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CHAPTER 1

Internal structure of the earth

The earth as a planet is made up, of among other things rocks. Rock in this sense means the material other than water that make up the earth (surface and interior). It has been and still is to some extent difficult to understand how the interior of the earth is like. Many questions have also been asked on the nature of rocks by many people. Questions such as: Are the rocks the same? Do they grow? Do they shrink?

It is therefore the aim of this chapter to try and come up with explanations that may help us to understand what is there, what happens and why such happen in the inner and outer parts of the earth.

1. What do you understand by the term Lithosphere?
2. With the aid of a clearly labelled diagram describe the internal structure of the earth.
3. What is the Earth's crust made up of?
4. Which rock type makes up most of the crust?
5. Describe the make-up and behaviour of each layer of the earth.
6. How do the rocks of the core create the earth's magnetic field?
7. Why do we attribute the creation of the magnetic field to the core?
8. Explain the difference between the upper layer (continental layer) and the lower layer (oceanic layer) of the crust.
9. What covers the space above the lower crust which is not covered by the upper layer of the crust?
10. Identify the layers that separate the layers of the earth?
11. What happens to the temperature as the depth increases?
12. Why does the temperature change as explained in (11) as one goes down?
13. How do we know about the internal structure of the earth?

Answers

1. This is the solid outer portion (layer) of the earth which includes, the continents and the ocean floor. This zone is also described by others as the 'stone sphere'.

2. The earth is made up of three layers as follows:

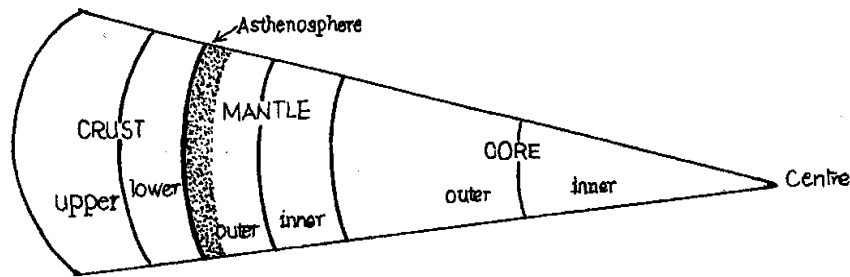


Fig. 1 Cross section of the earth's crust

Source: Young & Lowry: A course in World Geography:
The World: A systematic Geography

- the crust (lithosphere) which is divided into upper and lower crust. It is the thinnest layer.
 - the mantle (mesosphere) which is divided into outer and inner mantle.
 - the core (barysphere) which is also divided into outer and inner core. It is the thickest layer.
3. It is made up of rocks (i.e. any material other than water that forms part of the earth's crust is referred to as rock). This may be clay, sand, basalt and granite etc.
4. Granite.
5. All the three layers are made up of rocks which differ in the minerals according to the layers and in the depth where they are found as follows:

Crust

- it is about 10 - 40 km thick and consists of two layers as follows:
- upper crust (Continental crust) which is predominantly made up of granitic rocks rich in Silica and aluminium (collectively called SIAL). This constitutes the bulk of continents.
- lower crust (Oceanic crust) which is predominantly made up of basaltic rocks rich in silica and magnesium (collectively called SIMA). This constitutes the ocean floor. This is much more uniform in composition than the continental crust.

Mantle

- it is about 2900 km thick.
- is composed of rocks that are rich in iron, magnesium and partially silica.
- the upper part of the mantle is structurally weak.

- this is because there is a balance of temperature and pressure and this makes the material assume a molten form.

- this molten material is the one that is responsible for occurrence of volcanoes.

- this upper part is referred to as the Asthenosphere.¹

- the lower part of the mantle is solid.

- by volume, the mantle has the largest area than the crust and the core.

Core

- it is about 3475 km thick.

- it is composed of rocks rich in iron and nickel. (Collectively referred to as NIFE²).

- the outer core is thought to be in a plastic condition like very thick and stiff clay which is heavily compressed to become liquid and hot to be solid.

- the inner core is thought to be solid. Both the inner and outer core have rocks that have magnetic properties, hence, it is the origin of the earth's magnetic field.

- temperatures are extremely high (more than 1,800°C and the rocks are dense because the compaction is great.(see explanation in question 11).

Note that exact depths or thickness of the three layers are not known. Figures given in some physical geography books as well as in this booklet are just approximate figures.

6. The rocks in the core have magnetic properties. Magnetism is generated from the rocks and produce lines of force that pass outward to the earth's surface as the magnetic field. A magnetic needle therefore orients itself in a position of rest parallel to the lines of force.

It should be noted that the direction where the magnetic needle points, is not always the same. It changes probably because the magnetic field is not regular (fixed) as the interior of the earth is not rigid or dead.

The changes indicate that it originates or is produced with the help of parts of the earth that are fluid (in this case the outer core). This is because if it were from a part which is absolutely solid then any of the changes would be accompanied by the shaking of the earth.

¹Asthenosphere is a molten or fluid layer in the upper mantle. Though it is in a fluid state, it does not mean that it is full of movement as fluid matter normally is. It flows gradually at the rate of about 2 cm to 20 cm a year.

²NIFE - This is from Nickel thus the Ni and Iron whose molecular formula is Fe.

7. It is the layer that has rocks rich in Iron which act as a conductor that facilitates the penetration of the lines of force to the surface.

8. Upper Layer

-this is discontinuous because it is not there over ocean basins.

- it is predominantly granitic with rocks rich in silica and aluminium.

- the rocks in this are brighter (light in colour)) and less dense (are not heavy) e.g. granite and sandstone.

- temperatures are lower than in the lower crust.

Lower Layer

- it is a continuous layer which extends below both continents and oceans.

- it has basaltic rocks that are rich in silica and magnesium.

- the rocks are denser and darker than those of the upper layer

- temperatures are higher than in the upper crust.

See fig 2 below showing a cross-section of the two layers

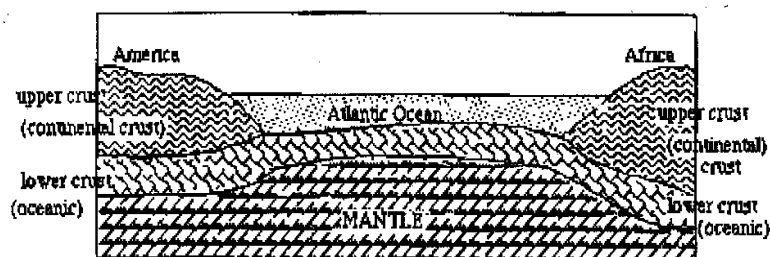


Fig 2 Cross section of the layers of the crust

9. It is covered by ocean/sea.
10. The crust and mantle are separated by a surface called the Moho discontinuity while the mantle and core are separated by the Gutenberg discontinuity.
11. The temperature gets higher i.e. 'about 12.5°C for every 1km of depth.'³
12. Because of the compaction⁴ of the rock material which generate heat. This heat becomes more as one goes deeper because the compression is even more due to a large mass of rock lying on top. Thus the more the mass on top, the more the compression and therefore the more the heat.

³Ortle & Cadice, Rocks and Minerals (1981) pg1

⁴Getting pressed together due to weight from the top.

Earth's surface

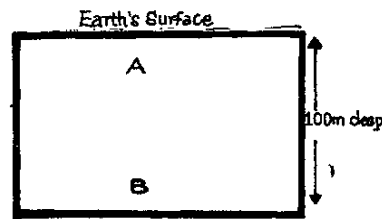


Fig 3 Cross section of a portion of the earth's crust

According to Fig. 3, the temperature at B will be higher than at A because there is more material on top of B than on A. Thus the more the overlying material the more the compaction and the higher the temperature (therefore more heat).

13. We know it through the following:

- through drillings that are made into the earth's crust e.g. mines, oil drilling, boreholes etc. Though the drillings haven't gone too far into the earth's crust, they have so far given some evidence on some of the aspects of the earth's interior.
- shock waves produced by earthquakes which are measured and analyzed by seismologists. They have deduced from their behaviour and have concluded that the earth has characteristics as described in the proceeding answers to the questions.
- volcanic eruptions also bring out material from the interior of the earth. These have been studied and conclusions made about the interior of the earth.

Earthquakes

14. What are earthquakes?
15. Explain the difference between a focus and an epicentre in an earthquake?
16. Why is the impact of an earthquake greater at the epicentre?
17. Is the impact of an earthquake always great at the point above the focus?
18. What are after shocks?
19. Explain how the shock waves of an earthquake move or are felt on the earth's surface?
20. Explain causes of the earthquakes?
21. How are earthquakes classified?
22. Which ones are the most dangerous?

