Lesson Thirteen

Running Water and the Development of Landforms

Aims

The aim of this lesson is for you to learn about:

- processes including
  - weathering and mass movement
  - erosion and deposition
- factors affecting these processes including
  - stream velocity
  - slope
  - geology
- the formation of
  - valleys
  - interlocking spurs
  - waterfalls
  - meanders
  - ox-bow lakes
  - flood plains and levees

Context

Running water has a significant influence on the development of land forms.

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Introduction

In the last lesson we looked at the three stages of a river from its upland source to its mouth opening at the sea. In the course of this journey flowing water influences the shape and development of the landforms through which it passes in a number of ways. It is these processes we will now turn our attention to.

However before we do this we must first understand that running water plays a key role in both **denudation** and **deposition**. The former refers to all processes which can wear down the surface of the earth, whereas the later refers to material being literally deposited (added) to a landform. These two broad terms cover much of what is to be discussed below as we think about the dynamic changes that occur to the surface structure of the planet we live on.

Four Key Processes that shape Landforms

1. Weathering

Weathering describes the process in which the upper layers of the earth's soils and rocks are exposed to physical (mechanical), chemical and biological conditions which cause some change to the structure of that material. Weathering always occurs in situ, at the original location of a land formation and is different from **erosion** because it does not involve any significant movement of material. We will now look at how river environments are involved in weathering.

Weathering can be divided into three major types:

- **mechanical**
- **chemical**
- **biological**

Mechanical Weathering

Mechanical weathering involves the **disintegration** of a rock into smaller particles without the chemical makeup of that rock changing significantly. It can occur in various ways but below are the major ways mechanical weathering is relevant to the river environment;

Frost Shattering occurs when porous rocks contain cracks and spaces within them allowing water to enter. When temperatures drop below freezing, ice will begin to form, expanding by 9% in volume over the size of the original liquid water. This often occurs at night when cooler conditions arise. Due to this expansion, pressure is exerted on the rock causing gaps and spaces to widen and eventually shatter. This repeated process is known as freeze-thaw action. Think back to the ways water moves, or transfers, through rock in a drainage basin, as we saw in Lesson One, It is through this process that mechanical weathering can operate in the river environment.

Salt Cystallisation occurs if water entering a space in a rock is slightly saline (salty). When that water evaporates away it can leave salt crystals behind. Over time these crystals can become bigger and exert pressure on the rock particles around them, causing them to break off in a similar way that occurs under freeze-thaw action.

Chemical Weathering

Chemical weathering involves the decomposition of rock where chemical reactions occur and cause changes to the internal structure of a material. These are often gradual and ongoing processes that can occur in many complex ways.

However the two main types of chemical weathering we need to think about within river environments are:

Oxidation - whereby a combination of the oxygen carried in water and the atmosphere reacts with surface rock structures to form hydroxides. Similar to rusting on metal, this process can cause rock to weaken and crumble.

Hydrolysis - a chemical reaction between mineral ions (a miniscule electrically charged atom) and the hydrogen ions contained in water that changes the shape of surface material, often causing bits to break off and crumble away.

Other chemical weathering processes you might come across include;

Hydration - this is closely related to mechanical weathering, but occurs where pressures become so intense that the chemical structure of a material is actually forced to change.

Dissolution - this occurs when acid rain forms, mainly from emissions of sulphur, nitrogen and carbon in the atmosphere, and falls into a river environment causing a variety of reactions with surface minerals.

Biological Weathering

Biological weathering can occur in a river environment when, due to adequate mineral, light and water supplies, living organisms are able to prosper in drainage basins and interact with the land surface.

At a larger scale, the spreading of tree or plant roots beneath the earth, in cracks and joints between rocks, can cause extreme pressures that shatter rock material. On a smaller scale, the growth of lichens and mosses on rock can cause changes to chemical conditions and the slow breakdown of material directly at the surface. We may also think about burrowing animals, rabbits for example, and the influence they have in removing soils from river banks and valley sides.

Furthermore, all these processes can interact in dynamic ways. For example, biological and mechanical weathering can open up physical spaces for chemical weathering to occur at greater rates. Think about water flowing through gaps of shattered rock. We shouldn't think about these processes acting alone, but as a complex system of active processes.

