Answers to Section P: Surficial Processes (Weathering and Erosion)

1. Distinguish between weathering and erosion

   Weathering is the break up of rock into smaller pieces by means of mechanical or chemical weathering, whereas erosion refers to the transportation of material from one place to another. Material can be removed and transported by gravity (mass wasting), rivers, glaciers, and wind.

2. Describe the processes and effects of physical (mechanical), chemical, and biological weathering

<table>
<tr><td rowspan="3">Mechanical Weathering</td><td rowspan="3">The physical break-up of rock with no changes in chemical composition. Breaks the rock into smaller pieces, which increases the surface area that aids chemical weathering.</td><td>frost wedging</td><td>Water seeps into cracks, freezes and expands, thus breaking apart the rock</td></tr>
<tr><td>exfoliation</td><td>Rock expands in the heat of the day, and contract when it cools; the repeated expansion and contraction stresses the rock and its cracks</td></tr>
<tr><td>abrasion</td><td>Small fragments collide with rocks and they break apart</td></tr>
<tr><td>Chemical Weathering</td><td colspan="3">The breakdown of minerals by chemical reaction with water, with other chemicals dissolved in water, or with gases in the air. Calcite reacts with acid and is therefore susceptible to acid rain. Many minerals oxidize when exposed to the air.</td></tr>
<tr><td>Biological Weathering</td><td colspan="3">The breakdown of rock due to biological activity. Trees grow roots that can break apart rock, burrowing animals can break apart rock.</td></tr>
</table>

3. Relate Bowen's reaction series to a mineral's susceptibility to chemical weathering

   The relative resistance to chemical weathering can be estimated by inverting Bowen's Reaction Series. Olivine is the least resistant to chemical weathering, in other words, it will be the first to react with any chemicals present. Quartz is the last and slowest to react with any chemicals. Those minerals that formed at the highest temperatures and pressures tend to be the least stable, or most easily weathered. Not all the constituent minerals of granite will weather at the same rate.

4. Identify types and causes of mass wasting

   ***Flow** refers to loose, unconsolidated material that moves as a fluid down a slope.*

Creep	**Very slow movement**
Debris flow	*Movement of particles, most are larger than sand particles*
Earth flow and mudflow	*Fine grained particles with large amounts of water*
Solifluction	*Movement of water logged soil over permafrost*

   *A **slide** occurs when large blocks of material move down a slope.*

Slump	*Downward slipping of a block of earth*
Rockslide	*Rapid movement of large blocks of material*

   *A **fall** refers to when material freely falls through the air. This occurs on very steep cliffs.*

Last part of #4's answer:

Causes of mass movement	
Effects of fluid	*Water seeps into the bedding planes of layered rock thus reducing friction*
Earthquakes	*Ground shaking loosens rocks and reduces friction*
Human activity	*Can include undercutting slopes for roads or mineshafts etc, removal of vegetation, changing natural runoff of rivers because of dams etc.*

5. Design or evaluate methods to control mass wasting

Slope modification	*Reducing the slope angle and reducing the load by removing some of the material on the slope.*
Removing fluid	*Using subsurface drains to carry the water out of the slope*
Retaining walls	*Placing supoorting materials against the slope*
Concrete	*Painting the rock face with concrete to remove the hazard of small rock pieces from falling*
SteelBeams	*Steel beams driven into the rock face to keep rock layers from sliding*

Use the following list of processes to answer question 6

- Ice wedging
- Root wedging
- Exfoliation

6. All of the processes above can be classified as
   a) hydrolysis.
   b) lithification.
   c) mass wasting.
   d) mechanical weathering.

7. An igneous rock contains the following minerals:
   amphibole, potassium feldspar, sodium feldspar, quartz.
   The mineral that would weather the **fastest** is
   a) quartz.
   b) amphibole.
   c) sodium feldspar.
   d) potassium feldspar.

   Amphibole is the first of these minerals to crystallize from a magma melt, according to the Bowen's Reaction Series, thus it is the most susceptible to weathering.

8. According to the Bowen Reaction Series, the mineral most resistant to chemical weathering is
   a) biotite
   b) olivine
   c) pyroxene
   d) muscovite

9. Silicate minerals that are **most** susceptible to chemical weathering at the Earth's surface
   a) must not be very dense
   b) form under conditions of high temperature and pressure, very different from conditions at the surface
   c) form at the surface by means of other weathering processes
   d) are all of the silicate minerals containing any iron or magnesium

10. Some buildings are particularly susceptible to atmospheric chemical weathering, especially in cities. This is because buildings are made of
    a) slate
    b) granite
    c) quartzite
    d) limestone

11. Which of the following is not characteristic of chemical weathering?
    a) Iron minerals oxidize
    b) Carbonate minerals dissolve
    c) Feldspar forms clay
    d) Granite rock exfoliates

Granite exfoliation is caused by temperature changes, thus it is mechanical weathering.

12. Which of the following is an example of physical weathering?
    a) The combining of pyrite and oxygen
    b) The breaking of rock by freeze – thaw
    c) The change from feldspar to clay
    d) The dissolving of rock by acid

13. Mechanical weathering accelerates the rate of chemical weathering by increasing the
    a) amount of surface area exposed to air and water
    b) amount of volume the rock occupies
    c) mass of the individual particles
    d) temperature of the rock

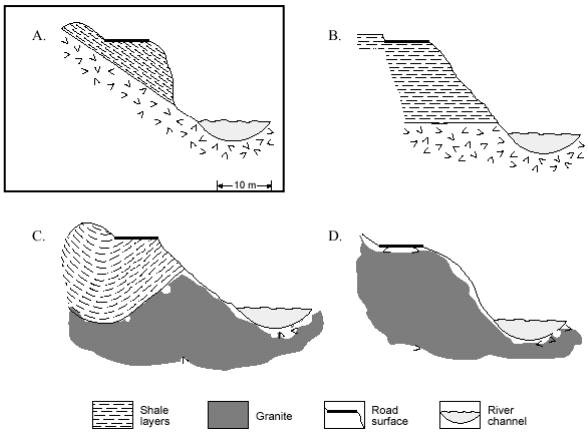
14. A granite outcrop weathers fastest in a climate that is
    a) cold and dry
    b) temperate and moist
    c) hot and moist
    d) warm and dry

15. Which of the following human activities is **least likely** to cause the failure of a steep slope?
    a) Installing perforated drainage pipes
    b) Excavating a road cut across the slope
    c) Cutting a homesite into the base of the slope
    d) Allowing septic drain waters into the slope sediments

The perforated pipes allow water to run through a slope, thus the soil does not become saturated.

16. A common result of poor logging techniques on steep slopes in British Columbia is a fast-moving, chaotic flow of water, soil, rock and trees that may travel for many kilometres. Flows of this type are known as
    a) rock falls.
    b) soil creep.
    c) nuée ardentes.
    d) debris avalanches.