23. Where are earthquakes measured?
24. Who measures the magnitude of earthquakes?
25. What do they use to measure the magnitude of the earthquake?
26. Suggest some of the hazardous effects of earthquakes?
27. Suggest measures that can be taken to avoid disastrous effects when earthquakes occur.

ANSWERS

14. They are shakings or vibrations of the ground that originate from a point known as a focus in the rocks of the earth. Slight ones or small scale shakings are known as Tremors.
15. Focus is the point in the interior of the earth where an earthquake originates while an epicentre is a point on the earth's surface which is directly above the focus and its where the impact of the earthquake is felt first and it is great.
16. This is because the epicentre is usually the point which is nearest the focus from the earth's surface (see fig 4). In the figure, B is nearer to the focus than A and C hence the impact will be more on B.

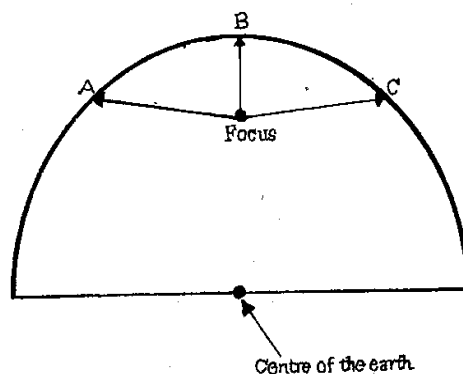


Fig 4 Showing how shock waves travel from the focus

Note that the focus should not in any case be confused with the centre of the earth. The focus is always well above the centre of the earth and near to the surface of the earth.

17. No, it's not always the case that the impact is great above the focus. Some times there could be a mountain above a focus and because of the mountain mass, the impact is minimal. In this case, the impact becomes greater far away from the focus where the mountain mass does not extend to.
18. Major earthquakes are usually followed by minor quakes and these are referred to as after shocks.

19. The movement of the vibrations (waves) of an earthquake can be equated to a gyre that is formed in water when a stone is dropped.

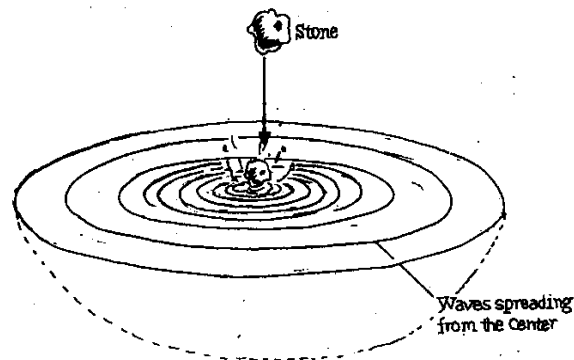


Fig 5 Basin of water

Note that the gyre is small and waves are near to each other where the stone has landed (which is like the Epicentre) and bigger away from the stone. Nearness denotes strong waves and those that are far apart denote weak waves thus where the earthquake dies down. In this case the impact would be more where the waves are strong.

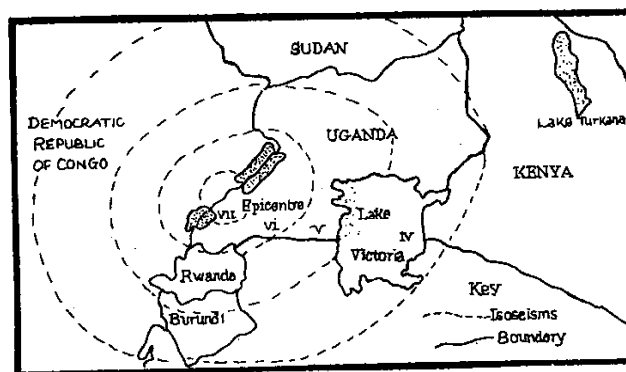


Fig 6 (Source: White R (1990) pg 23): Showing map of the area that was affected by an earthquake in Uganda in 1966.

The example used in Fig 5 can be supported by what happened in Uganda in 1966 on 20th March. The earthquake which shook Uganda on that day had serious effects. The map above helps us to understand the way it was felt. See the portions numbered in Roman numerals and match them with the explanations below.

"In zone iv, many people were woken up and a rumbling noise was heard. Some left their houses and experienced some difficulty in walking. Car burglar alarms were set off.

- ✓ In zone v, almost everybody was woken up. There was some panic and people left their houses. Noises were commonly reported in different ways as rumbling, roaring, bumping, humming, thunder or passing of a heavy lorry.

In zone vi panic was general and people rushed from their houses. Objects in houses were thrown to the floor and some window panes were broken. People shouted, children cried, and animals and birds shrieked.

In zone vii the shaking was violent and panic was widespread and noise was described as a loud roaring or resembling thunder. Most of the shops in Bundibugyo crumbled within three minutes though some collapsed in subsequent shocks...”⁵

From the above quotation, we can see that the shock is more near the epicentre just as the waves of the gyre are stronger near where the stone falls. Away from the epicentre the shock is weak just as the waves of the gyre are further away from where the stone fell.

20. - Earthquakes occur when rocks of the earth (bedrock) break due to some tension beyond their stretching limit⁶. As the rock breaks, it releases the energy that was stored in it which is then transmitted through the earth in form of vibrations.

It has to be noted that some breaks occur naturally while some are induced by human activities e.g. explosions. These also cause minor shakings of the earth especially in the areas around the occurrence.

- Volcanoes or earth movements e.g. folds or faults (these are discussed in the later pages). That is pressure or abrupt sliding from e.g. faults which may lead to part of the crust shaking.

- Extensive landslides may also produce shakings on a small scale.

Note that volcanic action is the commonest cause of earthquakes. These are caused by both extrusive and intrusive volcanoes.

21. They are classified according to the depth of their origin as follows:
- shallow earthquakes whose focal depth ranges from 0 - 70 Km.
 - intermediate earthquakes with a focal range of 70 - 300 Km.
 - deep earthquakes with a focal range of more than 300 Km.
22. The shallow ones. These cause alot of damage because they occur near to the earth's surface.
23. At seismographic stations.
24. Seismologists -these study the movement of waves through the earth.
25. The Ritcher scale to express the magnitude while a seismograph is used to record movement of earthquake waves.

⁵White R, Africa in focus, 1990, Pg. 23

⁶This refers to an extent beyond which something solid cannot withstand a force applied to it. If such happens something can break, explode or get deformed.

26 They are as follows:

- collapsing of buildings.
- powerlines may get mixed up and cause short circuits that often cause fire.
- they induce landslides when highlands e.g. hills, mountains are shaken.
- they cause large waves in the oceans called Tsunamis which sink ships and boats and cause damage to infrastructure along the coast.
- people may be killed. (Note that earthquakes do not kill people directly but through the above listed effects).
- they also make rivers to change their courses.

27. - Complying to warnings and orders by seismologists.

- Buildings should be erected away from vulnerable areas e.g. along faultlines or near dormant volcanoes (refer to life cycle of volcanoes in questions 38, 39, and 40).
- Buildings in areas that often experience them should be furnished with material that can absorb the shock of the earthquakes thereby sparing them from collapsing.
- Or buildings should be made of material that cannot easily get disintegrated e.g. wooden materials, plastic or fiberglass, or those that can absorb the shock from the earthquake.

Formation of rocks and other associated features

28. Which are the three types of rocks?

29. In what ways do rocks differ in general?

Answers

28. - Igneous.

- Sedimentary.

- Metamorphic.

29. They differ in the following ways:

- the degree of roughness or smoothness (whether their particles are coarse or fine).
- the way the particles are put together to form the rock (structure).
- how each was formed.

- how resistant the rock is to denudation and chemical action.
- their permeability (easiness to penetration by water).

Igneous

30. How are Igneous rocks formed?
31. What is magma?
32. When magma erupts, does it end up forming one type of rock?
33. How does lava differ from magma?
34. Where does magma originate from?
35. What is a volcanic eruption?
36. Through what does the magma come out?
37. Can volcanoes be predicted?
38. Describe the conditions that precede a volcanic eruption?
39. Mention the different stages of a volcano's life cycle.
40. Describe the volcanoes according to the stages of their life cycle.
41. Why is a dormant volcano regarded as the most dangerous?
42. How are Igneous rocks classified?
43. Which are the types of igneous rocks?
44. Explain the differences between volcanic and plutonic igneous rocks?
45. What are the characteristics of Igneous rocks?
46. Give some examples of igneous rocks.
47. What does texture of a rock mean?
48. How are igneous rocks classified according to texture?
49. What is the importance of texture in a rock?