Activity 1

Explain what is meant by these types of weathering:

a) mechanical

b) chemical

c) biological

2. Mass Movement

By mass movement we mean the process by which soil and rock move downslope under the force of gravity and a number of underlying factors. When the gravitational force acting on a slope becomes greater than the resistant force acting on a material structure the conditions for mass movement arise. There are various forms of mass movement, each with underlying factors;

1. **Creep**: the long-term process of gravity causing surface soil materials to move up and then down due to the effect of freeze-thaw. Over time this can cause large amounts of soil to warp or creep downslope due to loss of internal strength.

2. **Landslide**: slopes can become unstable, for example, when groundwater levels rise suddenly in heavy rain events, increasing the weight of a sheet of material and leading to the possibility of it slipping downwards.

3. **Rock fall**: this is a sudden form of mass movement which occurs when blocks of rock suddenly fall from a cliff face and collect at the base. It is often initiated by a quick burst of water into a drainage basin.

Once a mass of material has been subjected to the processes of mass movement it can be further eroded and continue to move through the river environment in a number of ways.

3. Erosion

Erosion refers to the removal of weathered sediment or rocks by the forces of wind, water and ice. Erosion processes are in action as a river flows from its source to its mouth. You will remember that there are three main sections in the course of a river: the upland tract, valley tract, and plain tract. Erosion occurs mainly, but not exclusively, in the upland and valley tracts, and deposition mainly, but not exclusively, in the plain or flat land crossed by the river as it nears its mouth. **Deposition** is when material is deposited due to the loss of energy within a river flow. **Transportation** is the process by which the river carries materials on its journey.

The Processes in the Upper Course

Transportation on the Upper Course involves several different processes that cause erosion:

- **Traction**: this involves the movement of large pebbles along a river bed in times of flood when the water volume and velocity are greater than normal.

- **Saltation**: this is when small pebbles jump along the river bed. The process has nothing to do with salt. "Saltation" comes from the Latin word 'saltare' meaning "to jump."

- **Suspension:** this is where mud, clay, and sand (collectively known as silt) are transported in the upper part of the river water. Silt is suspended in the water.

- **Solution**: this happens when material is chemically dissolved as it is transported by the river. Limestone, for example, is dissolved by weak acids in rainwater. It is carried in the river in solution.

As these processes take place they cause different types of erosion.

Types of Erosion

Material that is transported in a river wears away its banks and bed. As the **velocity** of a river increases, so too does the load it can carry and the rate at which it can erode. A river erodes in a combination of four ways:

1. When material such as large stones and even boulders being transported along the bed of the river collides and breaks up into smaller pieces. This happens mainly where rivers are flowing quickly in highland areas. The process is called **attritition**.

2. Particles of sand and silt, carried in suspension, rub against the banks of the river. River banks are worn away by a sand-papering action called **abrasion**, also referred to as **corrasion**. At a time of very heavy rainfall, rocks and pebbles of various sizes also heave against the bed and banks of the river. This process is more likely to occur in lowland areas.

3. Weak acids in the river dissolve rocks such as limestone, which form its banks and bed. This process can occur at any point of the river's course. This is called **corrosion**.

4. **Hydraulic action** occurs when the sheer force of the water in the river wears away its banks and bed by dislodging small stones and grit from the bed and banks of the river. Think for a minute about the dislodged stones banging against each other. What happens to them? Can you see that over a period of time constant colliding will break them down into smaller pieces?

4. Deposition

The river has force/energy when eroding and transporting. What do you think will happen to the material being transported as the river loses energy? Do you think that it will begin to drop its load? You are right. The load is of different sizes and shapes. How will this affect the order in which material is dropped?

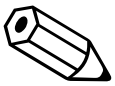
The river will begin to deposit its load as it loses its energy. This could be because of bends in the river. What happens here is that water is slower on the inside bend and deposits material, but is faster on the outside bend where abrasion takes place. The river also loses energy when there is no rain. Can you explain why?

Deposition occurs when a river lacks enough energy to carry its load. Deposition, beginning with the heaviest material first, can occur following a dry spell when the discharge and velocity of the river falls, or where the current slows down (at the inside of a bend, or where the river enters the sea, for example).

Factors that Influence these Processes: Stream Velocity, Slope and Geology

As you may have realized, **stream velocity**, **slope** and **geology** are all important factors in the operation of mass movement, erosion, deposition and transportation. With a high slope angle, such as in the upper tract of a river, the gravitational force acting on a river is much more than when this angle is reduced in the flatter plain tract. On steep slopes stream velocity is increased and more energy is therefore available to erode and transport bedrock material downstream. Underlying geology is also a key factor to consider as the internal strength of a rock will determine how resilient it is to the processes described above. All these processes interact in a

number of dynamic ways to cause the shape and form of the land to change and create the drainage basin landforms that we will study in the second part of this lesson.

