaking far more than layered sedimentary rock that may break loose and slip in the event of an earthquake.

- proximity to faults
  Living near an active fault is risky and any residents will be vulnerable.

- construction design
  The design and materials of the house is also a hazard during an earthquake. Houses made out of brick, clay (adobe) or un-reinforced rock will easily topple during an earthquake. Indeed, this is the most common cause of death during an earthquake. Buildings that meet earthquake code requirements are either wood frame houses or reinforced concrete or buildings that allow movement and vibrating.

6. Evaluate various methods of earthquake prediction (e.g. seismic gap, animal behaviour)
   Long term prediction involves historical data of previous earthquakes in the region, measurements of plate movement and movement along other fault lines within a plate. These only give vague estimates. This has forced city officials to upgrade building and bridges.
   Short term prediction tries to pinpoint the time and location. Seismologists look for signals of an impending large earthquake such as: foreshocks, odd animal behaviour, a change in the water table (dilatency data), an increase in radon gas in well water, rock resistivity changes and changes in the land. Only one documented case has been successful, the city of Heicheng in China was evacuated shortly before a large magnitude 7.3 earthquake in 1975. Short-term prediction is very difficult because not all earthquakes have the same precursors, so it is difficult to determine if indeed it is a warning of a larger earthquake to come, or just an isolated event.

7. Describe the differences between P, S, and L waves.

P waves	*Occur within the Earth, body waves*	*Push and Pull Compression waves*	*Fastest 4-8 km/s*	*Travel through solid and liquid*
S waves	*Occur within the Earth, body waves*	*Side to side Transverse, shear waves*	*Slower 3-4 km/s*	*Travel through solid only*
L waves	*Occur on the Earth's surface*	*Side to side Up and down*	*Slowest*	*Travel through solid only*

8. Define the terms epicentre, focus, liquefaction, tsunami.
   Epicentre *is the point on the Earth's surface directly above the focus.*
   The ***focus*** *is where the rocks break.*
   Liquefaction *occurs when the soil and other soft sediment turn to liquid while the Earth is shaking.*
   A ***tsunami*** *is a wave caused by an undersea earthquake. Out at sea it is a low amplitude but fast moving wave. As it reaches the shore it slows down and grows in height to be very destructive. A powerful tsunami raced along the North American coast all the way to California caused by the 1964 Alaska earthquake. In 1999 in Papua New Guinea a tsunami killed 2000 people.*

9. Explain how dilatancy data is related to earthquakes.
   Rocks that are under pressure from colliding plates that are stuck along the edges can have their pore spaces open up. Water can then infiltrate the space causing some lubrication so that the rocks will slip causing an earthquake.

10. Describe how a seismograph works.
    A seismograph records the ground motion during an earthquake. A pen draws a straight line on a rotating drum when the earth is still. When the earth shakes the drum, which is firmly attached to the earth, moves up and down relative to the pen. The pen doesn't move because it is suspended by a spring, inertia limits its motion.

11. A low energy earthquake that caused most of the buildings in a town to collapse would be rated
    a) low on the Richter scale and low on the Mercalli scale.
    b) low on the Richter scale and high on the Mercalli scale.
    c) high on the Richter scale and low on the Mercalli scale.
    d) high on the Richter scale and high on the Mercalli scale.

12. Which of the following is the **least** useful for predicting earthquakes?
    a) Height of sea level
    b) Amount of ground tilt
    c) Degree of micro-seismic activity
    d) Percentage of radon in ground water

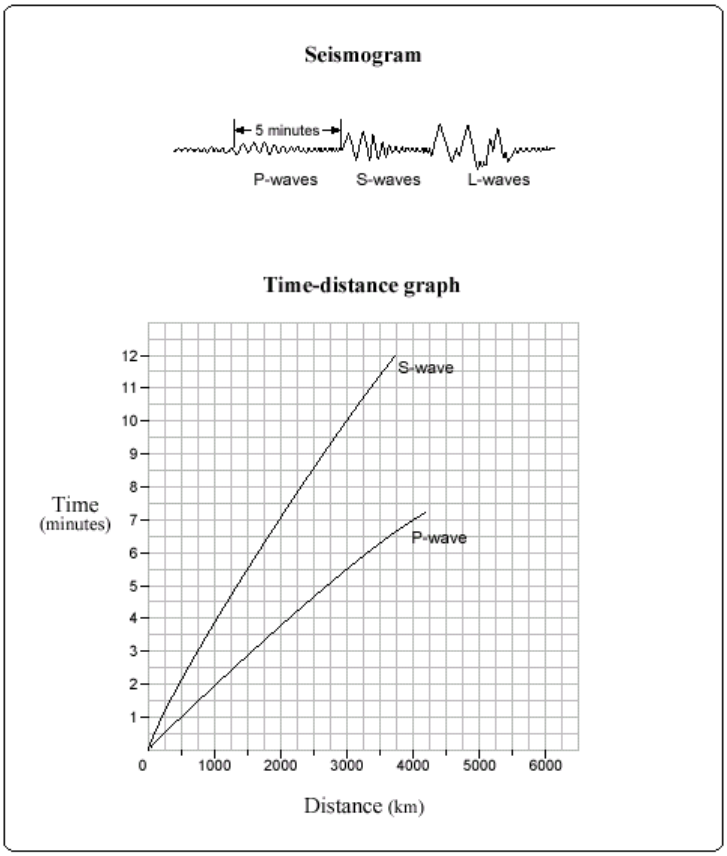
13. A magnitude 8 earthquake located 20 kilometres off the west coast of Vancouver Island would likely produce all of the following except
    a) a tsunami.
    b) landslides.
    c) a volcanic eruption.
    d) liquefaction of sediments.

14. Movement along a fault without the buildup of significant amounts of stress is known as
    a) creep.
    b) strain.
    c) stress rupture.
    d) elastic rebound.

15. Which of the following is the **most likely** cause of the largest magnitude earthquakes?
    a) Rift eruptions.
    b) Isostatic adjustment of the crust.
    c) Stress buildup between lithospheric plates.
    d) Major temperature changes in surface rocks.

16. Slow, continuous slip along a fault zone is called
    a) fault creep.
    b) ground slump.
    c) rock dilatancy.
    d) elastic rebound.

Use the following seismogram and time-distance graph for P- and S-waves to answer questions 17 and 18

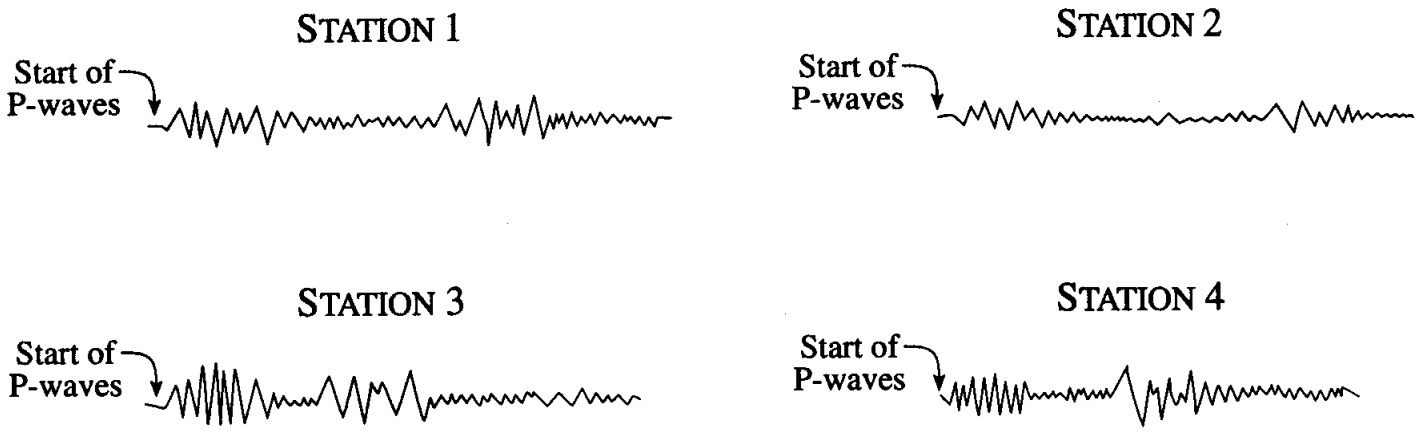


17. The distance from the seismometer to the epicentre of the earthquake is
    a) 1 300 km.
    b) 2 000 km.
    c) 2 750 km.
    d) 3 400 km.

The S waves arrive 5 minutes after the P waves. On the graph determine at what point there are 5 minutes between the P and S waves. Determine the corresponding distance.

18. The two curves on the Travel Time graph have different average slopes because
    a) P-waves travel faster than S-waves.
    b) S-waves have a side-to-side shaking motion.
    c) S-waves change velocity and P-waves do not.
    d) P- and S-waves travel through different materials.