Answers

30. They are formed by the cooling and crystallization of liquid rock material (lava) that comes out of the earth's crust due to intense heat and pressure; or the cooling and crystallisation of liquid rock material (magma) within the crust.
31. It is a term from a Greek word that means a thick porridge-like stuff. It refers to any hot molten material that is capable of moving inside the earth and has the potential to penetrate through weaknesses in the rocks of the crust.
32. This depends upon the origin of the magma, the minerals in the magma, etc. This means that if there were different minerals with different structures and the cooling of the magma with the various minerals is different, a single magma could produce different types of rocks.
33. Lava is molten rock material that has come out of the crust while magma is molten rock material inside the earth's crust.
34. It originates from the melting of the rocks in the lower ends of the crust and upper end of the mantle at depth usually between about 50-200 km below the surface of the earth.
35. This is when magma is forced out of the crust by the pressure generated due to intense heat. Apart from magma, some material come out in the form of broken solid fragments.
36. Through a vent or fissure (a vent is a hole or pipe-like feature and a fissure is a crack in the rocks of the crust).

Fissures are formed when tensional forces cause rocks to split and move apart without sliding.
37. It is difficult to predict volcanoes but scientists have done this by developing some warning systems. These detect possible volcanoes. They also look at possible conditions that precede volcanoes.
38. - Before the eruption minor earthquakes or tremors occur. These occur because of the magma beneath that tries to force its way out.

- Temperature within the surrounding area rises because the hot magma gets nearer to the surface hence the heat is emitted to the surface.

- Finally clouds of gas start coming out from the vent or fissure. This is a sign that the molten material is about to come out.
39. Active stage (Active volcano).

Dormant stage (Dormant volcano).

Dead or extinct stage (Dead or Extinct volcano).

40. Active volcanoes - they are those that are known to erupt frequently and are expected to erupt any time. Examples are Stromboli (Italy), Asama (Japan), Nyiragongo and Nyamulagira (Democratic Republic of Congo), Erte Ale (Ethiopia).

Dormant volcanoes - they are those that have not erupted in recent time but could erupt any time. Examples are Lassen Peak (California), Paricutin (Mexico).

Dead or Extinct volcanoes - those that stopped or ceased to erupt. They may have features associated with volcanoes but never erupt. Examples are: mount Kenya and mount Elgon.

41. - Cones⁷ from old lava may be blown violently and cause enormous damage if the volcano erupts again.

- Due to the long time they take to erupt again, people forget about them and live close to them, hence, their lives are at risk.

42. They are classified according to the texture and composition i.e. the nature and origin of the constituent material of the rock (origin and nature of magma)

43. Volcanic (extrusive igneous rocks)

Plutonic (intrusive Igneous rocks)

44. • Volcanic (extrusive)

- formed from molten rock material that has cooled outside the earth's surface

- they have small particles because they cool fast

- they are lighter in colour and some have a glassy appearance e.g. Obsidian, Quartz.

- others have spongy looks⁸ because of gases that were inside the molten material during cooling e.g. Pumice

- they are less dense

• Plutonic (intrusive)

- formed from material that has cooled inside the earth's crust

- they have large particles because they cool slowly

- they are denser than volcanic ones

⁷Top part of a volcano which has the shape of a cone. It is made up of a mixture of lava and fragments of rocks from the crust.

⁸Such looks come about just like the spaces that are created inside bread due to expansion caused by yeast.

- they are dark in colour
 - tongues of these rocks fill fractures in surrounding rocks which suggest that they were once in molten form
 - they are only seen after being exposed by erosion, or being pushed up by faulting or folding. Examples are: Granite, Gabbro, Diabase •
45. • They are crystalline⁹.
- They do not contain fossils
 - They are not laid down in layers
 - They contain vesicles¹⁰ if the lava had gases or bubbles in it during cooling.
46. • Basalt • Granite • Gabbro
- Diorite • Andesite • Rhyolite
- Syenite • Obsidian • Pumice
- Diabase • Tuff • Peridotite
47. It refers to the size, shape and arrangement of mineral grains of the rock.
48. • Fine grained ones are the volcanic igneous rocks i.e, those that have cooled on the surface of the earth.
- Coarse grained ones are the plutonic igneous rocks i.e, those that have cooled deep within the earth.
49. • It provides some record of the energy involved in the rock forming process and the conditions that existed at the time the rock originated.
- It also determines the strength of the rock.i.e, resistance of the rock to weathering.

Characteristics of volcanoes and their associated features

50. Explain the difference between Acidic lava and Basic lava?
51. Mention the features that result from eruption of different types of lava and their characteristics

⁹Made up of crystals. Crystals are the tiny individual particles that together make up a rock.

¹⁰Openings or holes in a rock.

52. Explain the importance of some of the features produced by volcanoes.

Answers

50. • Acidic

- it is very thick and viscous¹¹ because magma that formed them had a high boiling point
- they are rich in silica¹²
- small amounts of it hardly flow but form domes on the upper end of vents.
- a lot of pressure builds up in them due to gases that fail to escape, hence, are highly explosive and violent when they erupt
- they produce fine dust, ash and fragments of rocks.
- these produce rocks that are less dense and are lighter in colour.

• Basic

- they are fluid because the magma that formed them had a low boiling point
- they are poor in silica
- they flow freely for long distances and at times continuously for sometime
- they do not explode violently as is the case with acidic ones.
- basic lava produce rocks that are denser and are darker in colour.

51. • Features formed from Acidic lava and their characteristics

1. Ash/Cinder Cones

- they result from small volcanoes (minor eruptions).
- they form from dust, ash and fragments (cinders) that accumulate after an explosion and form a small -hill like structure (cone)
- the cones so formed are relatively small (rarely exceeding 200m in height and about 2.5 km in diameter).
- the slopes of the cones are steep such that wind easily erode the dust that accumulates

¹¹Showing signs of resistance to flow because the material is stickier.

¹²Most abundant mineral in the earth's crust and this also determines the acidity of rocks.

-the other materials that form these are loose that rain water permeates without eroding them for sometime.

Examples of such features are: Likaiyu and Teleki (Kenya), Monte Nuovo (Naples, Italy) Paricutin(Mexico),Volcano de Fuego(Guatemala), Jos Plateau(Nigeria).

2. **Composite Cones** (These are also referred to as strato-volcanoes)

-they are formed from big volcanoes

-eruptions of these are accompanied by steam, small rock fragments (cinders), very big rocks (bombs), ash and lava flows

-sometimes they are built of layers of ash and lava i.e. one on top of the other.

-generally they are high and steep sided.

Examples are: mount Kilimanjaro (Tanzania), mount Kenya (Kenya), mount Fujiyama (Japan) and mount Cameron(Cameroun), Mayon(Phillipines), mount St Hellen , (Washington, U.S.A.).

- Features formed from basic lava and their characteristics

Lava domes/Shield volcanoes

- these are formed from lava that flow without an explosion and is fluid (less viscous see footnote 11)

- they are formed from lava issuing from extensive cracks (fissure)

- the lava spreads extensively and form gentle domes which after a long period of denudation become shields. (refer to Q53 e.g. Mauna Loa -Mauna Kea (Hawaii))

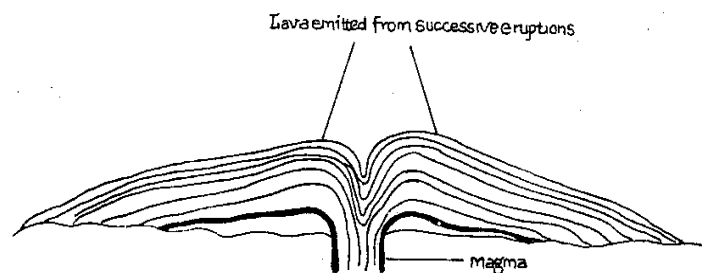


Fig. 7: Showing a shield volcano

Lava Plateaus

- these are formed from lava that comes out from a number of fissures spread over an extensive area

-they are rocky, high and steep with fairly flat tops

-the lava that forms them is of high fluidity (or low viscosity)

Examples are: Deccan Plateau (India), Ethiopian plateau(Ethiopia), Columbian Plateau(USA), Biu Plateau(Nigeria).