Activity 2	Transportation is an essential feature in the evolution of a river environment. Name four types of transportation within river channels and very briefly describe these processes.
	

River Environment Landforms: the Evolution of a Drainage Basin

Over a long period of time, the processes of weathering and mass movement, erosion and deposition can lead to the creation of a series of dramatic river environment landforms. We will begin our study of these by looking at the upper course of a river before moving downstream to the middle and lower course environments we studied in Lesson One.

V-shaped Valleys and Interlocking Spurs

Any spare energy possessed by a river near to its source will be used to transport large boulders along its bed. This movement results in the river cutting rapidly downwards, a process called **vertical erosion**. Vertical erosion leads to the formation of steep-sided, narrow valleys shaped like the letter 'V'. The **V-shaped valley** sides are steep due to soil and loose rock being washed downhill following periods of heavy rainfall. This material is added to the load of the river. The river itself is often forced to wind its way around protruding hillsides along the path of least resistance. These

hillsides, known as **interlocking spurs**, restrict the view up or down the valley.

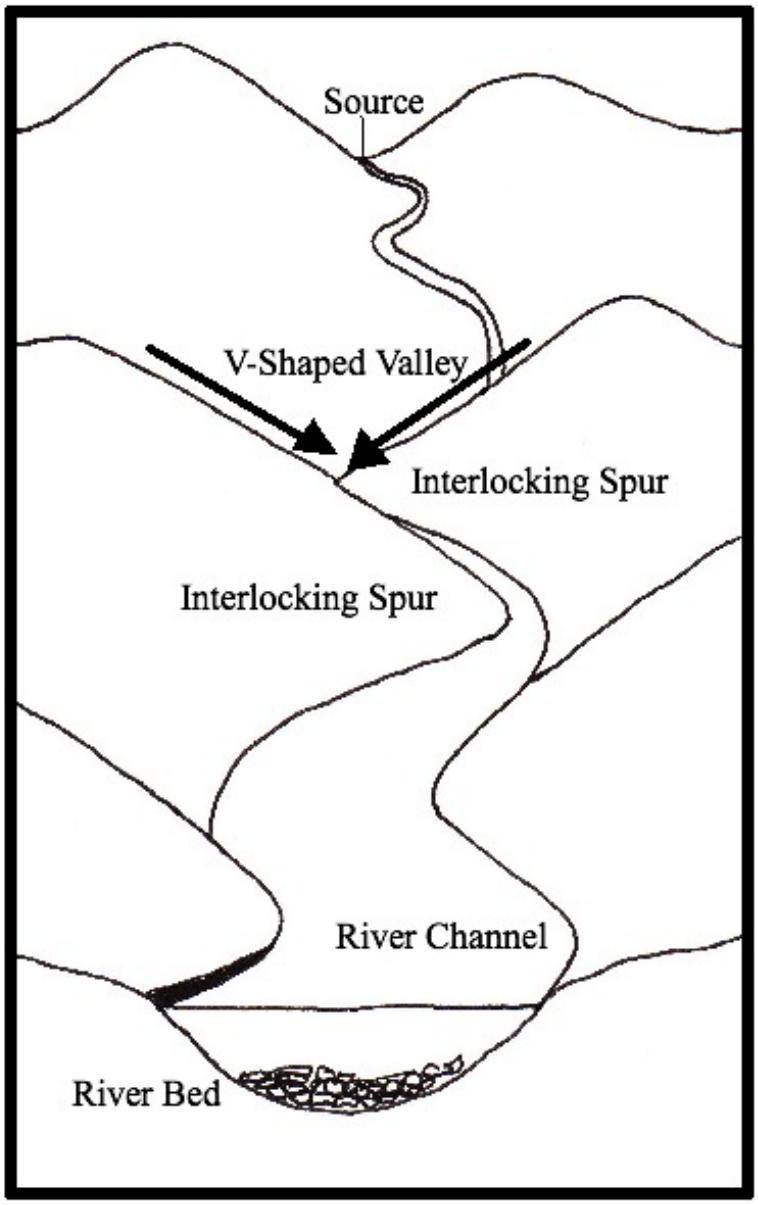


Figure 1: Interlocking spurs as part of a classic V-shaped valley formation

Waterfalls and Rapids

Waterfalls form when there is a sudden interruption in the course of a river. They may result from erosion by ice, changes in sea-level, and earth movements. Most waterfalls form when rivers meet a band of softer, less resistant rock after flowing over a relatively hard, resistant rock. The underlying softer rock is worn away more quickly, and the harder rock is undercut. In time the overlying harder rock will become unsupported and will collapse. After its collapse, some of the rock will be swirled around by the river, especially during times of high discharge, to form a deep plunge

pool. This process is likely to be repeated many times causing the waterfall to retreat upstream and leave a steep-sided gorge. For example, the Niagara Falls in Canada are retreating by up to one metre a year. Rapids occur where the layers of hard and soft rock are very thin, and so no obvious break of slope develops as in a waterfall.