17. Which of the following diagrams illustrates the **greatest** potential for failure of the slope above the river?



18. Which of the following mass movements is least likely to cause loss of life?
    a) Slump
    b) Soil creep
    c) Debris flow
    d) Rock avalanche

19. Which of the following is **not** a process of mass wasting?
    a) Oxidation
    b) Slumping
    c) Rockfall
    d) Solifluction

20. Which of the following factors is least likely to **trigger** a landslide?
    a) Force of gravity
    b) Earth tremors
    c) Rapid snow melt
    d) Heavy rainstorms

21. What is a talus slope?
    An accumulation of material at the bottom of a slope.

22. What is soil and how is it formed?
    Soil is the result of weathering on rock. Soil is loose, weathered rock material in which plants can root. There are four recognisable parts: 1) sand, clay or silt; 2) water; 3) air; 4) organic material

23. Why are landslides in B.C. most likely to occur in the springtime than other times of the year?
    There is more water that flows as a result of the springtime melt of the ice on mountaintops. The water reduces friction that increases the potential for slope failure.

24. A real estate agent is trying to sell you a hillside house in B.C. Describe some disturbing warning signs of slope instability that you may encounter as you tour the property.
    Within the house, some signs to look for are the retaining wall may not be perfectly upright, and there maybe cracks in the driveway or other parts of the house. Around the house, some warning signs to look for are trees that do not grow straight from base to top, or a nearby talus slope. Generally, the areas that are potential hazards are on the sides of steep slopes with a large water runoff in an earthquake zone.

Questions for Section Q: Surficial Processes (Running Water)

1. Identify the three types of stream load (solution, suspension, bedload) and describe how each moves in a stream

Solution	*The water dissolves minerals. The dissolved ions travel wherever the water goes. The ability of the stream to carry a dissolved load depends on the discharge (vol. / time) and chemistry, not velocity.*
Suspended load	*Water turbulence keeps sediment mixed with the water. Faster streams can carry larger particles because the turbulence is usually greater. As stream velocity decreases the larger particles drop to the bottom.*
Bed load	*A fast stream can roll or drag even large pebbles and boulders along the bottom.*

Note: "saltation" is not a type of load - just a bouncing-along way particles can move.

2. Relate stream velocity to sediment sorting

   The higher velocity stream will probably have more turbulence, which means that it can carry more sediment. The increased turbulence prevents the particles from settling to the bottom. The higher velocity stream can roll and drag the heaviest particles such as large pebbles and boulders. As the stream velocity slows the heaviest sediment cannot be carried and drops; as the water velocity continues to slow successively lighter particles will be dropped and as a result the sediment is sorted.

3. Relate such factors as load, gradient, discharge, channel shape, sediment composition, and human activities to erosion and deposition by streams
   - *Higher load means more erosion by abrasion and as the stream load decreases so does the erosion and more sediment is deposited.*
   - *Higher gradient means more erosion, and further down the river, the gradient decreases and so does the erosion and more deposition occurs.*
   - *Higher discharge means more erosion and as the discharge decreases so does the erosion and deposition increases.*
   - *Channel shape eroded will be V shaped in a mountain canyon, there will be very little deposition here in the canyon because the stream velocity is too fast. Meanders occur in flatter areas.*
   - *Larger sediment suspended can erode bedrock more easily, but as the sediment load becomes progressively smaller erosion decreases and deposition increases.*
   - *Human activities such as building levees and dams and deforestation can channel water and increases discharge and increase erosion. These human activities will invariably redirect deposition when the river direction is changed.*

4. Contrast particle size and shape, degree of sorting and sedimentary structures of stream, glacial, and wind deposits

	Particle Size and Shape	***Degree of sorting***	***Sedimentary Structures***
Wind	*Usually small (light weight) particles.* *Well-rounded but pit-marked.*	*Well-sorted*	*Dunes* *Hoo doos*
Streams	*Usually small to medium sized rocks.* *Well-rounded.*	*Well-sorted*	*Meanders* *Braided streams* *Oxbows* *Flood plains*
Glaciers	*All sizes of particles.* *Angular (usually).*	*Poorly sorted (unless in a stream process of a glacier)*	*Erosional(cirque, horn, arête, etc.)* *Depositional(moraines, eskers, erratics, etc.) Plus others!*

5. What is a meander and how does it form?
   A meander is a broad curve in a stream. It occurs as the river goes around an obstacle. Sediment is deposited at the most shallow side(inside of curve) where the river velocity is lowest which causes the river to bend.(Erodes occurs on the outside of the curve.)

6. What are oxbow lakes and how do they form?
   Oxbow lakes are parts of the river meander, which have been cut off. During a flood the river takes the shortest route rather than going around all the curves. After flood it stays on the short route.

7. Describe why and where deltas form.
   A delta a wide fan of deposit at the mouth of a river. It occurs when the river enters a still body of water such as the ocean or a lake. As the river speed slows down it deposits its load. River speed can be sufficiently low to even deposit the finest silt and clay particles.

8. Describe the stages along a river's length from the source to its mouth at an ocean.
   Young river valleys near the source of the river carve V shaped valley in mountainous area. Further downstream, mature rivers flow more slowly, are wider, meander and have more gentle slopes. Near the mouth of the river, an old age river has a very slow velocity, and widens into wide plains.

9. It has been suggested that many human activities have increased the severity of many floods. Describe some of these activities and how they have actually made flooding worse.
   There are many human activities that have worsened floods. 1) Forcing rivers to stick to one course can create problems for natural run-off especially during springtime when the river experiences a higher discharge. The river would like to take the easiest route and most natural route to the ocean. Creating man-made levees to force the water through can cause the river to back up and overflow causing devastating floods, ex. 1993 Mississippi Flood. 2) Deforestation stops the natural vegetation from soaking up water. 3) Dams divert the natural course of the river, ex. 1996 Saguenay, Quebec Flood

10. A river is likely to pick up more sedimentary material where it
    a) enters a lake.
    b) flows into a wider channel.
    c) flows around the outside of a meander.
    d) flows from a high gradient to a low gradient.

11. A major river flowing into a lake forms multiple channels as a result of
    a) an increase in velocity.
    b) an increase in gradient.
    c) a decrease in water volume.
    d) a decrease in sediment-carrying capacity.

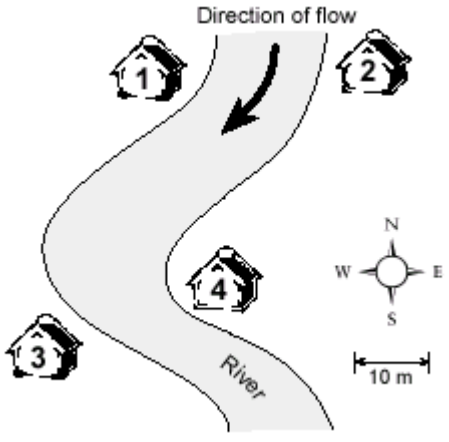
Use the following diagram that shows a river meander and four cottages to answer question 12 to 14

12. Which of the four cottages is in the **greatest** immediate danger from river erosion?
    a) 1
    b) 2
    c) 3
    d) 4

    The outside of a river bend has a greater velocity, thus more erosion occurs here.