Lava Plains

-these are flat areas covered by spilt and flowing lava (usually its basic lava that forms this) e.g. Snake basin (USA).

52. **Lava Plateaus**

- they give rise to important rivers that flow with speed and ideal for Hydro-electric power generation.

- their tops are sometimes ideal for forestry.

- others contain valuable minerals e.g. bauxite

Composite cones

-they also give rise to important rivers mostly from the ice that accumulate on their tops e.g. mount Kenya and Kilimanjaro. Such rivers e.g. Pangani river (Tanzania) whose source is on mount Kilimanjaro is used for irrigation and H.E.P.

-their slopes offer a wide range of areas suited to many crops e.g.bananas, coffee, and tea.

-because of the cool climate associated with such highland areas dairy and beef cattle rearing is also ideal on their slopes.

Extract 1

53. Read extract 1 and answer the questions that follow

"It was at 6.23 am on Saturday when a deafening booming sound was heard from the eastern part of Pwilit area. Later some smoke/gases could be seen floating in the atmosphere. After sometime news spread around that a red-hot-porridge-like stuff had come out of the earth's surface in the area and buried houses, crops and people alive.

Many people in as far as 50 km away heard the sound and some shaking of the earth was felt but could not know what was happening. It was then at 12.30 pm when they heard on the radio that Pwilit had been declared a disaster area and that....."

- a From the passage what do you think had happened in Pwilit area?
- b What might have caused the sound that was heard?
- c What was the red-hot-porridge-like stuff that came out?
- d Mention four effects of the event.
- e What geographical features would most likely form as a result of this?
- f Give two reasons for your answer in (e).
- g What advice would you give to the survivors of the disaster?

54. What is a shield?
55. Describe the areas in which shields are commonly found.
56. Describe the shields.
57. What features covered areas that today are shields.
58. Give some examples of shields
59. What is a Caldera?
60. How is a caldera formed?
61. How are Calderas important?
62. How do crater lakes develop?
63. Explain the good and bad social, economic and environmental effects of volcanoes?
64. How are intrusions of magma classified?
65. With the aid of diagrams, explain some of the features that are formed due to the intrusion of magma.
66. How are Igneous rocks important?
67. How have the high temperatures below the earth's surface affected hydrology?
68. What is the difference between a geyser and a hot spring?

Answers

54. It is a large area of very ancient¹³ (very old) rocks. The rocks are usually igneous and metamorphic which have been exposed. These have reached an extent where they have become resistant to erosion. This is so because of a long period of undergoing weathering and erosion.
55. They are found in areas that have for long been undisturbed (in terms of earth movements) except by erosion for most part of the geological time.
56.
 - They are extensive, low and relatively flat
 - The features found in them are a few meters high (this is because of prolonged denudation).

¹³Over 100 million years ago.

- They are composed of a complex mixture of metamorphic and igneous rocks (with granite as the dominant rock)
 - It should be noted that shields also contain sedimentary rocks but they are those that have undergone folding, faulting or peneplanation¹⁴, as such, they are able to resist forces like denudation.
57. Originally these areas or regions may have been covered by mountain ranges or have been high plateaus. This is so because it has taken millions of years of wearing out.
58. Laurentian, Deccan, Siberian, African, Baltic, Arabian.
59. It is a depression that forms on the upper part of a pre-existing volcano. It is formed either by the top of the already existing cone getting blown off or rocks that formed the pre-existing volcano are broken down and become part of the volcano (see fig 8a, 8b and 8c)

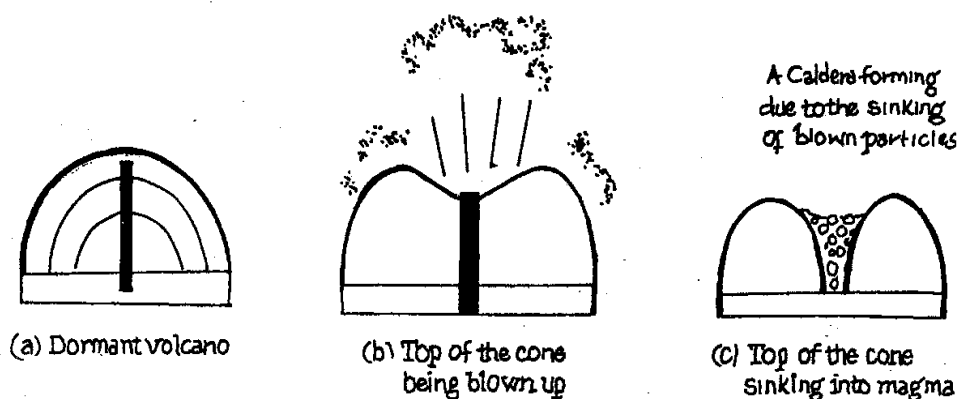


Fig. 8: Formation of a Caldera
Source: White R. (1990)

60. • When a volcano erupts violently thereby blowing off the upper portion of it (see fig 8b and answer to Q59)
- Through subsidence (collapsing of materials) within the bottom of a volcano, due to inadequate supply of magma from beneath to make it explode. The weight of the upper part of the cone so formed may result into it collapsing into the magma that is failing to reach the surface thereby forming a depression (see fig. 8c).

¹⁴This means the surface has been worn down to the level of almost a plain.

- Sometimes if the weight of a cone, hill, or any other protruding feature is more than the bottom or the root of the highland, the upper part may depress and form a caldera. The weaker bottom part can be made of such material as ash or magma. Such occurrences happen suddenly e. g. by being shaken by an earthquake.
61. Some have become sites for lakes (crater lakes) which have been useful to people e.g. Ngorongoro, L. Ngozi (Tanzania) , L. Shaka (Ethiopia), L. Toba(Sumatra), Oregon crater lake (U.S.A)
 62. They develop when calderas of dead volcanoes get filled up with water.
 63. Death of people from gases that suffocate them, lava flows that burn and bury them, being hit by cinders or bombs and from violent earthquakes that result from the eruption.

Bad effects

- Destruction of villages, towns and cities
- Seawaves (Tsunamis) resulting from eruption within the seas that dangerously affect coastal areas(coastal areas get flooded/ submerged).
- Volcanic surfaces usually become agriculturally unproductive for sometime.

Good effects

- Small amounts of ash falls may have positive effect over unfertile soils (i.e may change them to become fertile).
 - Volcanoes result in beautiful scenic features that attract tourists. e.g. Mt. Kenya and Kili-manjaro with snow covered tops.
 - Other volcanoes bring about new minerals that are of economic value e.g. diamond.
 - Crater lakes formed by volcanic explosions may be beneficial to people.
 - Some volcanic areas produce Geothermal¹⁵ steam which is used for heating domestically and in industries e.g, geothermal energy is used to produce electricity in Mexico, New Zealand, U.S.A
 - They produce volcanic hot springs from which people get hot water e.g, in Iceland they use water from hot springs to heat homes.
 - Volcanoes also serve as 'means' to the earths' interior i.e.the material they erupt help scientists learn about conditions within the earth.
64. They are classified according to their size, shapes, and relationship to the older rocks that surround them.

¹⁵Energy derived from the interior of the earth due to high temperatures.

65. • Dyke

- formed when magma is squeezed into vertical or slanting fractures
- in some rocks, magma has been forced into circular or oval fractures forming ring dykes.
- dykes are young in age than the rock they have invaded
- they change or alter the rocks they invade or those that are next to them (see fig 9)

Examples: the Kelang Gates Ridge (Kuala Lumpur), Arran (Scotland), Ship rock(Mexico)

• Sills

- they are formed when magma is injected into the bedding planes of sedimentary rocks
 - they form parallel to the rock strata (layers)
 - the intrusions alter the rocks on the upper and lower ends.
 - they sometimes form from diversions of dykes (see fig 9 - note the connection of A and B)
- e.g Palisade sill (U.S.A), Great Whin sill (England)

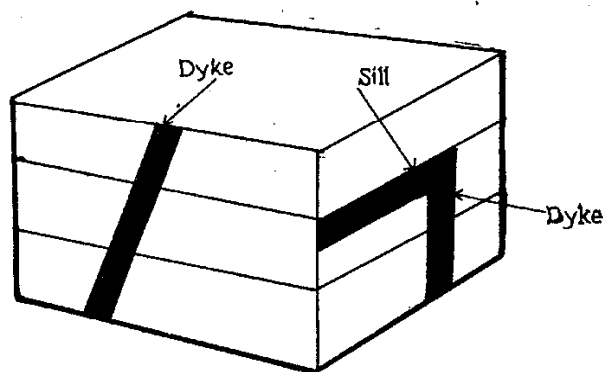


Fig 9: Small intrusive features formed by magma

• Laccoliths

- these are formed by thick magma which when injected between layers of sedimentary strata, pushes (arches) up the overlying strata.
- they have a mushroom shape (the arched top being the magma that pushed the strata and the pipe-like structure being the opening through which the magma passed). see fig 10
- the texture of the laccolith is usually not uniform.