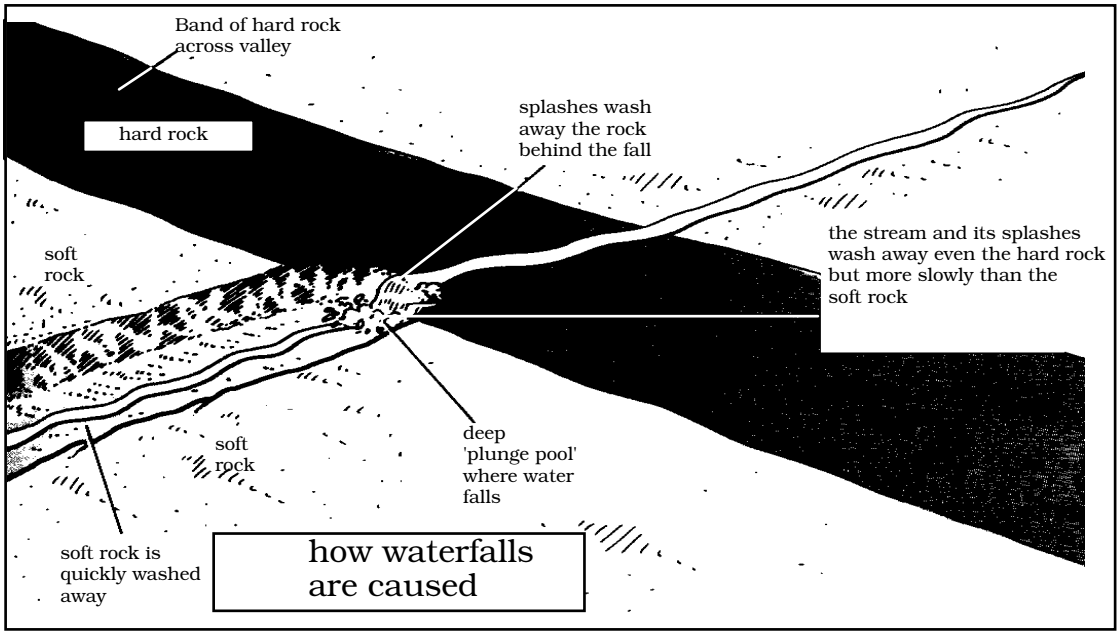


Figure 2: Waterfall retreat and the formation of a gorge

The Formation of Extensive Flood Plains and Natural Levees

In times of flooding water spills over the banks of a river and carries a fine mud called silt, or alluvium, with it. The silt is deposited as the water slows down and spreads out over the surrounding land, known as the flood plain. Due to the quick depletion of energy when a river bursts its banks, larger amounts of sediment are also deposited immediately next to the original river banks, leaving formations that build up and are known as levees.