Use the following seismographs to answer question 19



19. The seismographs above were recorded for one earthquake by using similar seismographs at four different stations. What is the correct order, from closet to farthest, in terms of distance from the epicentre to each station?
    a) 2,1,3,4
    b) 2,3,4,1
    c) 3,4,1,2
    d) 3,2,1,4

    Station 3 has the least time difference between the P and S waves. Station 2 has the most time difference between the P and S waves

20. Which of the following would **least** affect the Mercalli intensity rating of an earthquake?
    a) Direction to the focus.
    b) Local geologic conditions.
    c) Distance from the epicentre.
    d) Magnitude of the earthquake.

21. How could you tell from a seismogram that an earthquake was closer to station A than station B?
    a) The difference in the arrival times of the P and S waves was less at station B
    b) P waves arrived earlier at station B than station A.
    c) Amplitude of the waves on the seismograph at station A were larger.
    d) All of the above.

22. During an earthquake, minimum damage to a structure would most likely occur if the structure was located on
    a) delta deposits
    b) granitic bedrock
    c) unconsolidated fill
    d) tilted sedimentary beds

23. Any one earthquake can have
    a) one magnitude and one intensity
    b) many magnitudes and one intensity
    c) one magnitude and many intensities
    d) many magnitudes and many intensities

24. A seismograph will record the
    a) depth of a focus
    b) distance to an earthquake
    c) time an earthquake occurred
    d) time at which waves arrive at the device

The distance to an earthquake is only determined indirectly by using 3 different seismographs.

25. The minimum number of seismograph stations usually required to give the location for an epicentre is
    a) 1
    b) 2
    c) 3
    d) 4

26. A seismograph cannot be used to
    a) predict earthquakes
    b) record time of wave arrivals
    c) calculate distance to the epicentre
    d) calculate magnitude of the earthquake

27. How much more energy does an earthquake of Richter magnitude 5 compared to one of Richter magnitude 3 release?
    a) 30 times
    b) 900 times
    c) nearly twice as much
    d) 100 times

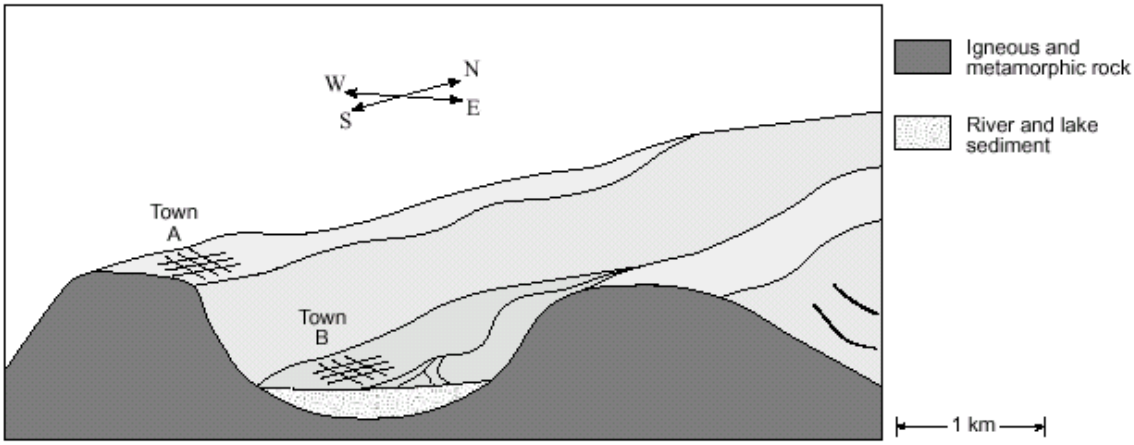
28. The earthquakes which occur the most frequently also
    a) cause damage to cities
    b) have small magnitudes
    c) generate large tsunamis
    d) occur in the middle of tectonic plates

29. Which of the following strategies would be most effective in reducing the possible damage to buildings due to soil liquefaction?
    a) Building large concrete retaining walls around structures
    b) Building earthquake resistant buildings that could withstand vigorous ground shaking
    c) Not building structures near coastal areas
    d) Not building structures on wet or unstable soils

30. There is geological evidence that the West Coast of Canada is an active earthquake zone, although this region has not experienced a large earthquake in a long time. Explain why a large earthquake may occur in the near future.

    The West Coast of Canada is on a fault boundary, the Juan de Fuca plate is subducting below he North American plate. Subduction zones normally exhibit large period earthquakes, so there is no reason to suggest that the West Coast should not experience a large earthquake as well. There is historical evidence all along the coast that suggests that the area has had large earthquakes in the past, these include a sudden and catastrophic sinking of coastal areas. The lack of seismic activity may indicate that the Juan de Fuca plate is stuck and not moving thus storing a lot of elastic energy which is ready to be released in a large earthquake. Or the lack of seismic activity may be because the plate is sliding smoothly beneath the North American plate and not building up any stress. Remember that Vancouver Island is being uplifted and tilted, indicating that pressure is building so it is unlikely that the plates are sliding smoothly past one another!

Use the following cut-away diagram of an area that has experienced a magnitude 6 earthquake to answer question 31.



31. The area shown in the diagram above experienced a magnitude 6 earthquake. The focus was located 30 km beneath Town B. Town B was more extensively damaged than Town A, even though both towns have the same construction standards, and have similar populations.

    a) Which town is likely to have a higher Mercalli Scale rating?
    Town B is likely to have a higher Mercalli Scale rating.

    b) What is the **most likely** reason for the extensive damage to Town B?
    The extensive damage to Town B is likely the result of the shaking and liquefaction of the lake and river sediments and the fact that Town B is closer to the focus of the earthquake than Town A.

    c) The P-wave and S-wave travel-time difference at Town B is slightly less than at Town A. Explain why this travel-time difference would occur.
    The P-S travel-time difference at Town B is slightly less than at Town A because Town B is closer to the focus.

    d) The people of Town B did not act on the advice of a local seismologist who noticed a variety of earthquake warning signs (precursors) prior to the earthquake. Describe **one** such precursor that the seismologist may have detected.
    Radon gas in well water, bulging, micro-quakes, rock resistivity changes, P-wave velocity change, unusual animal behavior.

Answers to Section M: Internal Processes and Structures (Isostasy)

1. Analyse the adjustment of the crust to changes in loads associated with volcanism, mountain building, erosion, and glaciation by using the concept of isostasy

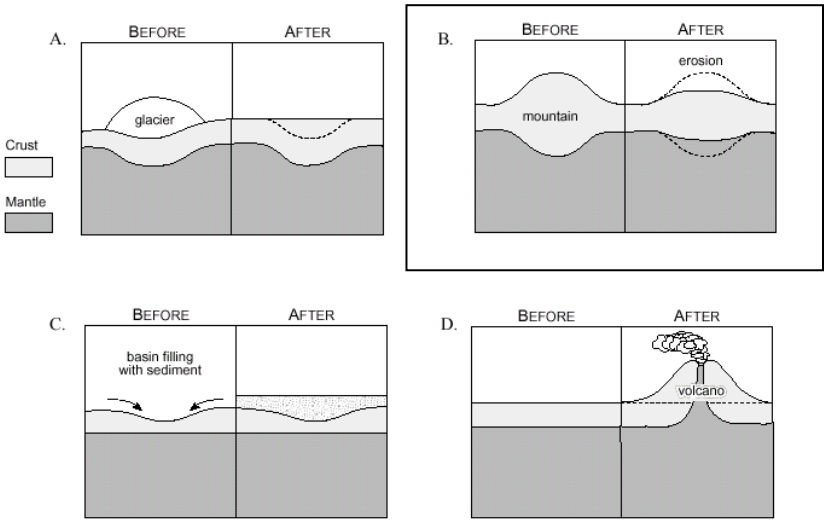
Isostasy refers to the concept of how the lithosphere floats on top of the asthenosphere. As a volcano is adding dense rock to the crust the lithosphere will sink lower into the asthenosphere. Mountain building is a result of the crust being folded, and this will cause the lithosphere to sink further into the asthenosphere. However, the opposite occurs during erosion as sediment is carried off the mountain the crust will rebound and float higher. During the ice ages the massive ice sheets pushed down on the continental crust to make it float lower. As the ice sheets melted the continental crusts has rebounded. So Northern Canada and Scandinavia are still rising.

2. Explain how mountains can rise even though they are eroding?

Mountains can rise even though being eroded because as a lot of material is carried off the mountain top the lithosphere floats higher.