- It may indicate slow cooling which result in large crystals and rapid cooling which result in small crystals. E.g Navajo mountain (Utah).

- Batholiths

- they are the largest rock masses in the earth's crust.

- they may be formed by one or more intrusions of magma but with similar composition.

- they cover a very wide area e.g. Chinamora batholith in Zimbabwe (about 1,600 km²), Nyika Granite (about 2,500 km²) in Malawi. Maragoli batholith in Kenya.

- the intrusions that form them absorb or engulf surrounding rocks.

- some have formed below mountains and have become roots of mountains.

- they only get exposed due to erosion and once exposed they may form plateaus with steep edges e.g. Dartmoor (England)

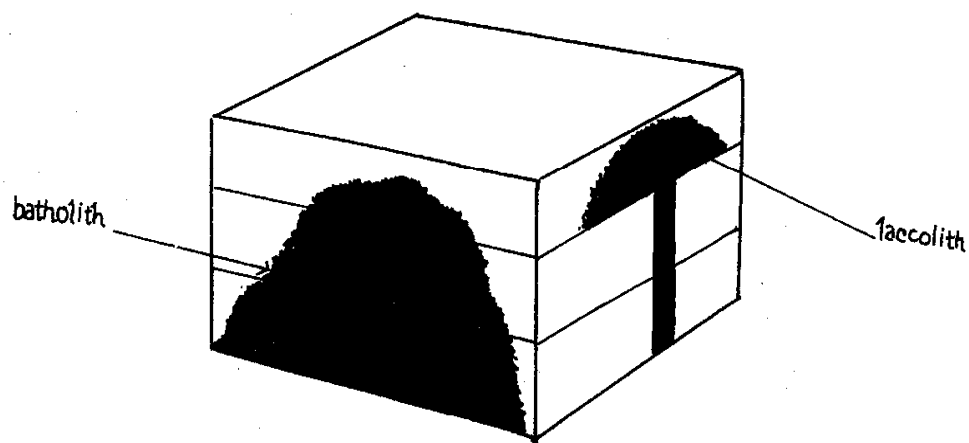


Fig 10: Major intrusive features formed by magma

It should be noted that these intrusive features are found in most places in Malawi. You can try to identify these within your area.

- 66.
- Can be used to construct roads e.g. granite for making bridge pillars.
 - Some contain valuable minerals e.g. copper, iron.
 - They help in holding loose earthy material which would otherwise be prone to environmental hazards. e.g. landslides, erosion.
 - Making jewellery e.g. from obsidian

- Some polish making e.g. polish from pumice powder.
67. They have led to the occurrence of geysers and hot springs.
 68.
 - A geyser is a spring of hot water and steam¹⁶ that comes out (at regular or irregular intervals) with great force when water has been heated above its boiling point due to increase in temperature and pressure. (This normally happens in a volcanic region)
 - Hot spring is a fountain of hot water that has been heated below the boiling point and comes out without a force. These are found where water sinks deeper into the crust and get heated by the intense heat below.e.g, hot springs at Mawira in Nkhotakota.

Sedimentary rocks

69. What are sedimentary rocks?
70. How are sedimentary rocks formed?
71. Explain how the rock particles get cemented together to form sedimentary rocks.
72. From where do the sediments derive?
73. Where are sedimentary rocks commonly formed?
74. How are sediments classified?
75. How are sediments graded according to particle size?
76. What's the relationship between size of sediments and the formation of strata?
77. What can we learn from a variety of sediments in the rock layers that form different sedimentary rocks?
78. What is the environmental importance of sediments?
79. What are the characteristics of sedimentary rocks?
80. Identify the different types of sedimentary rocks?
81. With examples, explain how each type of the rock in (80) was formed.
82. Why are animal fossils more plentiful than plant fossils?
83. Some fossils are found in unexpected places e.g, fossils of fish in the rocks of

¹⁶Hot boiling water and steam jets may be signs that there is hot magma not very far below the surface of the earth.

mountains located so many hundreds of kilometres from the ocean. How does this happen?

84. Are all sedimentary rocks formed far away from their source rocks?
85. Both olifers and aquifers are rocks - what's their difference?
86. What is the geographical significance of the chemically formed sedimentary rocks?
87. Give some examples of the way sedimentary rocks are stratified or bedded.
88. When were the sedimentary rocks formed?
89. State some of the uses of sedimentary rocks?

Answers

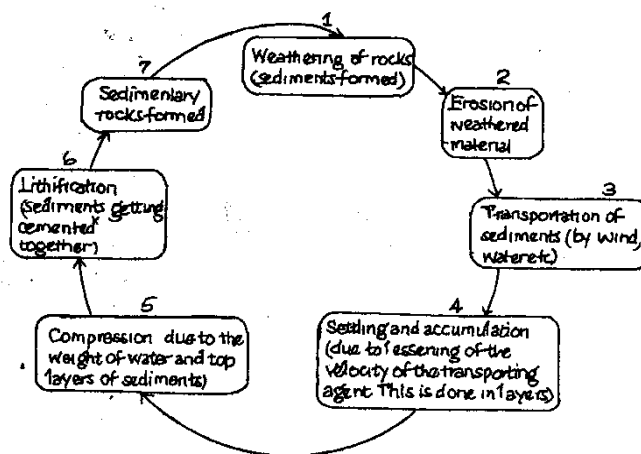
69. They are rocks that originate from other rocks through sediments that come from the breaking of other rocks e.g. Igneous rocks.
70. They are formed from sediments¹⁷ that are transported and accumulate below water bodies or at any calm (undisturbed) place then become compressed to form layers of sedimentary rocks.

OR

- They are formed from particles derived from previously existing rocks which are laid down after transportation by rivers, waves, wind, and ice.

It should be noted that the process is continuous because the breakup of one set of rocks provide materials for the formation of another set.

The process can be summarised as follows:



¹⁷Broken pieces of rocks

71. By among other ways the following:

- Clay and other tiny particles such as silt may help in having the particles come together and build up a single entity.
- Chemicals or chemical action cement them together through chemical bonding.

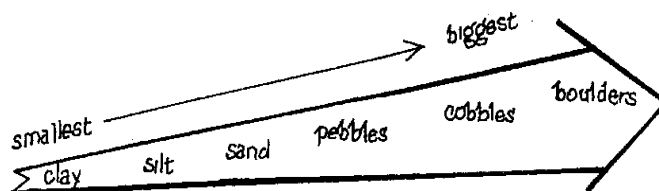
72. • From any type of rock including other sedimentary rocks (these are referred to as Clastic sediments¹⁸)

- From organic material and chemical precipitates such as salts in saline lakes (these are referred to as non-clastic sediments).

73. They are commonly formed in calm waters e.g. in swamps, lakes, seas (but there are some that are formed on land).

74. According to mineral composition and particle size

75. They are graded as follows (*see illustration below*)



76. Sediments (particle) size determines the ease of transportation and the layering. i.e. small ones are easily transported and coarser ones tend to settle at the bottom.

77. • Strata tell us more about climatic conditions that prevailed when sediments were being laid down

e.g. -mudstones reflect formation in a wet climate.

- rock salt gives evidence of too much heat and evaporation.

- coal seams indicate that they were formed in tropical rain forest climatic areas.

- Arrangement of particles may also reveal the orientation of e.g. coastlines where they were accumulated or the direction of movement of the transporting agent.

- One can also determine the transportation agent e.g. if particles are very small e.g. Loess one can easily tell that wind was the transporting agent, and if they are big e.g. boulders, one would know that wind cannot transport this but water or glaciers.

¹⁸Those that are formed from particles of other rocks.

Examples: Coal (from plants)

Chalk, Coral, Shale (from animals)

- Chemically formed - some salts may accumulate in water after evaporation in saline lakes. Such masses of salts get compacted and cemented and form a rock.