13. Which house is most likely to have been built on sediment?
    a) 1
    b) 2
    c) 3
    d) 4

    The inside of a river bend has a lower velocity, thus sediment is deposited here.



14. Which of the following locations in the stream would experience the lowest velocity?
    a) 1
    b) 2
    c) 3
    d) 4

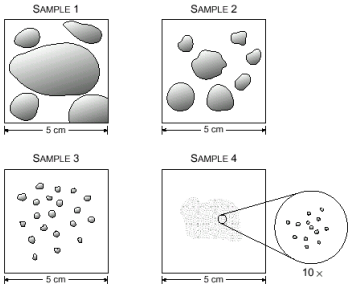
15. A pail of murky river water is allowed to stand still until it becomes clear. This change occurs because the sediment load was
    a) rolling
    b) saltating
    c) dissolved
    d) suspended

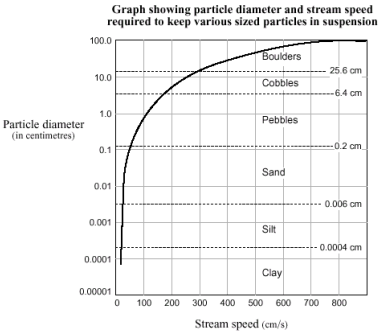
16. Which of the following would best describe a wind deposited sediment?
    a) Angular particles and well sorted
    b) Rounded particles and well sorted
    c) Angular particles and poorly sorted
    d) Rounded particles and poorly sorted

17. The load of sediments in a stream that moves in intermittent contact with the stream bed moves by
    a) solution
    b) saltation
    c) diffusion
    d) suspension

18. As a stream slows in velocity, which size sediment is likely to be deposited first?
    a) pebble size
    b) sand size
    c) clay size
    d) silt size

Use the following sketches of stream sediments and the graph to answer questions 19 to 21





19. The **largest** particle that could be moved in suspension by a stream flowing at 150 cm/s is
    a) silt.
    b) sand.
    c) a pebble.
    d) a cobble.

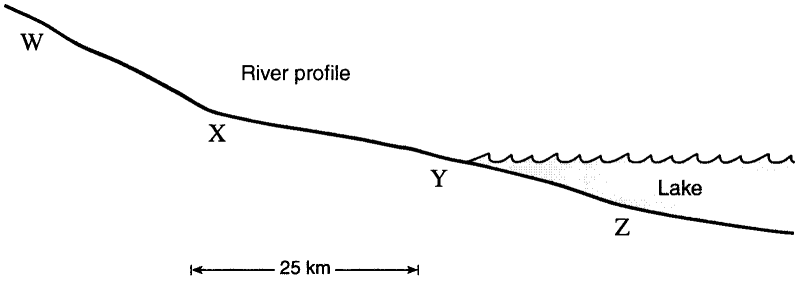
20. A sample of sediment taken from the stream bottom where the stream velocity was less than 20 cm/s would **most likely** look like sample
    a) 1
    b) 2
    c) 3
    d) 4

21. Compared to the stream sediment samples shown, a sample taken from glacial till would contain sediment which is
    a) less rounded and well-sorted.
    b) well-rounded and well-sorted.
    c) less rounded and poorly-sorted.
    d) well-rounded and poorly-sorted.

22. At a given point along its course, a stream has a cross sectional area of 10 m^2. Water flows past this point at a rate of 2 m/s. What is the discharge of this stream?
    a) 20 m^3/s
    b) 10 m^3/s
    c) 10 m^2
    d) 2 m/s

23. Which of the following rock types would cause the greatest dissolved load in a stream?
    a) Shale
    b) Basalt
    c) Sandstone
    d) Marble

Use the following diagram to answer question 24 to 26



24. The rate of stream erosion is probably greatest between
    a) W and X
    b) X and Y
    c) Y and Z
    d) X and Z

25. Most deposition will occur at
    a) W
    b) X
    c) Y
    d) Z

26. Poorly sorted angular sediments will most likely be found at
    a) W
    b) X
    c) Y
    d) Z

Answers to Section R: Surficial Processes (Glaciers)

1. Describe how each of the following erosional and depositional glacial features form:

erosional features:

U-shaped valley	*The characteristic shape of a glacial valley. As a glacier moves it plucks rocks from the sides and bottom of the valley.*
hanging valley	*A glacier gouged a deep trough across a tributary glacial valley. Since the glacier receded it left an abrupt drop on the sides of the valley. A tributary glacier mouth lies high above the valley floor.*
cirque	*Glaciers erode by plucking loose rock from the surrounding bedrock. A cirque is formed when an alpine glacier on one side of a mountain erodes the bedrock at the top of the mt. It forms a horseshoe, bowl-shaped depression.*
horn	*Formed when three or more alpine glaciers erode the mountain on different sides. This can create a sharp pyramid shaped peak*
arête	*Formed when two alpine glaciers erode the mountain on opposite sides to form a ridge between.*
glacial striations	*Striated bedrock are scratches on the bedrock formed as rock carried by the glacier underneath scrapes across the bedrock.*

depositional features:

glacial erratic	*Large isolated boulder carried far from its parent bedrock and deposited when the glacier melts.*
ground moraine	*Formed when a receding glacier deposits till in a relatively thin layer over a broad area.*
recessional moraine	*As the glacier retreats it may periodically stop. If the end of a glacier remains in the same place for some time it will deposit till as it melts at the same rate as moving forward.*
terminal moraine	*Deposit of till at the furthest extent of the glacier's advance*
lateral moraine	*Deposit of till along the sides of a glacier from material that fell onto the glacier as eroded off the mt sides.*
medial moraine	*Deposit of till in the middle of a glacier as two lateral moraines have merged as glaciers flow together.*
drumlin	*Upside-down canoe-shaped hills made of till from when a glacier runs over a previously deposited moraine.*
kame	*A cone-shaped hill of sorted sediment that was layers in the bottom of a lake on top of the glacier. When the glacier melted, the pile was left.*
kame terrace	*A small mound of sorted sediment left by a stream or lake that was between a glacier and the valley wall.*
esker	*A long ridge formed from deposition in bed of a meandering stream that flows through a glacier. When glacier melts bed is deposited as a winding "s-shaped curve."*

2. What are some clues that you could look for using erosional and depositional features to determine which direction a glacier flowed in an area?

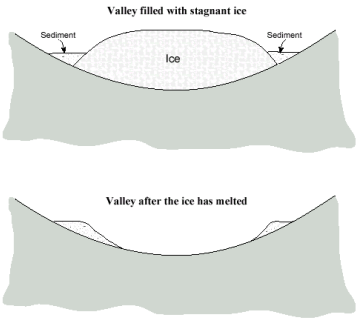
Glacial striations indicate the direction the glacier flowed. Drumlins indicate the direction of the glacier because they are elongated parallel to the direction of flow. A terminal moraine indicates the furthest extent of a glacier. A kame terrace would indicate the furthest extent up a valley wall the glacier advanced. An esker would be parallel to the direction of the glacial flow.