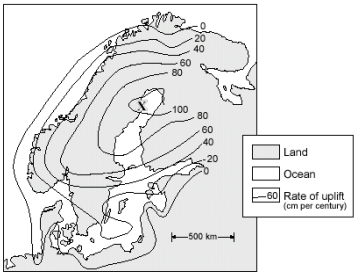
3. Which of the following is a result of isostatic adjustment?
   a) Glacial flow down a valley
   b) Crust sinking beneath a delta
   c) Displacement along a transform fault
   d) Mountain building at a convergent plate boundary

4. Which of the following "before and after" sequences shows the correct Isostatic response?

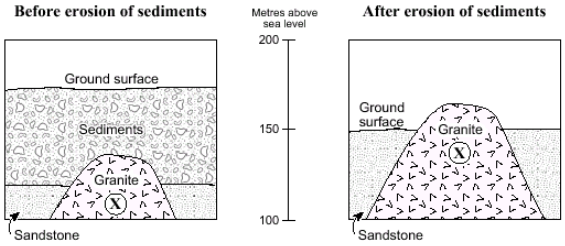


Use the following map that shows rates of crustal uplift in Scandinavia to answer question 5. The numbered lines join points of equal crustal uplift.

5. At location X, the crust is rising
   a) fastest because this is where the Pleistocene ice cap was the thickest.
   b) fastest because this is where the Pleistocene ice cap was the thinnest.
   c) slowest because this is where the Pleistocene ice cap was the thickest.
   d) slowest because this is where the Pleistocene ice cap was the thinnest.



Use the following diagram to answer question 6 and 7.



6. After the sediments have been eroded, location **X** in the granite will be at a higher elevation above sea level. What is the name given to this process.

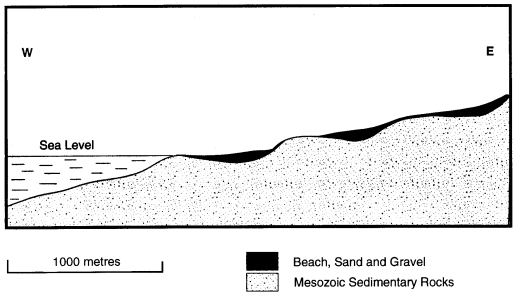
Isostasy

7. Describe why the granite is now above sea level.

   As the overlying sediment erodes weight is removed from the lithosphere. As a result the lithosphere crust can float higher on the asthenosphere. The granite batholith will be at a higher elevation than before.

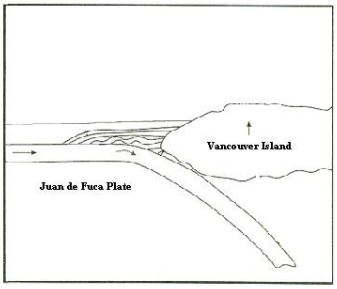
Use the following cross-section of part of the coast of western Vancouver Island to answer question 8

8. One prominent feature of the coastal section is the series of beaches at different heights above sea level. Give two geologically reasonable explanations for how the beaches could have formed. The first should involve plate tectonics, and the second explanation should involve glaciation. Draw diagrams to help illustrate your answer.



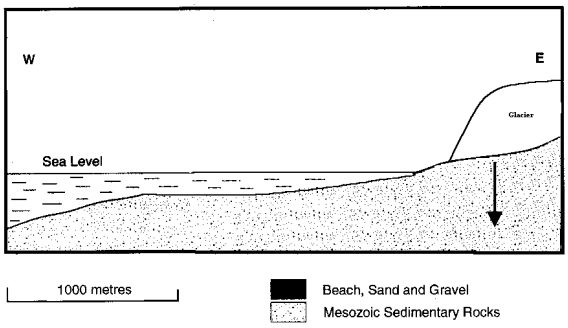
a) Explanation 1 (Plate Tectonics)

Vancouver Island rises as the Juan de Fuca plate subducts below the North American plate. The tremendous forces of collision lift and create mountains, thus leaving beaches abandoned.



b) Explanation 2 (Glaciation)

During the ice age the enormous weight of the glaciers pushed the lithosphere down. But when the glaciers melted the weight was removed and the lithosphere has rebounded, thus leaving beaches abandoned. In this diagram the two beaches furthest west are submerged because the lithosphere has sunk lower.



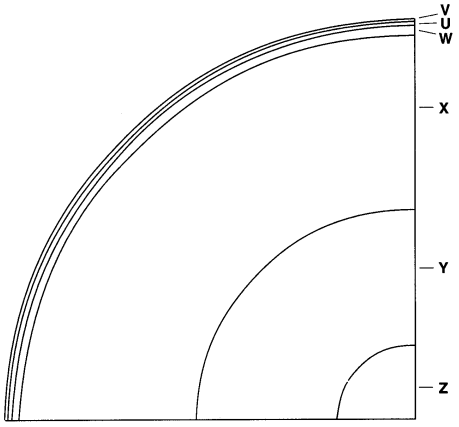
Answers for Section N: Internal Processes and Structures (Earth's Interior)

1. Give evidence for the fact that the earth is layered

   Seismologists have used the fact that earthquake waves, and those waves produced by nuclear explosion tests, travel through the Earth from one side to the other. P waves travel through solids and liquids, whereas S waves only travel through solid. Since S waves are not detected on the other side of the Earth from the epicentre of an earthquake, there must be a liquid layer in the Earth. P waves pass through the centre of the Earth to be detected on the other side. However, because P waves refract (change direction) at different layers within the Earth there is a "shadow zone" where no waves are detected. From this data it can be concluded that the Earth has a solid core that is surrounded by a liquid outer core. The crust mantle boundary is determined by analyzing data that suggests the wave speed of P and S waves changes.

2. Diagram or model the interior of the earth, labelling all principal parts and showing the approximate thickness of each layer

V	Crust	*7 km to 70 km thick*
U	Lithosphere	*100 km thick*
W	Asthenosphere	*250 km thick*
X	Mantle	*2900 km thick*
Y	Outer Core	*2000 km thick*
Z	Inner Core	*1400 km thick*



3. Differentiate among the layers of the earth and describe their characteristics

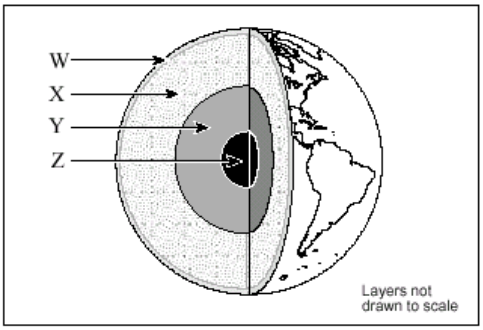
***By composition**:*		
Crust, Oceanic or Continental	*7 km to 70 km thick*	*Cool, rigid rock, silicate rocks*
Mantle	*2900 km thick*	*Hot, ultramafic; top solid, upper part plastic*
Core	*3400 km thick*	*Iron, nickel*
By physical properties		
Lithosphere	*100 km thick*	*Cool, rigid rock; crust and top of mantle*
Asthenosphere	*250 km thick*	*Hot plastic, ultramafic, upper mantle*
Mesosphere	*2500 km thick*	*Hot, rigid and brittle*
Outer Core	*2000 km thick*	*Liquid iron, nickel*
Inner Core	*1400 km thick*	*Solid iron, nickel*

4. The layer of the earth that is solid, has the lowest seismic velocities and is composed of silicate material is the

   a) crust.
   b) mantle.

5. The study of seismic records shows that P- and S-waves speed up then slow down again as they pass through part of the earth. The **best** explanation for this suggests that the waves pass through
   a) plastic zone.
   b) solid, a liquid, then a solid.
   c) cool solid, a hot liquid, then a cooler solid.
   d) solid, a denser solid, then a less dense solid.
6. Which of the following is the **best** evidence that the earth has a layered internal structure?
   a) Xenoliths
   b) Drill core samples
   c) Composition of lavas
   d) Sudden changes in the velocity of P- and S-waves

Use the following diagram of the earth's interior to answer questions 7 and 8



7. The layer that will absorb S-waves is
   a) W
   b) X
   c) Y
   d) Z

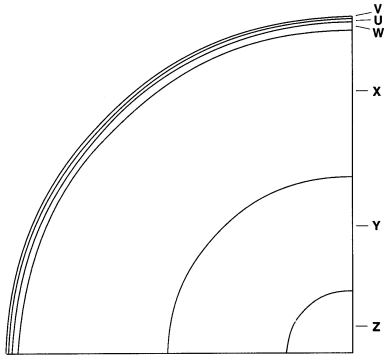
This is the liquid outer core.

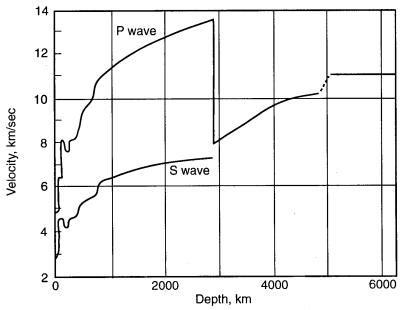
8. The layer that contains the lowest density silicate rocks is
   a) W
   b) X
   c) Y
   d) Z

The crust has the lowest density and made from silicate rocks.