Examples: Gypsum, Rocksalt, Dolomite

82. • When a living thing dies, the soft fleshy parts usually decay quickly and the hard structures remain. Plants don't contain the hard structures (bones) as the animals hence are scarce.

It should be noted that the chances of an animal or plant to become a fossil are very rare. Only a small fraction of all the once living things have become fossils. This is because most of them have been attacked by bacteria, scavengers, or by natural chemical changes that make them to decay.

83. Such are fossils that were buried in sediments that accumulated in the ocean and later the sedimentary rocks so formed got uplifted during the fold mountain building period. Because of the uplift of the land, the sea water moved away or further off to some distance from the mountains that formed.(see on how fold mountains are formed)
84. • Not all are transported for long distances. For example; Conglomerate are developed in areas close to their source rocks because:
- they are formed from large particles which would be difficult to be moved by agents for a long distance.
85. Oilifers are rocks that hold oil in their spaces while aquifers are those that hold water in their spaces.
86. Since evaporites accumulate in specific areas/basins due to prolonged evaporation, they give clues of ancient climatic and other conditions that prevailed (refer to answer to question 77.)
87. Cross bedding -this is when sediments form ripples or dunes (sandwaves). As they migrate up and over the sand wave they accumulate by getting down slope.The steep slope so formed is therefore in inclined layers (see fig 12)

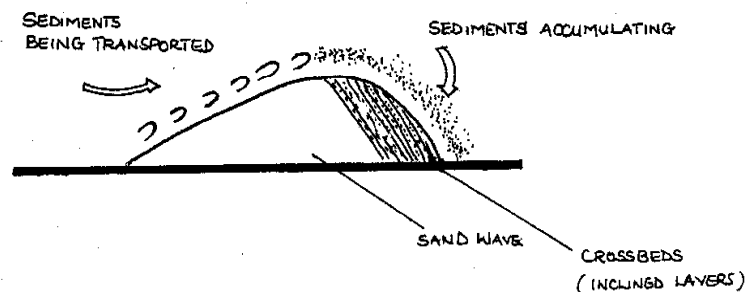


Fig 12: Cross bedding

- Graded bedding -in this, sediments are layered by progressively decreasing in grain size in an upward direction (see fig 13)



Fig 13: Graded bedding

88. The process that formed the sedimentary rocks began several millions of years ago and they are still going on today. The process takes a long period of time (as long as the processes e.g. deposition and accumulation are not disturbed by other forces).
89.
 - They are used for building purposes e.g. limestone is crushed and made into cement, dolomitic limestone for the manufacture of lime and vim.
 - Other organically formed sedimentary rocks are used for the manufacture of fertiliser.
 - They contain hydrocarbons that are sources of power e.g. petroleum and coal.
 - Other chemically formed rocks e.g. salts are used for improving the taste of foods and others e.g. gypsum is used in the manufacture of cement as a drying or hardening agent.

Metamorphic rocks

90. From where do metamorphic rocks originate?
91. How do the existing rocks become metamorphic rocks?
92. Describe some of the notable changes that occur when a rock has been metamorphosed?
93. Which are some examples of metamorphic rocks and their original form?
94. Explain the difference between contact and regional metamorphism?
95. Under what conditions is metamorphism likely to take place?
96. Give examples of the areas where one is likely to find metamorphic rocks.
97. What are some of the uses of metamorphic rocks?
98. What is the relationship between/among the three types of rocks(i.e. Igneous, Sedimentary and Metamorphic)?
99. How do rocks influence the landscape of an area?

100. Suppose you were a member of an oil prospecting team and you visited areas with the following rocks, sandstone, granite and gneiss.
- (a) Which area would you hope to find oil
 - (b) Why have you mentioned the area in (a)
 - (c) Give reasons why you think the other areas would not be ideal for oil drilling
 - (d) To what use would the rocks in the areas which cannot have oil be put?
101. Some rocks, be it igneous, sedimentary or metamorphic contain mineral deposits. Identify some mineral deposits in Malawi, where they are found and their uses.
102. How are relative/comparative ages of rocks (or features) determined?
103. How then are ages of rocks determined?

Answers

90. From other existing rocks i.e. Igneous, sedimentary and even preexisting metamorphic rocks.
91. They change in the nature of the original rock (i.e. its mineral composition, texture and structure) when subjected to environments or conditions that are different from those in which they were formed by any of the following:
- by compression from the weight of overlying rocks
 - movements inside the earth's crust i.e. colliding of tectonic plates.
 - by heat from pressure within the crust or nearness to flows of igneous rocks.
 - by chemical action. This may be due to gases or water containing other minerals that change the form of the rocks.
92. • Layers of the rocks are modified or disappear completely
- Fossils get obliterated²¹ completely
 - Vesicles in a rock disappear completely
 - Rock particles are squeezed together making them to have new shapes e.g. elongated shapes from rounded ones.

²¹Signs of presence of fossils disappear as they get assimilated to the rock they were in due to metamorphism.

- Rocks become hard and denser than before

Note that new minerals are also formed but this is difficult to be noticed.

93. • Clay to Slate • Coal to Graphite
- Granite to Gneiss • Limestone to Marble
- Sandstone to Quartzite • Shale to Hornfels
- Conglomerate to Metaconglomerate • Basalt to Amphibolite
94. Contact metamorphism is when rocks within a small area under the prevailing conditions have been changed e.g. when magma/lava intrudes or spills over other rocks and change them (see Fig 14).

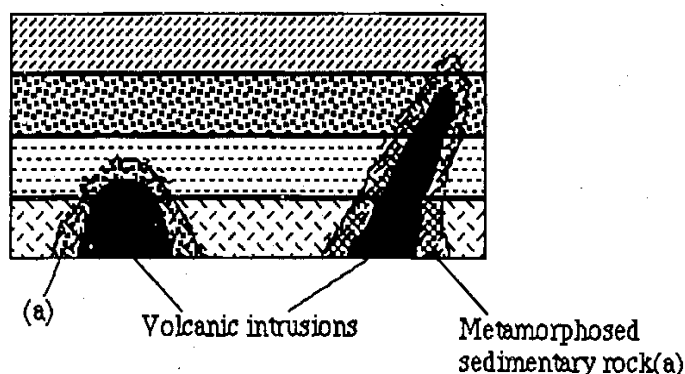


Fig 14: Metamorphism in sedimentary rock

- Regional metamorphism is when rocks along an entire margin of a continent have been modified e.g. colliding of tectonic plates²² change rocks along the parallel of the collision.

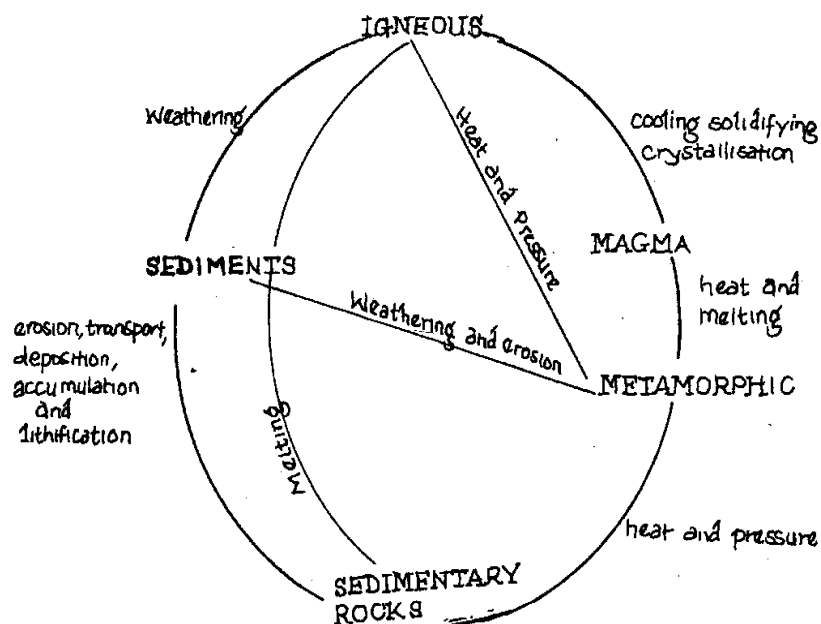
It should be pointed out here that when or where metamorphism of rocks has gone beyond its limit e.g. where a whole mass of rock gets completely melted - such an extreme case is referred to as ultrametamorphism. Such a process results into an absolutely new magma getting formed. In this case the resulting rock from this magma cannot be classified as metamorphic but as an igneous rock. This explains how other rocks like sedimentary or metamorphic are turned into igneous rocks.