3. Describe glacial deposit (in terms of sorting, roundedness.)
   Glacial deposit is poorly sorted because a glacier can move everything and because everything is moved together. Particles are angular unless they were in a stream or lake associated with the glacier.

4. Where do icebergs come from?
   Icebergs come from glaciers that reach the ocean and break off. The process of breaking off from the glacier is called calving.

5. Describe the difference between an alpine glacier and a continental glacier.
   Alpine glaciers can be found in mountainous areas and are smaller than continental glaciers. Continental glaciers have an area larger than 50 000 km^2. Alpine glaciers can be found on all continents, but continental glaciers can be found today only in Greenland and Antarctica.

Use the following cross sections to answer question 6



6. The sediments at the sides of the valley were deposited in glacial streams and lakes. These deposits are
   a) eskers.
   b) kettles.
   c) kame terraces.
   d) lateral moraines.

7. What is the **best** information that glacial striations can provide geologists?
   a) The exact date of glaciation.
   b) The thickness of the ice sheet.
   c) The speed the glacier was moving.
   d) The direction of the glacier's flow.

8. Compared to stream sediment, a sample taken from glacial till would contain sediment which is
   a) less rounded and well-sorted.
   b) well-rounded and well-sorted.
   c) less rounded and poorly-sorted.
   d) well-rounded and poorly-sorted.

9. The **furthest** advance of a glacier is **best** indicated by
   a) kettles.
   b) drumlins.
   c) kame terraces.
   d) terminal moraines.

10. A terminal moraine could not be used to provide information on a glacier's
    a) furthest advance
    b) direction of flow
    c) rate of ice formation
    d) maximum size and shape

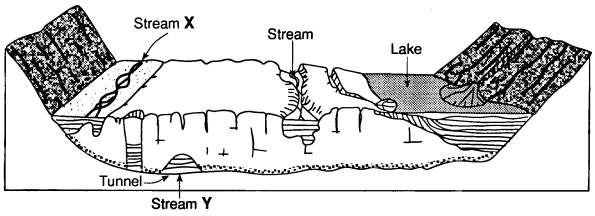
11. Which of the following is not a feature of glacial deposition?
    a) Kame
    b) Esker
    c) Cirque
    d) Moraine

A cirque is a feature of glacial erosion.

12. The name given to a narrow ridge between two glacial valleys is a(n)
    a) esker
    b) tarn
    c) arête
    d) cirque

Use the following diagram to answer questions 13 and 14

13. When the glacier has melted completely, the depositional feature which will have formed from stream **X**'s sediments will be a(n)
    a) esker
    b) drumlin
    c) kame terrace
    d) recessional moraine



14. The composition and form of the sediment which will be deposited by stream **Y** will usually be a(n)
    a) stratified, snake like ridge
    b) unstratified, snake like ridge
    c) stratified tear-drop shaped hill
    d) unstratified tear-drop shaped hill

This is known as an esker.

15. What is the name for the material that forms stripes down the length of a glacier?
    a) Terminal moraine
    b) Recessional moraine
    c) Medial moraine
    d) Ground moraine

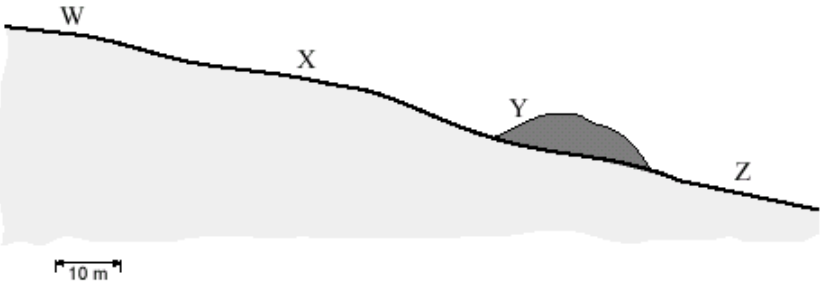
16. All of the following glacial features could be used to determine the original direction of an ice flow **except**
    a) drumlins
    b) striations
    c) eskers
    d) kettles

Drumlins, striations and eskers can all provide clues as to the direction of flow of the glacier.

17. A bowl shaped depression at the head of a glacier valley is called
    a) a kettle
    b) an arête
    c) a cirque
    d) an oxbow

Refer to the cross section below of a terminal moraine to answer question 18

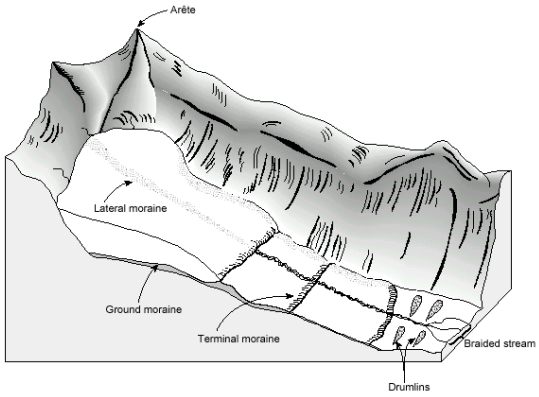
18. The only glacier in the area deposited the terminal moraine. In which of the following locations would erratics **least likely** be found?
    a) W
    b) X
    c) Y
    d) Z



This is past the terminal moraine – the furthest place the glacier went.

Use the following cut-away sketch of a glacier in a valley to answer question 19

19. A geology student drew the sketch above from memory. A few errors were made in the details and the labelling of the sketch. Name four such errors, and describe how the drawing could be corrected.



Error 1 and correction:

A horn has been labeled as an arête. The arête would be a knife-like edge between the horns.

Error 2 and correction:

A medial moraine has been labelled as a lateral moraine. The lateral moraine would be at the valley side of the ice.

Error 3 and correction:

A recessional moraine has been labelled as a terminal moraine. The terminal moraine would be the farthest one down the valley.

Error 4 and correction:

The drumlins are pointing in the wrong direction. The pointed ends should be pointing down the valley.

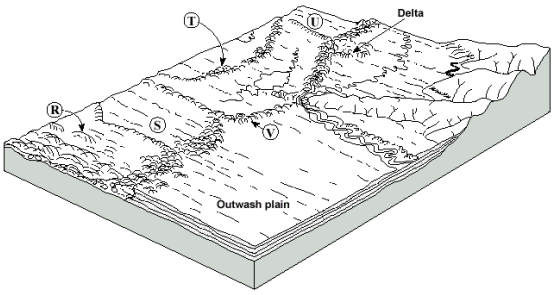
Error 5 and correction:

Drumlins are not usually associated with alpine glaciation. They should not appear on the diagram.

Error 6 and correction:

Braided stream should be closer to end of glacier.

Use the following diagram of an area that has recently been partially covered by a continental glacier to answer questions 20 to 22



20. The features at **R** are small, elongated hills composed of till and shaped by the advancing ice sheet. These features are
    a) drumlins.
    b) kame terraces.
    c) outwash ridges.
    d) lateral moraines.