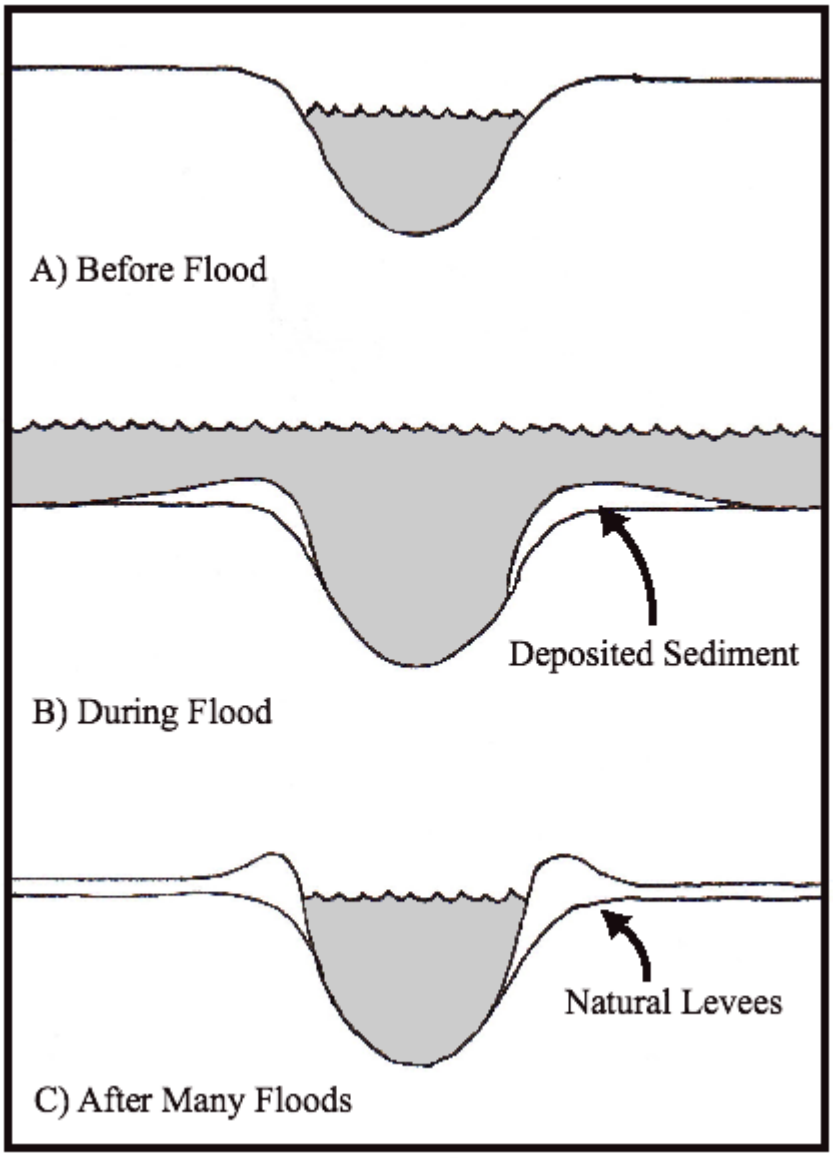


Figure 3: The formation of natural levees

Meanders and Ox-bow Lakes

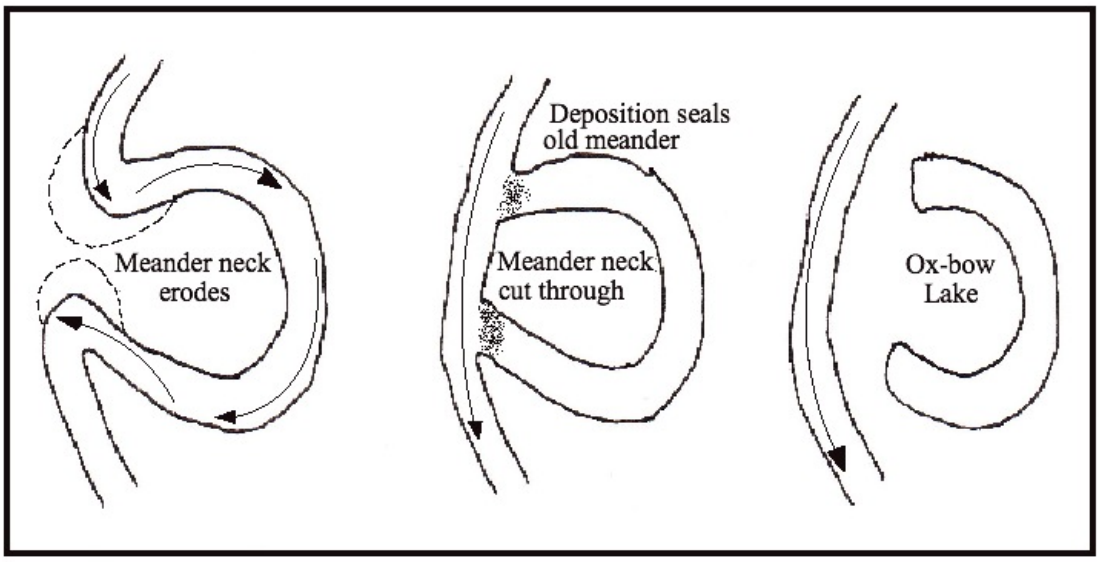


Figure 4: The formation of meanders and ox-bow lakes

As a river approaches its middle course it usually begins to flow over flatter land and often develops increasingly large bends known to geographers as **meanders**. Meanders occur when the gradient of slope is reduced, thereby reducing vertical erosion forces. This causes sideways (lateral) erosion forces to increase.