95. Though metamorphism is a complex process, it may be strongly influenced by the following:
- the presence or absence of fluids in the rocks.

²²A portion of the lithosphere that float on the asthenosphere.

- the time taken to have the rock heated
 - the length of time and amount of pressure that is there.
96. • Shields
- Eroded mountain ranges.
 - Volcanic areas and zones of collision of plates.
97. • Some are used as building stones e.g. marble is used to erect statues because of its colour and hardness.
- Some are used as material for roofing e.g. slate
 - As raw material for manufacturing pencils i.e. graphite from which the middle material of a pencil is derived.
98. The rocks originate from each other i.e. both igneous and metamorphic may originate from sedimentary, and sedimentary and metamorphic from igneous. Igneous and sedimentary may also originate from metamorphic rocks.

This can be easily explained by the rock cycle as illustrated below.



Note that the formation of rocks according to the rock cycle can start anywhere. There is neither a point where exactly a rock starts to form nor is where it stops forming; it is an endless process.

99. • The landscape of an area is influenced by the strength of the rocks that form it as follow
- strong rocks that are resistant to denudation form highlands or shields.
 - weak rocks form low land and valleys because they are easily weathered and eroded.
 - the eroded material i.e. sediments form flat areas.

101

Mineral Deposit	Type of Rock	Where its found in Malawi	Uses
Limestone	Sedimentary	Changalume	-production of cement -improving the condition of the soil
Dolomite mable	Metamorphic	Matope, Lirangwe Balaka, and Ntcheu	-production of lime
Coal	Sedimentary	Sumbu-Nkombezi area, Chiromo, Livingstonia (Kaziwiziwi)	-Source of power
Bauxite	Igneous and Metamorphic	Mulanje Mountain	-production of alluminium

102. In determining the ages of rocks, relative dating is used whereby chronological order of events is used to establish the approximate age. Several principles (methods) are used to achieve this as follows:

• Principle of superposition

- this looks at the layout of undisturbed sedimentary rocks. i.e. the oldest layers are on the bottom and the youngest are on top. This principle assumes that sediments that formed the layers were deposited in a horizontal manner and that the rocks have not been disturbed to an extent of having the layers put upside down.

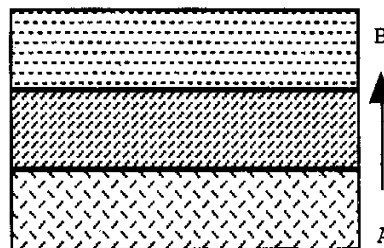


Fig15: Showing layers of a Sedimentary rock

In the above (fig15), the layer A was the first to be formed and the rest of the layers up to B formed later. This then means layer A is older than the rest

- Principle of cross-cutting relations

- in the rocks, new features or occurrences e.g. faults or igneous intrusions are younger than the rocks they cut or they intrude e.g. dykes, sills, laccoliths are younger than the rocks they intrude or cut across.

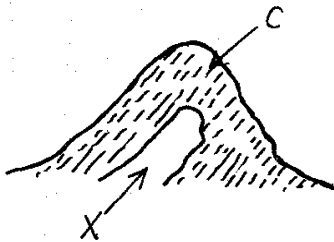


Fig 16a Joint in a rock

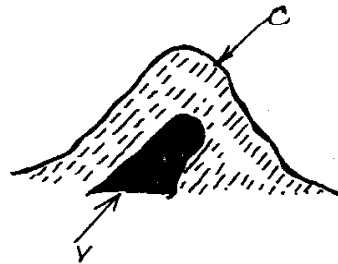


Fig 16b Joint intruded by magma

In fig 16a the rock has a joint X and this has later been filled by intruding magma as in fig 16b. In this case Y is younger than the whole rock C because it formed at a later date.

- Principle of succession in landscape development

- this looks at the original looks of certain features when they have just been formed and the way they look after many years of existence. e.g. Young fold mountains are high while old fold mountains are low because they have undergone certain processes for a long time which the young fold mountains have not. Therefore such processes tell us about the series of stages having been undergone which help in determining the relative age of the features and their associated rocks.

- Principle of faunal²³ succession.

- this works on the fact that certain animal species have existed at different periods of time and that their fossil remains would be found in the different rocks according to when they (rocks) were formed. To understand this simply, we could use the example of the way iron age people used to bury the dead.

²³A collective term that refers to animals.

Let's assume that some people in Malawi were being buried together with their belongings and that dates of their burials were not indicated. (In this case, the grave will stand for rocks and material remains will stand for fossils). It would be found out for example that those buried in the 1950s would mostly have no remains of radios, no watches, no stereos, videos because then it was difficult to have them. Those buried in the 60s would probably have some remains of radios (transistor radios), watches (zobo watches), gramophones, no videos. For the 70s radios would have changed to phillips, watches to Oris, Timex, gramophones to record players, a few videos. Come the 80s and 90s radios would be sony, hitachi watches (citizen, seiko), stereos instead of record players and some graves with remains of videos with new developments e.g. remote control gadgets²⁴.

From the above example one would easily tell the different times by associating with what was in fashion then. If these graves were rocks we would think in terms of those without radios, watches, gramophones. to be older because they were buried when the materials were scarce in the earlier years. Those with latest models of watches, radios and videos with remote controls would be young because they contain material of a later age. Those in between the old and the young ages would be considered to be of intermediate age. It should be noted that the above methods do not give the exact ages of rocks

103. • Radioactive dating which is based on the measurement on the uniform decay rate of radioactive elements in the rocks e.g, Potassium, Uranium.
- Carbon dating is another method which looks at the rate of decay of carbon.

CHAPTER 2

Theory of plate tectonics

Almost everyone has at one time or the other thought that the earth's crust (especially the land and not sea) is just a rigid mass of matter that is absolutely dead. However, advancement in age has seen us experience certain occurrences e.g. earthquakes/tremors, flash floods or we have come across features that we have probably failed to understand how they occur or how they were formed. To many, mountains, and valleys are features that were already made during creation.

This chapter therefore will try to help us understand how some of the features we see were formed. The chapter opens up with questions on a theory that forms a basis of understanding the earth and the forces that have shaped it.

1. What does tectonic activity mean?
2. What are plates?
3. Explain the theory of plate tectonics (of continental drifting),
4. Explain the cause of the disintegration of Pangea.
5. If the movement of the molten material that led to the splitting of the earth is slow, how did this lead to earth drifting as shown by the plates today?
6. How do the movements in the asthenosphere affect movement of plates?
7. Do the plates cover the whole earth?
8. Are all the plates entirely covered by the continents?
9. The plates cover the whole earth, how do they move when the whole earth is covered by them? To where do they move?
10. What name is given to points where the plates collide each other?
11. Explain the different kinds of plate boundaries and how these help to explain the theory of earth drifting?
12. Mention some features or processes associated with each type of boundary
13. Volcanoes are associated with plate boundaries. Are all volcanoes found along plate boundaries?
14. How do those not along the plate boundaries occur?
15. Give examples of volcanic islands that have been formed at an extension boundary (constructive margin)

17. Describe some of the movements within the different boundaries and give examples of features or processes going on along the boundaries.
18. Give evidence to support the theory of plate tectonics.
19. How does the theory help us?
20. Explain the geological difference between the area of the plates themselves and the areas where they meet/separate (converge or diverge)?
21. How do the plates move?
22. Describe major geological processes or features that occur or are formed where there is movement of the plates?
23. What else happens when the plates collide, diverge or slip past each other apart from those mentioned in Q 22.

Answers

1. It means the breaking and bending (deforming) of rocks in the earth's crust due to different forces that depend upon the condition in which the rocks are subjected to.
2. These are portions of the crust (lithosphere) that float on molten underlying material (the Asthenosphere ref. to foot note 1) and move when tectonic forces make them to.
3. This theory suggests that the earth was at first one land mass and was named Pangea²⁵. This later got disintegrated and formed bits of landmasses that we know today as continents.
4. Among the many thought-to-be-causes, heat melted rocks below the crust and radio activity²⁶ created slow moving convection currents which caused the plates to move literally. The above is thought in terms of convection currents within the fluid/molten layer (asthenosphere) that created slow moving convection currents that caused the plates to move. Such convectional currents can be likened to the behaviour of water when its heated in a container see fig 17. The point at which the water is going in different directions can be likened to the point where plates began to break away.

²⁵The word means all lands.