21. The farthest advance of the glacier is indicated by
    a) S
    b) T
    c) U
    d) V

All the glacial features such as drumlins and eskers are behind V. Beyond V is the outwash plain.

22. The deposit of ground moraine at **S** is also shown in photograph 7 on page viii of the Data Booklet. Which of the following **best** describes the texture of the sediment in the ground moraine?
    a) Well-sorted, with smooth, well-rounded boulders
    b) Very poorly-sorted, with smooth, well-rounded boulders
    c) Well-sorted, with striated, sub-rounded and angular boulders
    d) Very poorly-sorted with striated, sub-rounded and angular boulders

Questions to Section S: Surficial Processes (Ground Water)

1. Describe the nature and constituents of subsurface water, including water table, zone of saturation, zone of aeration, perched and confined water tables, aquifers, and impermeable layers.
   Ground water comes from rainwater that seeps into porous rock in the ground. The water trickles down until a layer of impermeable rock and "fills up" the ground. The top of this water layer is called the water table.

Water table	*The top of the zone of saturation*
Zone of saturation	*Below the water table where the pore spaces in the rock are filled up with water*
Zone of aeration	*Above the water table where the pore spaces in the rock are not filled up*
Perched water table	*The water table in a small region is higher than the general water table due to an impermeable rock layer at one location*
Confined water table	*When an aquifer is overlain by impermeable rock, the vertical movement of water is restricted. Water may build up enough pressure to rise under its own pressure once the well is dug – an artesian well.*
Aquifer	*Porous and permeable rock that holds enough water to be useful as a source of water*
Impermeable layer	*Water does not flow easily through an impermeable layer.*

2. Demonstrate how the abundance, availability, and movement of subsurface water are directly related to the porosity and permeability of geologic materials
   A porous rock is able to hold water within its pore spaces. A permeable rock allows water to flow through the rock within its pore spaces. An aquifer would need to be both porous to hold a lot of water but also permeable for the water to move to get it out.

3. Draw a subsurface water profile including all the terms you described in #1.
   The data would most likely be measured in metres from the impermeable bedrock lying below. The water table is not a level surface but follows the general contour of the land, provided there is no abrupt change in the layers of rock below the surface. A lake or river occurs where the land surface cuts below the water table. The water table changes seasonally, and with human activities.

4. Describe how the following human activities affect the quality and quantity of groundwater:

   - urbanization

   Human consumption lowers the water table. A cone of depression will form around a well because although water can flow through an aquifer it is not fast (a few millimeters to meters per year only.) Many areas around the world the water is withdrawn at a faster rate than it is recharged. If well are dug to near the ocean the water supply could be contaminated with salt water.

   - waste disposal

   Septic tanks contaminate the local supply of ground water. Rainwater that seeps into the ground can dissolve various pollutants. Dumps and landfill sites can pollute the groundwater supply because the rain that falls on the site will pick up many chemicals and percolate into the ground and contaminate.

- agriculture

Animal waste can make it into the groundwater supply because rain picks this material up when it soaks into the ground. This occurred in Walkerton, Ontario in May 2000 when cow manure contaminated with E. coli bacteria made it to the local water supply and a few people died, and made thousands sick.

- conservation and reclamation

There are a few methods to control the quantity and quality of groundwater extracted. A recharge basin is designed to catch surface water and let it seep into the ground. Another is to move the surface water from one drainage basin to another using aqueducts.

The quality of groundwater can also be improved by not allowing waste to seep into the ground along with the water. Solutions include an impermeable layer below a dump, or ensuring the surface run-off that could pass through a polluted area such as a cow field or landfill site is redirected to an area that will not be part of anyone's drinking supply. A local well could ensure a clean drinking supply by drilling up hill above the septic tank.

Over time and distance the polluted water does decontaminate as it passes through sub-surface sand.

5. Where does ground water come from? How does it get into the ground?

Ground water comes from rainwater that seeps into porous rock in the ground. The water trickles down until a layer of impermeable rock and "fills up" the ground. The top of this water layer is called the water table.

6. Why is ground water sometimes hot?

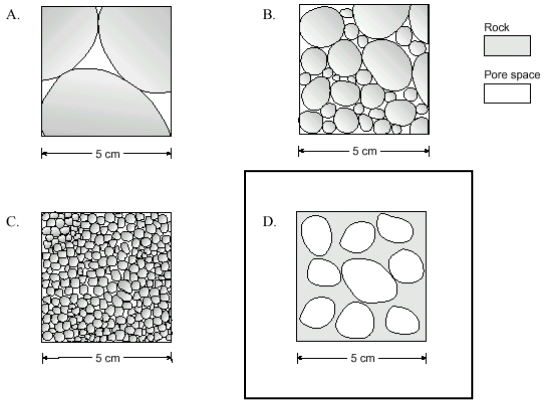
When the ground water passes near a magmatic intrusion it can heat up. If the water boils it can move upwards under a lot of pressure and erupt as a geyser or form a hotspring.

7. A well that produces a reliable, year-round supply of water must reach
   a) into impermeable bedrock.
   b) just above the zone of saturation.
   c) only as far as the zone of aeration.
   d) below the lowest level of the water table.

8. Which of the following events would indicate a rising water table?
   a) Lake levels drop
   b) Shallow well go dry
   c) Base flow in streams is high
   d) Springs dry up

All other options indicate a decrease in the level of the water table.

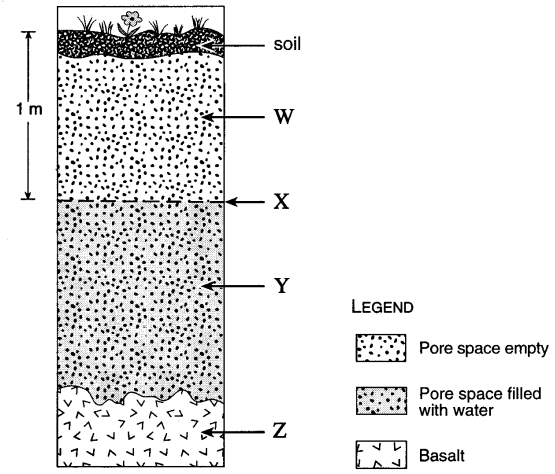
9. The sample that would have the **greatest** porosity and the **least** permeability is



The rock can hold a lot of water, but clearly it cannot possibly flow anywhere.