When a river reaches a point where lateral erosion occurs significantly most water is naturally directed towards the outside of a bend (see Figure 4). At first the erosion is gentle, but becomes exaggerated over time.

A repetitive process takes place where friction is reduced and velocity increased on the outer bend of the river. Therefore the river will have more energy to transport material in suspension towards the outer bank and corrosion may occur. The outer bank will be further undercut then it will collapse and retreat until erosion on the outside bends results in the neck of the meander getting narrower (again refer to figure 4).

Eventually, usually at a time of flood, the river cuts through the neck and shortens its course. The fastest current will now be flowing in the centre of the channel and deposition is more likely to occur next to the banks. The original meander will be blocked off leaving a crescent-shaped ox-bow lake. This lake will slowly dry up, apart from during periods of heavy rain, and become covered with reeds and grass.

Activity 3	Sketch the 3 stages of levee formation and briefly describe in one paragraph the process involved.
	

Activity 4	Go to the GeographyAlltheWay website and click on the link below for River Processes: http://www.geographyalltheway.com/igcse_geography/natural_environments/river_processes/river_processes.htm From this page use the links to 'The Upper Course', 'The Middle Course' and 'The Lower Course' to explore the images and videos showing the processes described in this lesson. For example, when you click on 'The Upper Course' there is a 'rollover' diagram to explore, and two further links to 'Long Profiles and Valley Cross Sections' and 'Niagara Tours'. When you have explored these, go back to the first page and explore 'The Middle Course', and then 'The Lower Course'. The videos, images and activities will help you to consolidate your learning for this lesson.

Self-assessment Test: Lesson 13

1 What is meant by weathering?

2 Name three weathering processes.

3 What is meant by mass movement?

4 Briefly outline how a river moves material downstream. Include the words erosion, deposition and transportation.

5 Name the four types of erosion.

6 Draw a series of sketches to show the development of a meander leading to the formation of an ox-bow lake.

7 Explain how the development of levees may lead to the surface of a river channel being higher than the river's floodplain.

Answers to Activities

Activity One

Refer to thes section on Weathering in the lesson and check your answer.

Activity Two

1. **Traction**: this involves the movement of large pebbles along a river bed in times of flood when the water volume and velocity are greater than normal.

2. **Saltation**: this is when small pebbles jump along the river bed. The process has nothing to do with salt. "Saltation" comes from the Latin word 'saltare' meaning "to jump."

3. **Suspension:** this is where mud, clay, and sand (collectively known as silt) are transported in the upper part of the river water. Silt is suspended in the water.

4. **Solution**: this happens when material is chemically dissolved as it is transported by the river. Limestone, for example, is dissolved by weak acids in rainwater. It is carried in the river in solution.

Activity Three

Refer to Figure 3 above to check your sketches of levee formation.

In times of flooding water spills over the banks of a river and carries a fine mud called silt, or alluvium, with it. The silt is deposited as the water slows down and spreads out over the surrounding land, known as the flood plain. Due to the quick depletion of energy when a river bursts its banks, larger amounts of sediment are also deposited immediately next to the original river banks, leaving formations that build up and are known as levees.

Answers to Self-Assessment test: Lesson 13

1. Weathering describes the process by which the upper layers of the Earth's soils and rocks are exposed to physical (mechanical), chemical and biological conditions that cause changes to the structure of that material. Weathering always occurs in situ, at the original location of a land formation and does not involve the transportation of material.

2. Mechanical. Chemical. Biological.

3. Mass movement is the process by which soil and rock move downslope under the force of gravity in conjunction with a number of underlying factors including slope angle, recent rainfall events and temperature fluctuations.

4 Erosion or the removal of weathered material causes loose sediment to then be carried in a river via transportation, provided enough

energy is available to do so. When there is too little energy to carry material deposition occurs. This means that sediments come to rest further down stream in the river environment.

5. Attrition, abrasion, corrosion, hydraulic action.

6. Refer to Figure 4 above, including annotations.

7 In times of flooding water spills over the banks of a river carrying a fine mud called silt or alluvium with it. As the water slows down this is deposited and spreads out over the surrounding land, known as the flood plain. At the same time, larger amounts of sediment are deposited immediately next to the original river banks, due to the quick depletion of energy when a river bursts its banks, leaving formations that build up and are known as levees. Therefore after a flood a river can rise to a higher level than previously, due this build up of levee material.