Use the following diagrams which show a cross-section of the Earth, and a graph of P and S wave velocities against depth in the Earth, to answer question 9-11

9. The S waves have no velocity below a depth of about 2900 km. This is because the S waves
   e) have run out of energy
   f) are entering a liquid layer
   g) are entering a plastic layer
   h) are entering a super-dense layer





10. Both P and S wave velocities increase as they pass down through layer X. This increase in velocity is because with increasing depth, layer X becomes
    a) cooler
    b) denser
    c) richer in quartz
    d) less pressurized

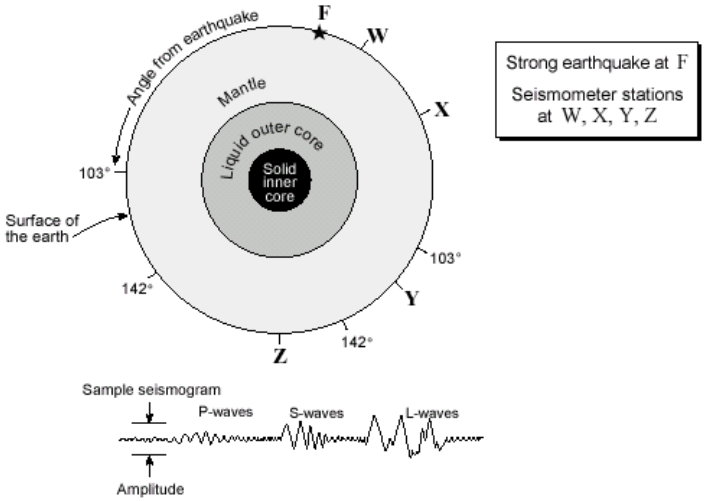
11. A layer which is composed largely of iron and nickel is
    a) U
    b) W
    c) X
    d) Y

The liquid outer core, Y, is composed of iron and nickel.

12. The Earth's overall density is 5.5 g/cm^3, yet the density of the crust averages only 2.8 g/cm^3. This fact implies that
    a) the densities of the mantle and core must be greater than that of the crust
    b) the densities of the mantle and core cannot be determined
    c) the Earth was never homogeneous in composition
    d) the mantle and core probably have a density of 5.5g/cm^3

13. The P wave shadow zone occurs because
    a) P waves travel faster than S waves
    b) P waves refract at the outer core – mantle boundary
    c) P waves are shear waves
    d) S waves obstruct the path of P waves

Use the following sketch of the cross section of the earth to answer question 14



14. A strong earthquake occurred at location F.

a) The time difference between the arrival of P- and S-waves is known as the P- and S-wave interval. Describe how the P- and S-wave interval varies between stations **W** and **X**.
There is a greater P- and S-wave interval at station X than at Station W because X is further away from the epicentre than W

b) Describe the difference in amplitude between direct path P-waves at station **W** and at station **X**.
There is less amplitude at station X than at station W because X is further away and the earthquake waves lose energy as they pass through the Earth.

c) Explain why no direct path S-waves would be recorded at station **Z**.
S-waves are absorbed by the liquid outer core before they reach station Z.

d) Explain why no direct path P-waves would be recorded at station **Y**.
P-waves are refracted away as they cross the core boundary, therefore they are not recorded at station Y.

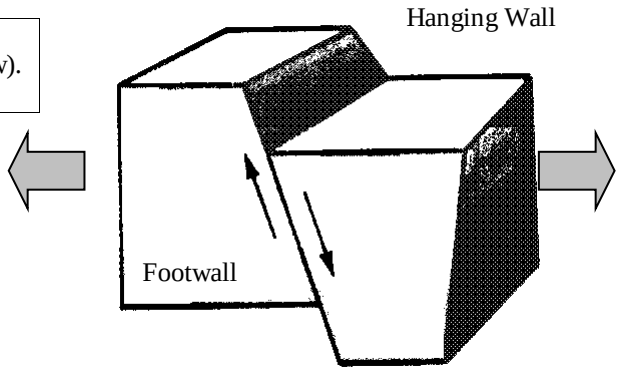
Answers to Section O: Internal Processes and Structures (Structural Geology)

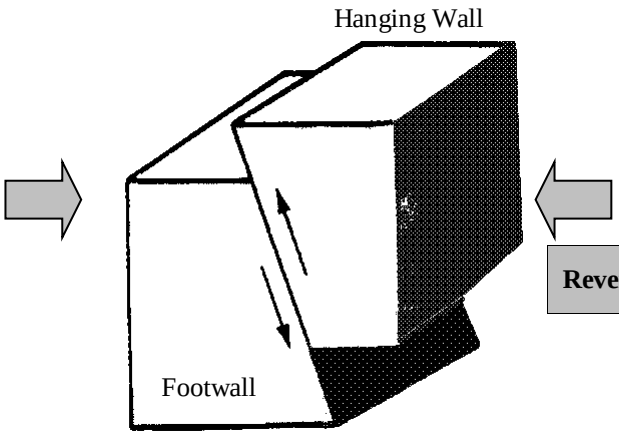
1. Describe the factors that determine if a rock will behave in a plastic or brittle manner when stressed.
   When rocks behave in a plastic manner they undergo a large deformation for little added stress. The rock will not return to its original shape. When rocks behave in a brittle manner the rocks break before any real plastic deformation occurs. Temperature and pressure both affect whether a rock will behave in a plastic manner or brittle: there is more temperature and pressure inside the Earth, and these rocks tend to behave in a more plastic manner than those colder and less pressurized rocks near the surface. Another factor is tensile vs. compression stress. Different rocks behave differently when subjected to squeezing or pulling. Or the same rock may behave in a plastic manner when compressed, but a brittle manner when stretched.

2. Distinguish between faults and joints.
   Where there is no movement along a fracture in the rocks it is a joint, but if there is relative movement it is a fault.

3. Draw dip-slip (normal, reverse, thrust), strike-slip (left lateral, right lateral), and transform faults. Include arrows showing appropriate forces associated with the various types of faults (compressional, tensional and shear forces.)

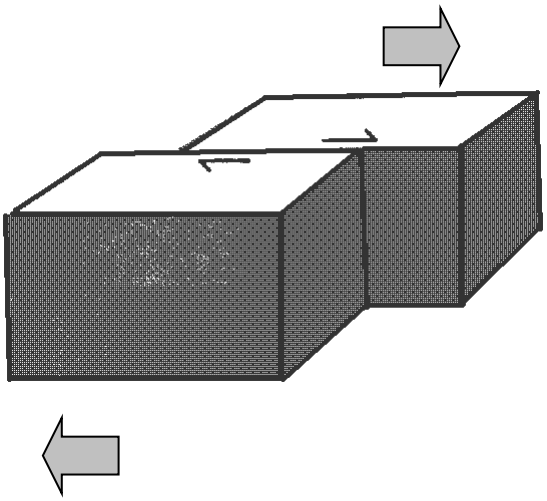
Normal Fault	If the hanging wall (above) moves down relative to the footwall (below). Tensional forces.





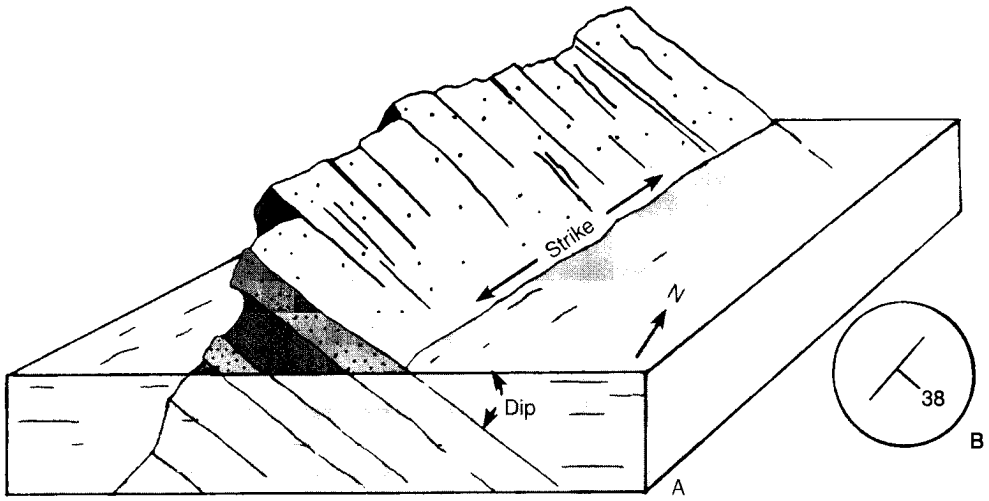
Reverse Fault	If the hanging wall moves up relative to the footwall. Compressional forces.