Use the following sketch of a cross section to answer question 10 to 12

10. The water table is indicated by
    a) W
    b) X
    c) Y
    d) Z

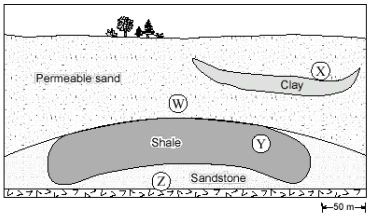


11. The zone of aeration is indicated by
    a) W
    b) X
    c) Y
    d) Z

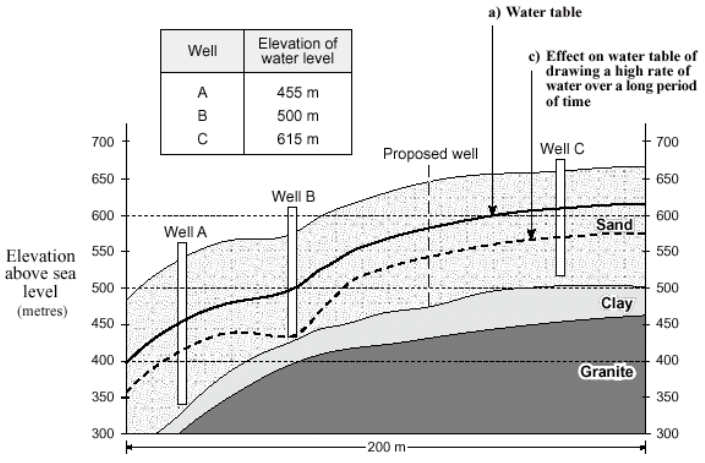
12. The zone of saturation is indicated by
    a) W
    b) X
    c) Y
    d) Z

Refer to the following cross-section sketch to answer question 13

13. Which of the following is the **most likely** location for a perched water table?
    a) W
    b) X
    c) Y
    d) Z



Use the following cross section to answer question 14

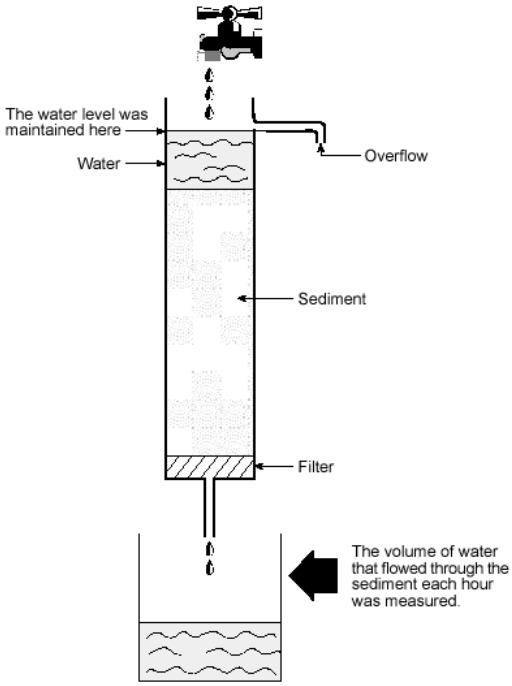


14. a) Use a **solid** line to sketch on the cross section the level of the water table. Clearly label the water table on the diagram.

    b) At what elevation (in metres) will the proposed well **likely** strike water?
    The proposed well will likely strike water at about 550 m to 600 m.

    c) It is proposed that water be drawn from Well B at a very high rate for industrial use for a period of five years. Use a **dotted** line to sketch on the cross section the change in the total water table of the area that would result from this heavy extraction. Clearly label the change in the water table on the diagram.

Use the following diagram and table to answer question 15



15. A student used the equipment shown on the previous page to determine the rate of water flow through a variety of sediments. The student also measured the porosity of each material by determining how much water was required to completely saturate the dry sediment.

a) **According to the data** for the well-sorted sediments, what is the relationship between particle size and porosity of the sediments?

The smaller the particle size, the greater the porosity, or the larger the particle size, the smaller the porosity.

b) Which of the six sediments listed in the table would make the best seal to stop toxic waste from leaching from a toxic waste pond? Give a reason for your answer.

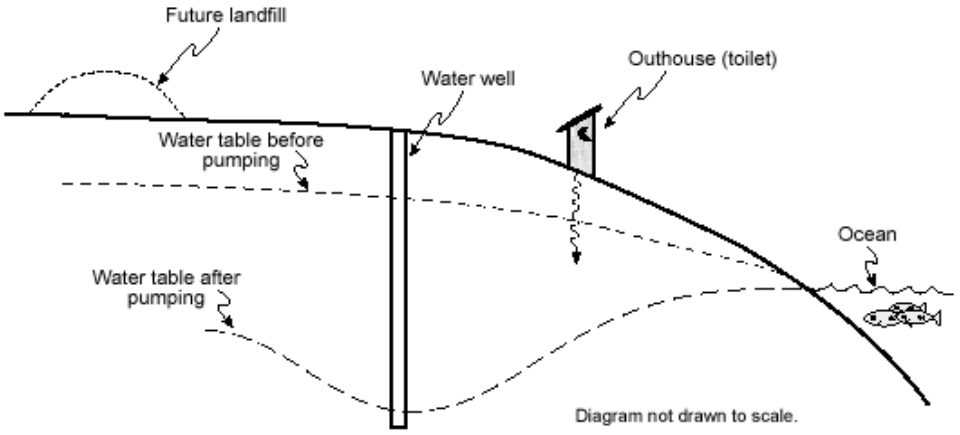
Clay because it has the smallest flow rate, and thus the lowest permeability.
The toxic waste would move through very slowly.

c) Give a reason why the permeability and porosity of the silty sand is so different from the permeability and porosity of the well-sorted sand.

The smaller silt particles tend to fill the spaces between the sand particles, therefore reducing both the porosity and the permeability.

Sediment	**Flow rate of water (litres per hour)**	***Porosity* (%)**
Well-sorted gravel	3000	30
Well-sorted sand	250	40
Well-sorted silt	0.5	45
Well-sorted clay	0.0001	55
Silty sand	5	20
Glacial till	0.2	10

Use the following cross section of a water well to answer question 16



16. a) The people using the water well in the diagram above should be very concerned about the quality of their water supply. Describe two existing problems for a well in this location.

Waste from the outhouse could leach into the water supply.
Saltwater from the ocean could reach the water table.
High use/low recharge in the summer could lead to the use of bottom water.
The well would become dry.

b) What measures could be taken to prevent material from the future landfill site from leaching into the water supply?

Line the base of the landfill with clay.
Line the base of the landfill with plastic.
Cover the landfill to prevent rainfall reaching the landfill.
Collect, remove, or treat leachates.

17. A large area on a hillside has been suggested as a landfill site for garbage generated by a small nearby city. You are asked for a geologic appraisal of the site to determine if local subsurface water supplies might be affected. What geologic factors would you investigate and why?

The underlying bedrock should be examined because if is porous and permeable the run-off from the landfill will affect the ground water. If the land underlying the landfill site it granite or another impermeable rock it is less likely for material to leach into the water supply. The surrounding rock should have few or no fractures through which contaminated water can easily flow. The rock surrounding the landfill should have no economic value. The local ground water supply should flow away from the surface to allow maximum time to purify. The rainfall for the area should be low, as to decrease the amount of leaching into the ground. The water table should be low and the zone of aeration should be thick as to avoid the chance of the water table rising above the level of the ground to carry much of the contaminated material away.