Thrust	A reverse fault with a very shallow (low angle) dip. Compressional forces.



Strike Slip (Transform)	If the relative movement along a fault is horizontal in the direction of the strike. This diagram is a right lateral strike slip fault. Shear forces.

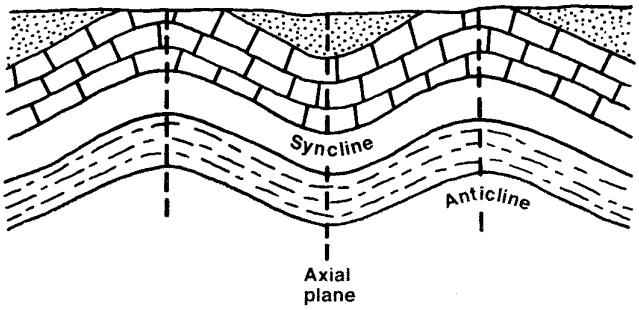
4. Draw a diagram to explain the dip and strike of a structure.
   Strike is the compass direction of a line formed by the horizontal and inclined rock layers. Dip is the angle between the horizontal and inclined rocks.



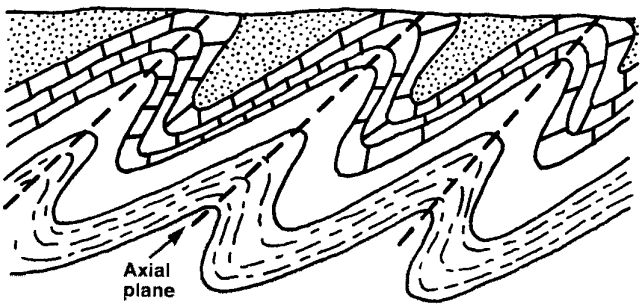
The strike and dip symbol would be: (Note that the symbol is always a perpendicular capital T.)

5. Draw a dome, basin, anticline, syncline, and overturned fold, and include arrows showing appropriate forces associated with these structures.

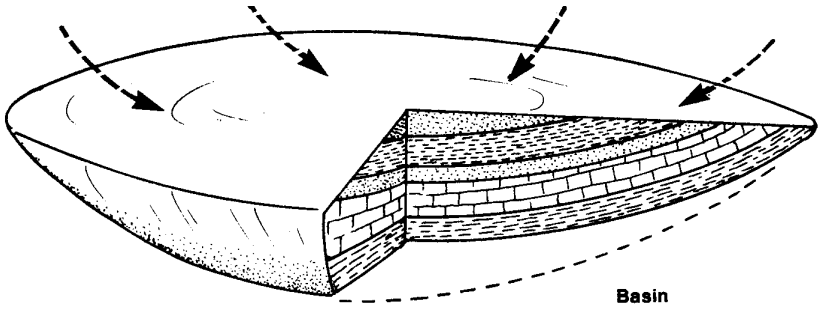
Anticlines	***An upward fold***	***The oldest rocks are in the middle and the youngest rocks have eroded***
Synclines	***A downward fold***	***The youngest rocks are in the middle and the oldest rocks deep underneath***



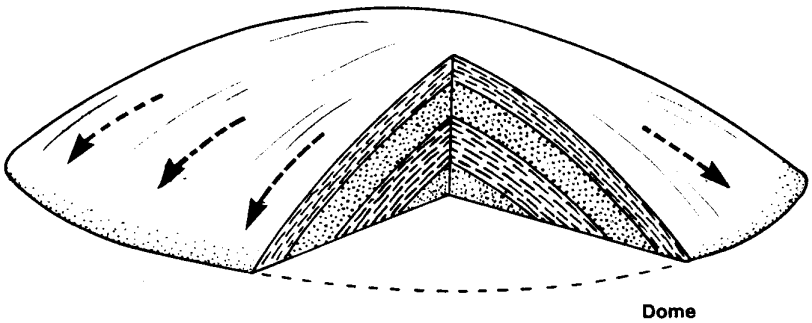
Overturned folds	The fold is tilted to the horizontal	The limb is folded right over.



Basin	A downward fold in a circle.	The youngest rocks are in the middle and the oldest rocks deep underneath

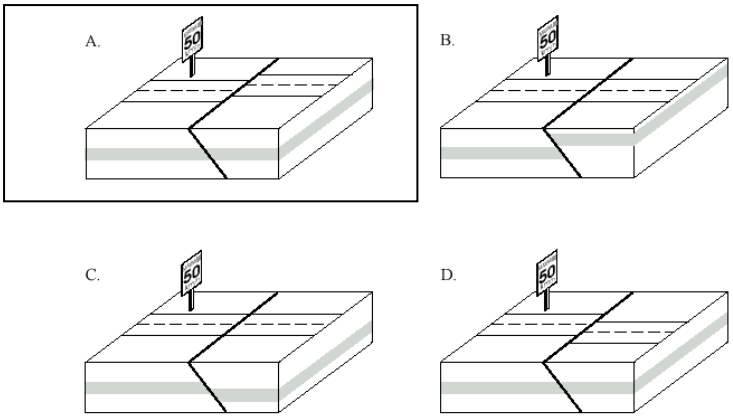


Dome	An upward fold in a circle.	The oldest rocks are in the middle and the youngest rocks are eroded.

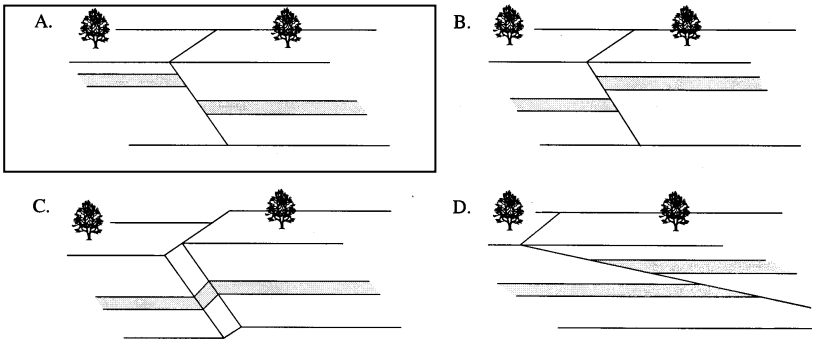


Note: all folds are formed by compressional forces as found at converging plate boundaries.

6. Which of the following block diagrams shows a left lateral strike-slip fault?



12. A fault that results from crustal stretching is represented in diagram



A is a normal fault in which the block to the right, the hanging wall, has slipped down relative to the footwall.

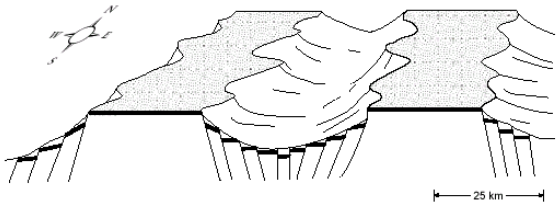
13. Thrust faults would most likely occur at plate boundaries that are
    a) divergent
    b) transform
    c) convergent
    d) constructive

14. What type of faulting commonly occurs as a result of tensional stresses?
    a) Reverse fault
    b) Normal fault
    c) Thrust fault
    d) Strike – slip fault

Use the following diagram to answer question 15.

15. The structures shown in the diagram **most likely** formed at a boundary where the plates were
    a) moving apart.
    b) rising upwards
    c) coming together
    d) sliding past each other.

These are all normal faults



16. Which of the geologic map symbols represent a tilted rock layer with a strike of 0 degrees and a dip of 45 degrees east?

a) 

b) 

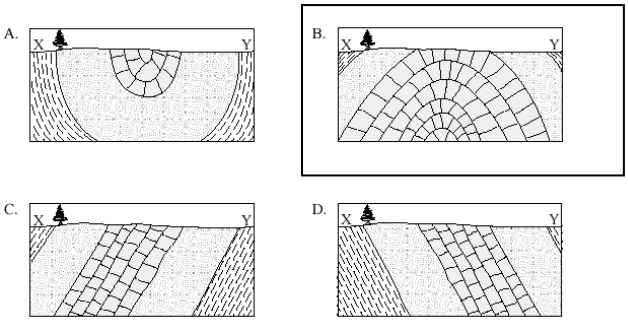
c) 

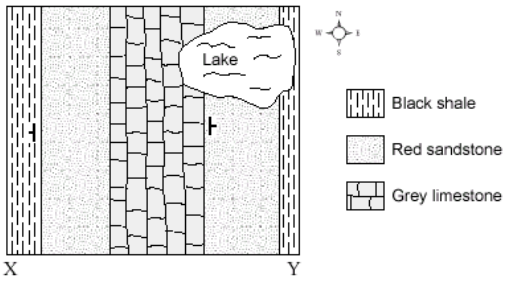
d) 

17. When excessive stress is applied to rocks at great depth where temperatures and confining pressures are higher, the rocks are likely to
    a) rupture in a brittle fashion
    b) deform in a plastic manner
    c) continue to behave elastically, without any permanent effects of strain
    d) rupture in a brittle fashion initially and then begin to deform or bend in a plastic fashion

Use the following map to answer question 18 and 19.

18. Which of the following sketches corresponds to the cross section along **X** and **Y** in the map above?



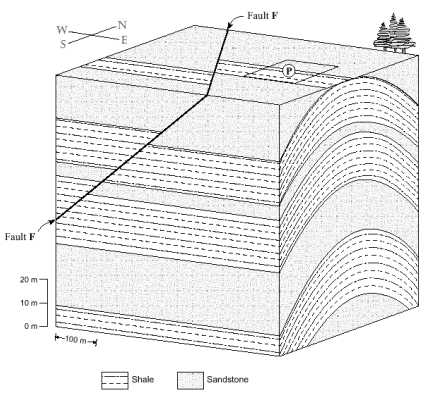


19. The name given to this structure is
    a) anticline
    b) syncline
    c) thrust fault
    d) basin

20. Which layer is the oldest?
    a) Black shale
    b) Red sandstone
    c) Grey limestone
    d) Cannot be determined
    e)

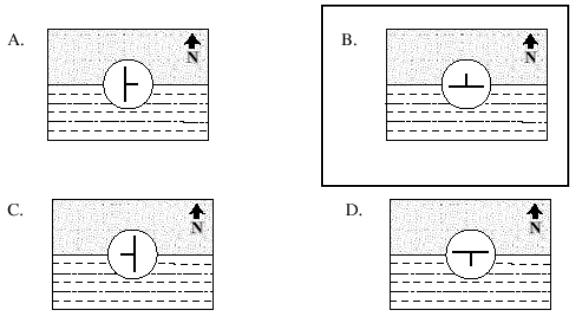
Use the following geologic block diagram to answer questions 21 to 23.

21. There has been no vertical movement on fault F. Fault **F** would be **best** classified as a
    a) normal dip-slip fault.
    b) reverse dip-slip fault.
    c) left lateral strike-slip.
    d) right lateral strike-slip.

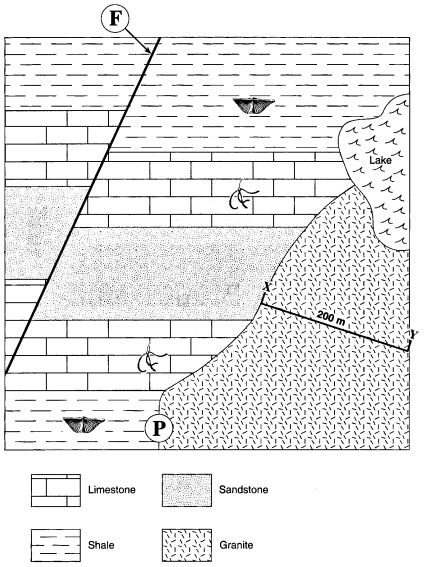


22. The fold shown on the block diagram would be **best** described as a
    a) plunging syncline.
    b) plunging anticline.
    c) non-plunging syncline.
    d) non-plunging anticline.

23. Location **P** lies on the contact between the shale and the sandstone. The correct strike and dip symbol at location **P** would be



Use the following map to answer questions 24 to 29.



24. Fault F would be classified as
    a) thrust
    b) normal
    c) reverse
    d) strike slip

25. Which layer is the oldest?
    a) limestone
    b) sandstone
    c) shale
    d) granite

The graptolite in the limestone is older than the brachiopod in the shale. Therefore, the centre sandstone must be even older

26. What is the name of the fold which has affected the sedimentary rocks?
    a) Syncline.
    b) Anticline.
    c) Plunging syncline.
    d) Plunging anticline.

The oldest rocks are in the middle, therefore it's an anticline.

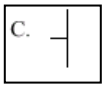
27. Describe one change you would expect to see in the fossiliferous limestone due to contact metamorphism near the granite intrusion.
    The fossils would be destroyed by metamorphism. The limestone would be more like marble. The limestone would loose porosity

28. What changes in crystal size would be observed by a geologist as she walked the 200 metre section from **X** to **Y** across the granite?
    The crystals would become larger, because the cooling time would have been longer further from the edge of the granitic intrusion.

29. The contact between the granite and the shale at position **P** is dipping to the west. The correct strike and dip symbol at position **P** is

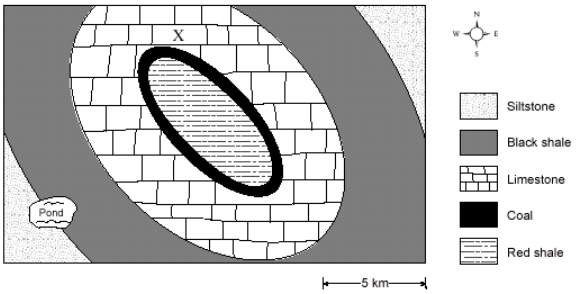
A. 

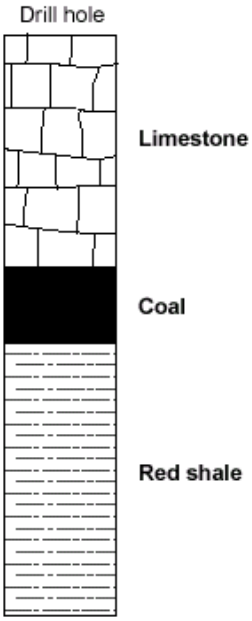
B. 

C. 

D. 

Use the following sketch map of a geological structure to answer question 30.





30. The geological structure shown in the sketch map is either a dome or a basin.

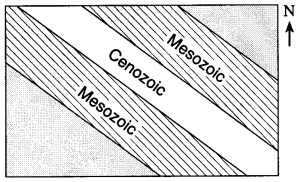
a) Give evidence involving:
i) the dip and strike of the strata, and
ii) the ages of the strata
that a geologist could look for to prove whether the structure is a dome or a basin.

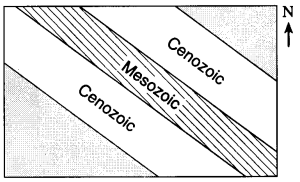
i) Evidence using the dip and strike of the strata:
If it were a dome all the strata, rock layers, would dip away from the centre, whereas if it were a basin all the strata would dip toward the centre.

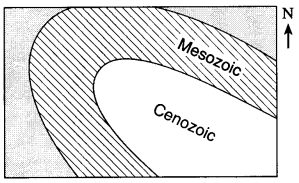
ii) Evidence using the ages of the strata:
If it were a dome the oldest rocks would be at the centre, whereas if it were a basin the youngest rocks would be at the centre.

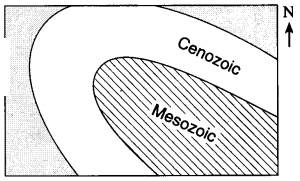
b) A vertical hole drilled at location **X** on the structure encountered three different rock strata. Assuming that the structure is a **dom**e, sketch, in the space provided below, the first three strata that would be encountered in the drill hole.