Answers for Section D: Earth Materials (Sedimentary Rocks and Processes)

1. Outline the origin and process of formation of sedimentary rocks (clastic, chemical and biochemical.)

   Sedimentary rocks are made from fragments of previously existing rocks. All rocks on the Earth's surface gradually break apart into smaller pieces. These pieces or fragments are referred to as clasts. Rivers, wind, glaciers or gravity carries the clasts to other locations. They become rounded and separate by size. Eventually the clasts are deposited. The pore space between the clasts decreases as the particles pile up. Water seeps through the pore spaces and in the water usually calcite is dissolved. When the water evaporates the calcite remains to cement the clasts together into a sedimentary rock. The whole process of compaction and cementation is called lithification.

   Clastic sediments include sand, pebbles and cobbles in a river bed whereas chemical sediments are dissolved particles in water. Clastic sediment becomes clastic sedimentary rock such as sandstone and chemical sedimentary rock is formed when the water evaporates and leaves behind the dissolved ions to precipitate and crystallize. These include rock salt and limestone. Biochemical sedimentary rocks form when life is involved in the formation of the rock (i.e. shells glued together.)

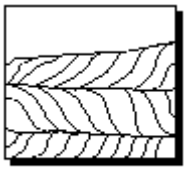
2. Describe the features of and identify the following sedimentary rocks:

conglomerate	*clastic*	*Large (>2 mm) rounded particles; gravel*
breccia	*clastic*	*Large (>2 mm) angular particles; gravel*
sandstone	*clastic*	*sand (0.1 mm to 1 mm) barely visible*
shale	*clastic*	*mud (<0.05 mm)*
limestone	*chemical*	*primarily precipitation of calcite*
chert	*chemical*	*precipitation of silica; from skeletons of marine organisms*
gypsum	*chemical*	*precipitation of calcium sulphate*
rock salt (halite)	*chemical*	*precipitation of halite (NaCl)*
coal	*organic remains*	*lithified plant remains*

3. Diagram and/or describe the following sedimentary features and describe a sedimentary environment where each might be found:

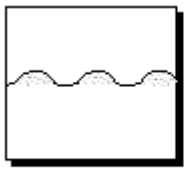
Stratification	*Layering that develops as sediment is deposited. Important for determining the relative ages of layers and for correlating nearby sedimentary layers.*

Crossbedding	*Occurs when small sedimentary layers lie at an angle relative to the main sedimentary layering. Quite common in wind blown sediments.*



Cross bedding

Ripple marks	*Formed when water flowing over sand creates parallel ripples and is preserved when the sand lithifies. The ripple marks preserve the original direction of the river. Asymmetric ripple marks indicate the river flowed only one direction whereas symmetric ripples would indicate the river flowed in both directions.*



Symmetrical ripple marks

Asymmetrical ripple marks

Mud cracks	*Formed when water evaporates and the mud dries. They indicate alternate drying and flooding of the area.*

Mud cracks

Graded bedding	*A type of bedding in which the largest particles collect at the bottom. Finer particles settle more slowly and can be found at the top.*
Varves	*A type of layering which shows a seasonal pattern. The layering can be tracked on a year to year basis.*

- Well or poorly sorted sediment

A faster moving river, or faster moving wind can transport larger particles. But as the river or wind slows the largest particles will be dropped and deposited. In this way a river can sort its sediment load. As the river makes its way to the ocean, it will slow down. Every time it slows down it will deposit the largest sediment it is carrying. The longer distance the particles are carried in the river the longer time they will have to abrade and become rounded. The further from the source the more opportunity the particles have to become broken, abraded or dissolved. Poorly sorted sediments result when water or wind are suddenly stopped so the entire load being carried is dropped in one spot.

- fossils and organic structures

Fossils and other organic structures are a common feature of sedimentary rocks. The hard parts of the organism are best preserved. Fossil evidence in a sedimentary layer is important for determining the relative age of the layer. The types of fossils found indicate the type of environment that existed when the sedimentary layer was formed, i.e. marine, shallow river, desert etc.

4. Where in your own area would you look for rounded and sorted sediment?

*Well sorted sediment would be found **downstream** near the mouth of a river. This is where the river slows down and is able to carry only the smallest particles. The mouth of the Fraser River, Delta and Richmond has a lot of well sorted sediment and this makes for fertile farm land.*

5. Explain why almost all sedimentary rocks are layered, or bedded.

*Sediment is almost always **deposited** in a **layer by layer** process. This may result in different colours and textures as the mineral composition change between deposits.*

6. Sedimentary rock makes up
   a) about 5% of the Earth's mantle
   b) less than 5% of the Earth's crust
   c) 50% of the Earth's crust
   d) 12% of the Earth's core

7. The conversion of loose sediment to hard rock is called
   a) compaction
   b) precipitation
   c) lithification
   d) metamorphism

8. A clastic sedimentary rock has angular clasts ranging in size from 2 mm to over 100 mm. What is the name of this rock?
   a) Breccia
   b) Sandstone
   c) Conglomerate
   d) Shale

   Conglomerate has rounded clasts or particles. Sandstone has much smaller clasts and shale even smaller

9. In which of the following environments would chemical sedimentary rocks likely form?
   a) Coastal deltas
   b) Restricted bays of warm, shallow water
   c) High energy beaches
   d) Deep sea floor

   The warm water will have a chance to evaporate and leave its dissolved load behind as a chemical sedimentary rock.

10. Which of the following characteristics of clastic rocks would provide the most useful information for determining the source area of the rocks?
   a) Rock name.
   b) Presence of mud cracks
   c) Composition of clasts
   d) Thickness of bedding

   All sedimentary rocks are made from particles that originate somewhere else. The composition of those particles would be unique to a certain region.

11. Which of the following is most likely to decrease during the lithification of sediment?
   a) Density
   b) Porosity
   c) Grain size
   d) Cementation

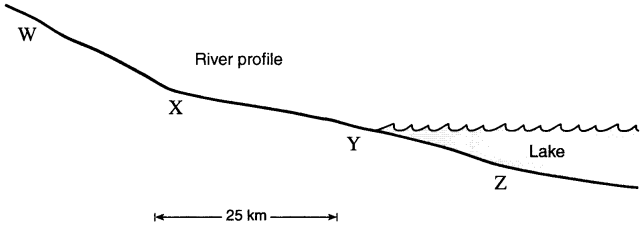
   Sediments get squeezed until there is very little space between the clasts.

12. Which of the following sedimentary rocks would most likely contain fossils?
   a) breccia
   b) gypsum
   c) limestone
   d) conglomerate

   Conglomerate and breccia sized clasts would destroy any organism before it had a chance to become a fossil.