31. Which sketch represents a map view of a plunging anticline?

A 

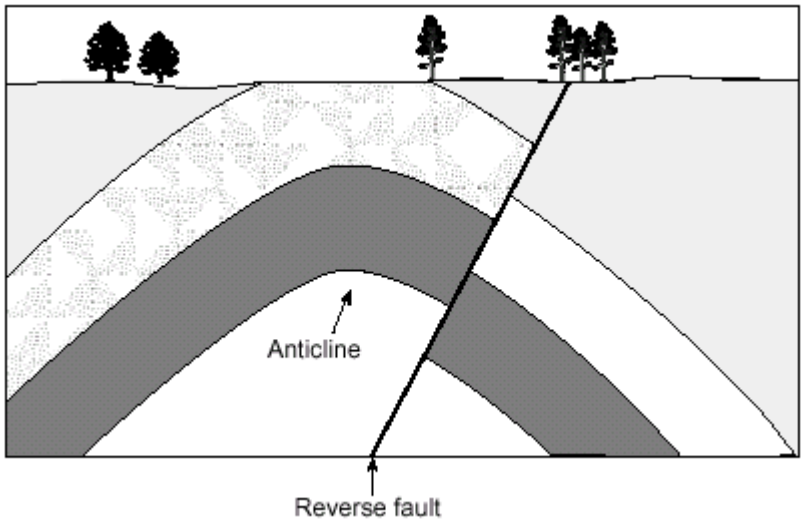
B 

C 

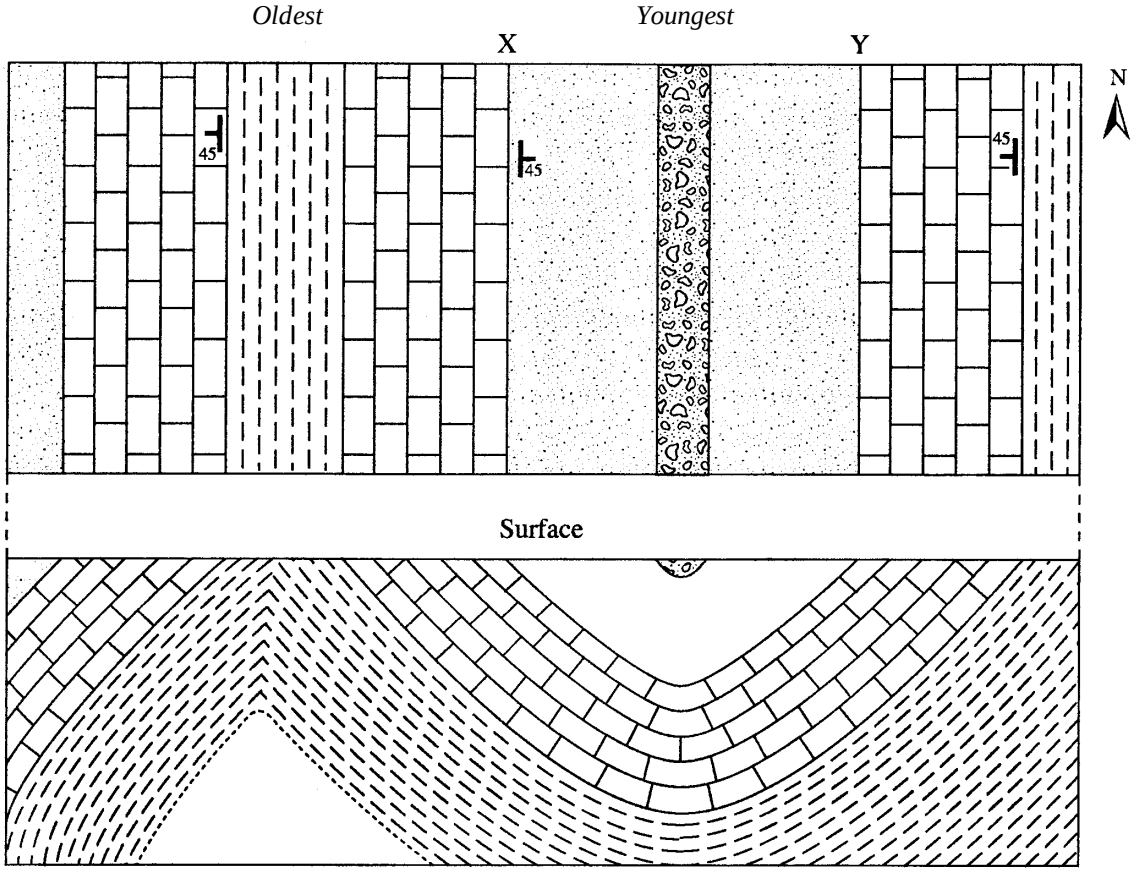
D 

32. Explain why you made your choice for question 31.
Anticlines have their oldest rocks in the middle, the Mesozoic occurred before the Cenozoic. A plunging fold occurs when the fold axis dips down from the horizontal. In this case the plunge is to the southeast.

33. In the space provided below, sketch and clearly label a cross section that contains an anticline cut by a reverse fault



Use the following map of exposed sedimentary rock layers to answer question 34



34. The map above has been constructed by sampling the surface rocks and measuring strike direction and dip angles.

a) Complete the cross section for the map area above.

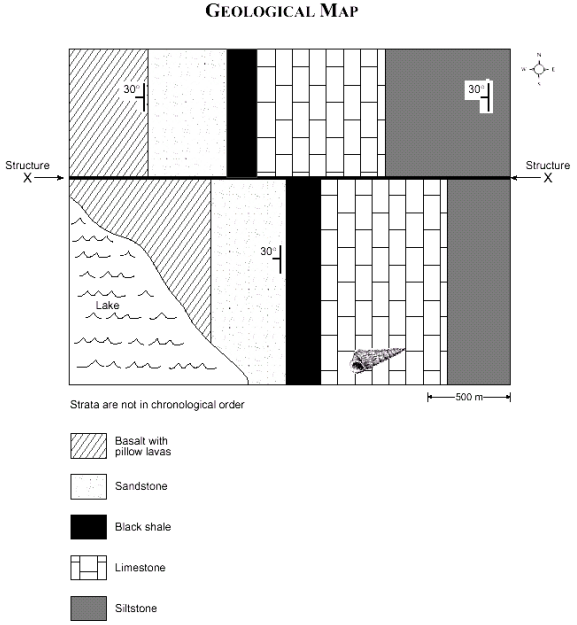
See above

b) Name the structure found between X and Y

Syncline

c) Label the oldest layers and youngest layer

See diagram above

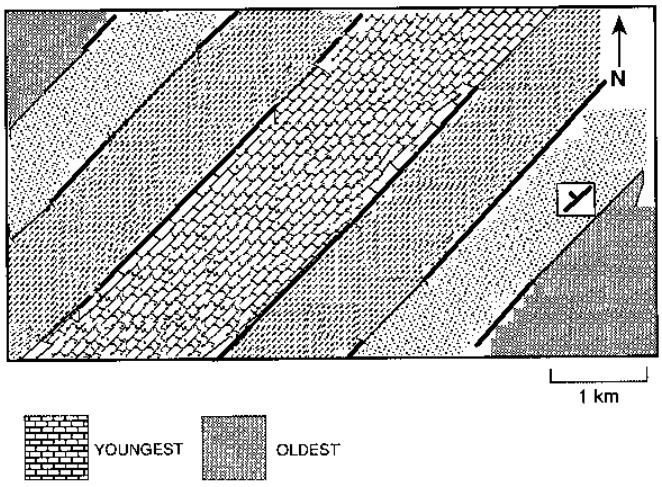


Use the geological map on this page to answer questions 35 to 36.

35. The orientation of the strata shown on the Geological Map is
    a) strike east, dip 30 degrees north.
    b) strike south, dip 30 degrees east.
    c) strike north, dip 30 degrees west.
    d) strike west, dip 30 degrees south.

36. The movement along structure **X** on the Geological Map is entirely **vertica**l. Structure **X** is **most likely** a
    a) joint.
    b) dip-slip fault.
    c) unconformity.
    d) strike-slip fault.

Use the following map of outcrops to answer question 37.



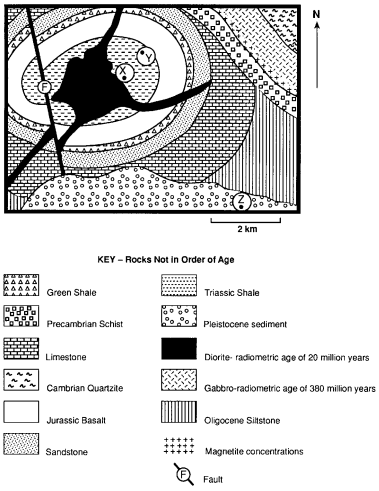
37. This map includes the geology of various outcrops in a small region. It reveals a geological structure.
    a) Complete the map view of the geologic structure on the diagram.
    See above

    b) Name the geological structure. Give evidence to support your answer.
    A syncline because the youngest layer is in the middle

    c) Draw the correct strike – dip symbol in the box on the diagram.

    See above. The strike – dip direction is about 45^0 NW, but the dip angle cannot be determined.

Use the following map to answer questions 38 to 43 on the next page.
The map area is generally flat except for the northeast section where the land surface rises steeply in a hill formed from nearly horizontal layers of schist, gabbro and quartzite units.



38. Name the type of fold which is shown on the flat part of the map and describe, with reference to the available geologic evidence, how the fold would likely have formed.
    It is a dome. This is because of the general shape of the structure – circular, and because the oldest rocks are in the middle of the structure.

39. Would the type of stress that formed the fault have been compressive, tensional or horizontal shear?
    There is no indication of any vertical displacement and so the fault must be due to horizontal shear, it is a strike slip fault.

40. Describe how the schist, gabbro and quartzite units may have come to be overlying the folded rocks and give evidence, from the geologic map, for your reasoning.
    The schist, gabbro and quartzite units are not of the same general shape as the dome and they are indeed much older than the rocks of the dome. In addition, these overlying units have been metamorphosed. The schist, gabbro and quartzite units have likely been thrust faulted over the top of the dome units. However, the sequence could be accreted material along an old coastline.