13. The best sedimentary classification of rock salt is
   a) clastic
   b) detrital
   c) organic
   d) evaporite

Use the following diagram to answer questions 14 and 15



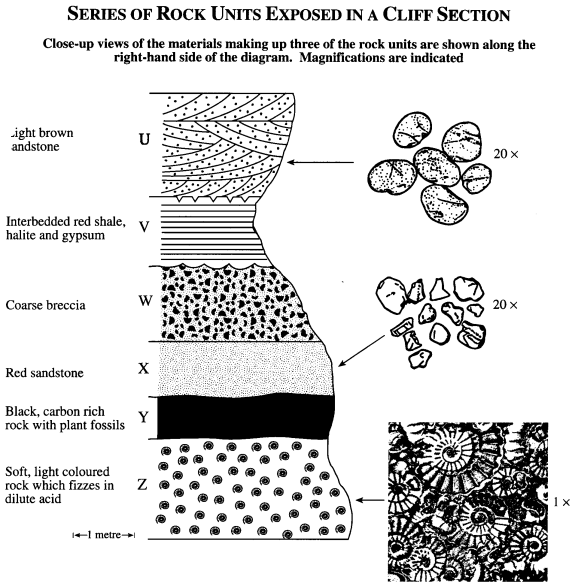
14. Where would you most likely find angular and poorly sorted sediments? Explain your answer.
   Probably near location W. The river cannot transport the largest clasts. These particles cannot have travelled far so it will not be rounded.

15. Describe the sediment that would be found at Z.
   The sediment at Z will be fine mud and silt.

Use the diagram of a Series of Rock Units Exposed in a Cliff Section on the next page to answer questions 16 to 19

16. From the evidence shown, in which of the following sedimentary environments was Unit U most likely deposited?
    a) River
    b) Desert
    c) Alluvial fan
    d) Shallow marine

The cross bedding is in alternate directions.



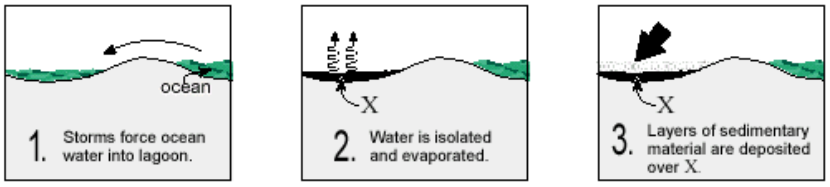
17. The rock unit which contains the best evidence of alternate flooding and drying is
    a) V
    b) W
    c) X
    d) Y

Very thin layers and microscopic particles.

18. Which rock unit is composed of clastic sediments that have been transported the shortest distance?
    a) U
    b) V
    c) W
    d) X

19. Which rock unit could be mined and used for making fertilizer or cement?
    a) V
    b) X
    c) Y
    d) Z

Use the following sequence of events to answer question 20 and 21



20. A sedimentary rock has formed at **X** as a result of the sequence of events shown above. This rock would **most likely** be
    a) chert.
    b) shale.
    c) siltstone.
    d) rock salt.

21. The sedimentary rock found at X would most likely be classified as
    a) an evaporate
    b) clastic
    c) well sorted
    d) organic

22. Which of the following is a sedimentary rock formed by the lithification of silt and clay?
    a) Shale
    b) Breccia
    c) Sandstone
    d) Conglomerate

23. Which of the following sedimentary rocks is a chemical precipitate?
    a) Sandstone
    b) Coal
    c) Chert
    d) Shale

Quartz dissolved in hot water.

24. Small, rounded grains composed of calcite are most often found in
    a) sandstone
    b) limestone
    c) shale
    d) mudstone

25. Small, spheroidal grains composed of quartz are found in
    a) sandstone
    b) limestone
    c) shale
    d) mudstone

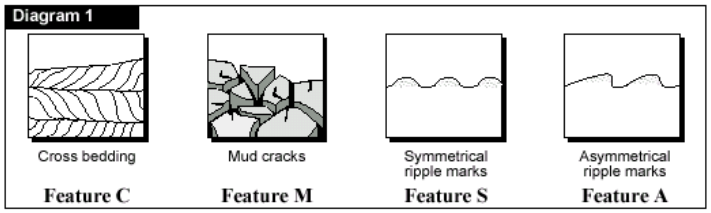
26. Which of the following is **not** a clastic sedimentary rock?
    a) Conglomerate
    b) Sandstone
    c) Chert
    d) Shale

27. A biochemical sediment consists largely of coral and shell debris. If this sediment were lithified, it would become
    a) coal
    b) chert
    c) limestone
    d) conglomerate

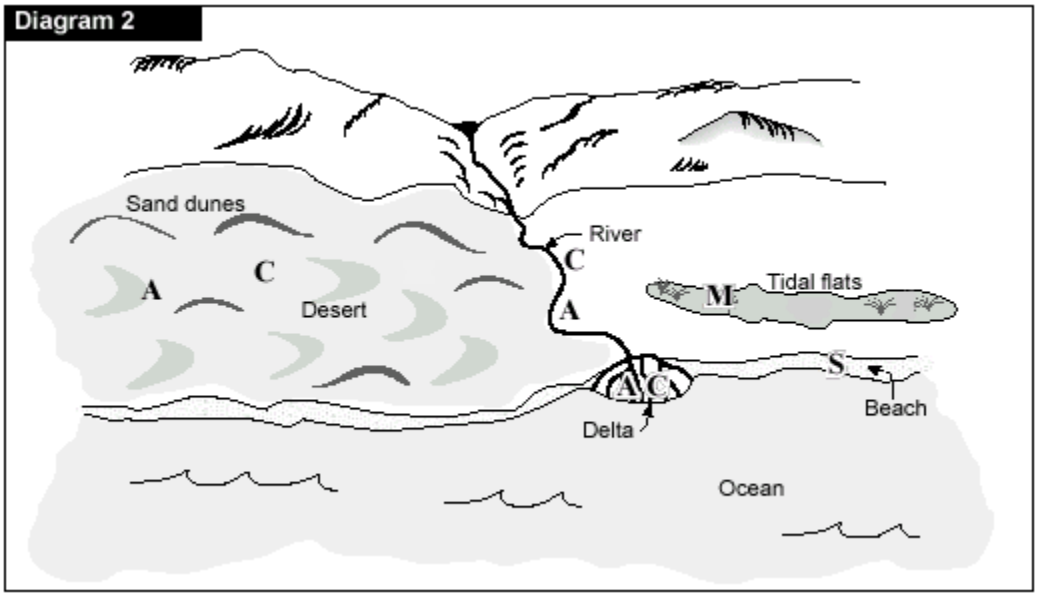
28. In which environment would coal deposits most likely form?
    a) River bed
    b) Coastal swamp
    c) Beach environment
    d) Deep ocean environment

29. If a beaker of seawater were left to evaporate and dry out, the minerals left present in the container would most likely be
    a) biotite and quartz
    b) gypsum and halite
    c) fluorite and galena
    d) calcite and chalcopyrite

Use the following features in the diagram below to answer question 30



30. a) Indicate a location **where** each of the features could form, by placing the letter of the feature on diagram 2.



b) Describe **how** the features you have chosen were formed.

Feature	Description of how feature formed
C: Cross bedding:	*Occurs when small sedimentary layers lie at an angle relative to the main sedimentary layering. Quite common in wind blown sediments Formed by the direction of sediment-carrying currents (water or wind).*
M: Mud cracks.	*Formed when water evaporates and the dried mud contracts*
S: Symmetrical ripple marks:	*Formed by the oscillation of current motion, back and forth, as with tides coming in and out.*
A: Asymmetrical ripple marks:	*Formed by currents moving in one particular direction.*