41. The gabbro unit has a rich concentration of magnetite towards its base. Describe how the magnetite was concentrated in this way.
    The magnetite was concentrated by crystal settling, while the gabbro was cooling. The magnetite crystallizes from the magma melt and settles to the bottom of the chamber because it is more dense than the magma.

42. Place the following events in correct order

Events in random order
Intrusion of the gabbro
Deposition of the limestone
Intrusion of the diorite
Formation of the fault
Metamorphism to form the schist

Events in correct order	
Formation of the fault	Youngest
Intrusion of the diorite	
Deposition of the limestone	
Intrusion of the gabbro	
Metamorphism to form the schist	Oldest

43. List in the correct order, the name and age of the first five rock units which would be encountered in a drill hole at point Z.

Order	Name of rock unit and age
1st	Pleistocene sediment
2nd	Oligocene siltstone
3rd	Limestone
4th	Sandstone
5th	Green shale

Answers to Section E: Earth Materials (Metamorphic Rocks and Processes)

1. Relate the types and characteristics of metamorphic rocks to parent rock, temperature, pressure, and chemical conditions

   The metamorphic changes in a rock depend on the mineral composition of the parent rock, and on the temperature and pressure to which the rock is subjected. As the temperature increases minerals become unstable and break down to form new minerals. As the pressure increases the texture of the rock becomes more compact and dense, and mineral grains can become aligned parallel to each other, which is perpendicular to the directed stress. As pressure increases minerals grow in size. The chemical conditions of a rock can be altered by the presence of hot water that migrates through pores. The hot water can take away or add new elements.

2. Describe the features of the following metamorphic rocks: slate, phyllite, schist, gneiss, metaconglomerate (stretched pebble), quartzite, marble.

Slate	*Parent rock is shale. Mineral grains are too small to be seen unaided. Foliated rock; mica lines up.*
Phyllite	*Progressively more metamorphism than slate. Mineral grains are very small. Foliated rock; mica lines up.*
Schist	*Further metamorphism than phyllite. Visible mineral grains. Foliated rock; mica lines up more.*
Gneiss	*Strongest metamorphism. Large visible grains. Foliated rock. Compositional banding.*
Metaconglomerate (stretched pebble)	*Formed when sedimentary rock conglomerate undergoes directed stress and metamorphism.*
quartzite	*Metamorphism of quartz-rich sandstone. Non-foliated. Crystals look shinier and flatter. Quartz grains grow together.*
marble	*Metamorphism of calcite rich limestone. Non-foliated. Will fizz with hydrochloric acid.*

3. Contrast the two major categories of metamorphic rocks: foliated and non-foliated

   Foliated metamorphic rocks are those rocks that show a parallel alignment of mineral grains. Foliated rocks are layered likes sheets of paper, each mineral takes up a new layer. Non-foliated rocks comprise mostly of one mineral and show non-layering.

4. Contrast the two types of metamorphism: contact and regional

   Contact metamorphism *refers to a magma intrusion that comes into contact with the surrounding country rock and alters the rock due to its heat. The adjacent rocks will be metamorphosed. It is a local phenomenon. Because contact metamorphism commonly occurs without deformation or any stress, the rocks are non-foliated (i.e. quartzite and marble.)*

   Regional metamorphism *affects broad areas of the crust, usually due to tectonic activity and mountain building. Rocks affected by regional metamorphism will be subjected to a lot of directed stress. The rocks will be foliated (i.e. slate, phyllite, schist.)*

5. Describe changes that occur in the country rock and in the intrusion at a contact

The country rock that comes into contact with an intrusion will be altered; the rock closest to the intrusion will be altered the most. Higher temperature metamorphic minerals will be found next to the intrusion and lower temperature metamorphic minerals will be found further away. The intrusion will cool more quickly at the boundary and will have smaller crystals than those further from the boundary.

6. Relate metamorphic rock type to the concept of metamorphic grade

Shale(sedimentary) is the parent rock of slate(metamorphic.) When shale undergoes some heat and pressure it metamorphoses into slate. Slate is a low-grade metamorphic rock. If more temperature and pressure is applied the rock becomes phyllite. More temperature and pressure results in a rock called schist; the most amount of temperature and pressure before the rock melts results in a rock called gneiss.

shale ⇒ slate ⇒ phyllite ⇒ schist ⇒ gneiss

parent rock low grade ⇒ high grade

7. What are the most distinguishing features of a metamorphic rock compared with those of an igneous rock or sedimentary rock?

Many metamorphic rocks show foliation; the mineral grains are arranged in parallel and show a layering. Non-foliated rocks are comprised of mostly one mineral. In all metamorphic rocks the mineral grains look flattened and squashed. Metamorphic rocks are rather sparkly and dense.

8. What kinds of changes occur in a rock as it is metamorphosed?

*The **texture** of a rock can change because as the rock is metamorphosed the mineral grains grow and their shapes change. A layered texture will arise when a rock is subjected to both increased temperature and deformation called foliation.*

*The **mineral composition** of the rock can also change because there is sufficient heat to allow atoms to recombine to form new minerals.*

9. Why are fossils less likely to be found in metamorphic rocks than in the rocks from which they were derived?

Many fossils would be deformed or destroyed during the process of metamorphism.

10. Which of the following factors involved in metamorphism is likely to produce strong foliation in a metamorphic rock?

a) Increased directed stress
b) Increased confining pressure
c) Presence on hot fluids passing through the rock
d) Increased temperature

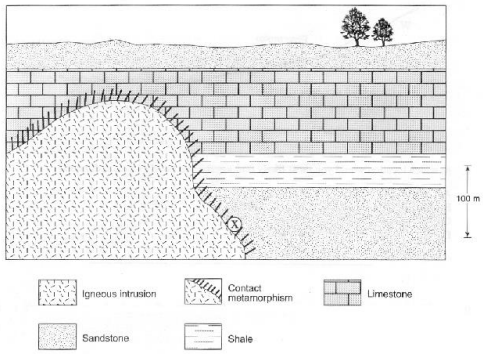
11. Which of the following causes a chilled margin of fine-grained igneous material to be found at the edges of plutons?

a) Rapid cooling
b) Partial melting
c) Contact metamorphism
d) Fractional crystallization

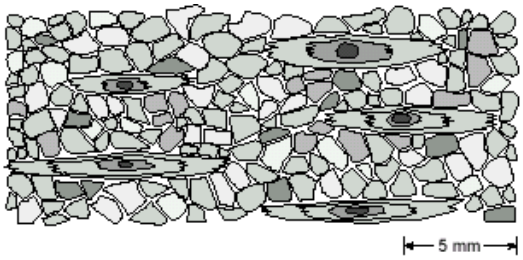
When hot magma intrudes much cooler country rock, the melt near the contacts is rapidly cooled. The result is a chilled margin recognizable because the rock near the margin is finer grained than the interior of the

Use the following diagram to answer question #12

12. Which of the following rocks would you expect to find at location X in the diagram?
    a) Chert
    b) Schist
    c) Marble
    d) Quartzite



Use the following sketch of the texture of a metamorphic rock to answer question 13.



13. Which directions of maximum compressive stress **most likely** caused the alignment of the elongate crystals in the metamorphic rock?
    a) ⇒ ⇐
    b) ⇐ ⇒
    c) ⇑ ⇓
    d) ⇓ ⇑

Mineral grains grow at right angles to the directed stress.

14. Which of the following pairs shows the correct relationship between a metamorphic rock and its parent rock?

	Parent Rock	Metamorphic Rock
a)	shale	quartzite
b)	limestone	marble
c)	gypsum	phyllite
d)	sandstone	slate

15. Which of the following would be an **unlikely** result of regional metamorphism?
    a) Greater rock porosity
    b) Formation of foliation
    c) Increased rock density
    d) Formation of a new mineral

Metamorphism squeezes the rock, which decreases the pore space between the minerals.

16. Contact metamorphism leads to nonfoliated rock types because the
    a) temperature is not high enough
    b) mineralogy is not correct
    c) pressure is not sufficient
    d) water content is not high enough

17. In a rock, metamorphism increases the
    a) volume
    b) density
    c) porosity
    d) solubility

18. Which of the following rocks represents the highest degree of metamorphism?
    a) Shale
    b) Phyllite
    c) Slate
    d) Schist

19. The chemical compositions of metamorphic rocks depend on the
    a) temperature to which they have been raised
    b) pressures to which they have been subjected
    c) effects of both pressure and temperature
    d) composition of the original rock

20. The most likely result of the metamorphism of granite is
    a) marble
    b) slate
    c) gneiss
    d) quartzite

21. In comparison with slates, schists have
    a) a deeper colour
    b) a lower mica content
    c) larger crystals
    d) no foliation

22. In which type of metamorphic rock are fossils most likely to be preserved?
    a) Slate
    b) Schist
    c) Gneiss
    d) Phyllite

All other rock types have a greater degree of metamorphism. The fossil will likely be destroyed.