²⁶Production of force or movement by the breaking up of atoms of a substance. In this case movement of molten rock is induced by the further breaking of the atoms of the molten material.

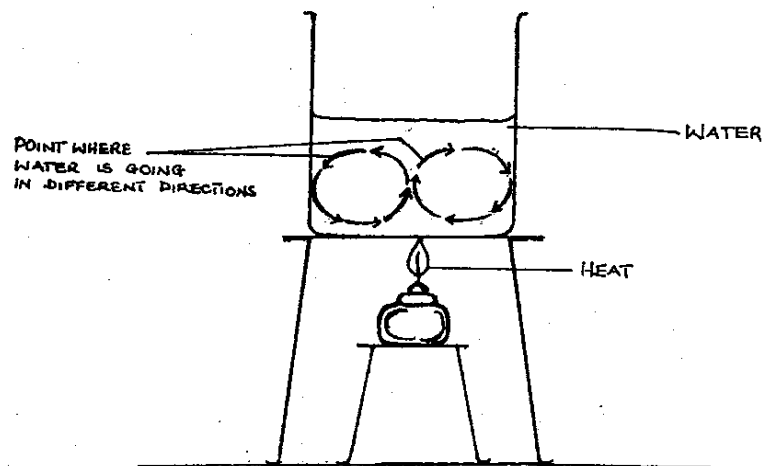


Fig 17: Convection current in water

5. It should be remembered that the drifting of the earth took place several millions of years ago. Though the rate is a very slow one but if we consider it to have taken such millions, this small rate adds up to several hundreds or thousands of kilometres of movement.
6. The stable lithosphere (which is largely dry and solid) floats on the asthenosphere, therefore movement inside it (asthenosphere) makes the fluid mass carry along with it the solid lithosphere. The movement in the different directions of the convection currents make the lithosphere to split (see fig. 17)
7. Yes, they do.
8. No, others are largely covered by sea e.g. the Pacific Plate (see fig. 18a).

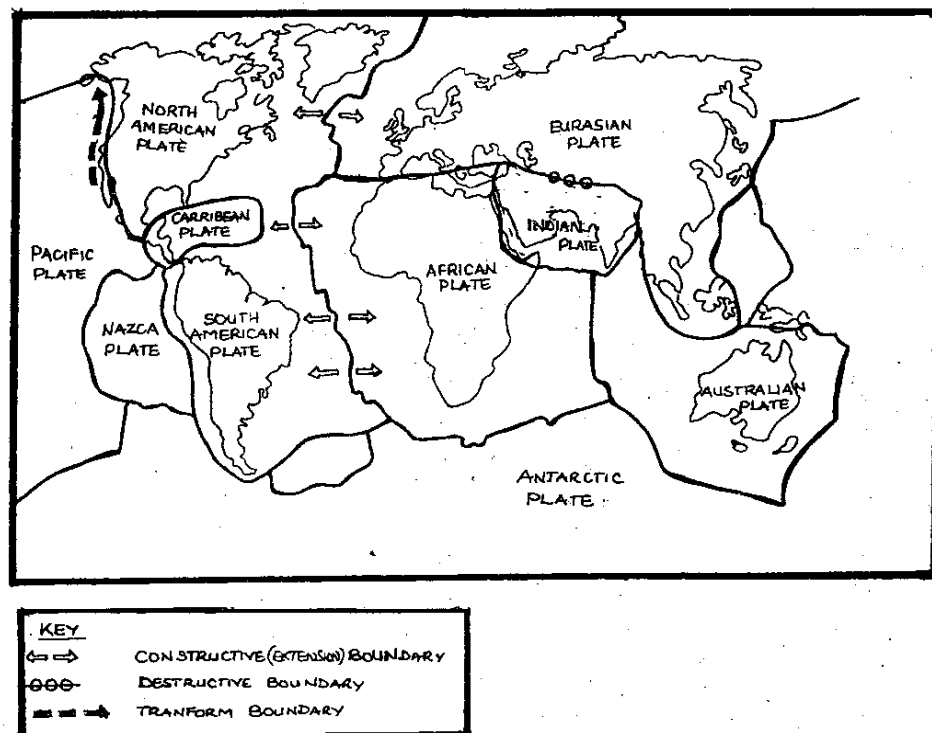


Fig. 18a: Plate boundaries

Source: Grimwade K. *Physical and environmental geography*,
Hodder and Stoughton (1994)

9. • Since the earth is a sphere, the shifting plates hit into each other (collide). While they collide, the following happen and give room to their movement:
- The plates containing the dense oceanic crust are forced to move down into the asthenosphere and get consumed by melting and getting assimilated into the molten mass (see fig 18b and 18c)

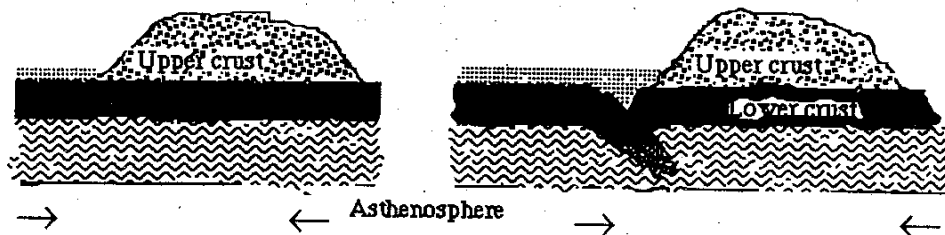


Fig 18b: Upper and lower crust floating on the asthenosphere

Fig 18c: Oceanic crust melting into the asthenosphere

- Plates that contain lighter continental crust fail to sink back into the asthenosphere (as explained in Fig. 18b and fig 18c) and instead such continental margins get deformed into folded mountain belts. The Himalayas is a good example which is said to have been produced when the Indian plate collided with the Eurasian plate.

10. Plate boundaries.

11. • Extension boundaries (constructive margin)

- these are zones where the earth's crust is extending or is lengthening. This is occurring because of some lava which is upwelling from the depth. These mostly occur on the oceanic crust.

Such flows of molten material give birth to new rocks, volcanic islands etc. These features give a new and extended face of the ocean floor. The mid Atlantic Ridge is the best example. Such extension of the sea floor is also referred to as the sea floor spreading.

It should be noted that the extension of the ocean floor by the upwelling magma does not lead to a more pronounced length of the sea floor itself because the marginal parts of the ocean crust (see fig 19) sink back into the asthenosphere

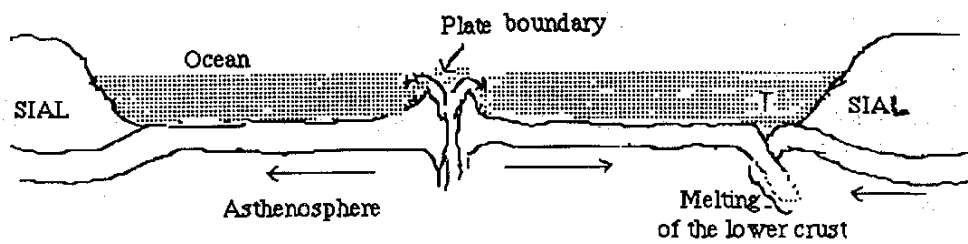


Fig19: Sea floor spreading

Source: Nyamwera C. Rifts and Volcanoes (1980)

- Compression boundaries (Destructive margin)

- this is where plate movements lead to two plates getting squeezed together. This happens when plates move in opposing directions. In this case, one plate is forced below the other. The one going down forces its way into the molten stuff thereby getting melted or destroyed. (The area where the plates descend and sink into the molten layer is referred to as the subduction zone). The material or mass above it then gets squeezed together to form folded features.

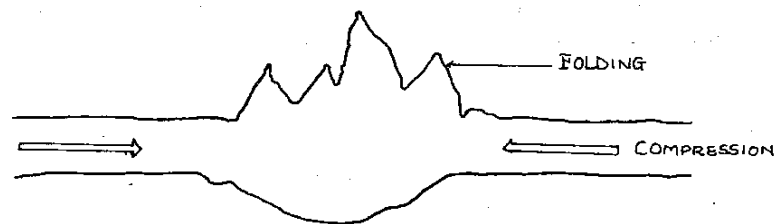


Fig 20: Folding

- Transform fault boundaries (conservative margin)

- these occur where two plates are colliding against each other sideways. Usually in this process the rocks simply change their position and structure. A good example of this is the San Andreas fault where the Pacific plate is grinding its way along the edge of the American plate.

It should be noted that the movements explained above in relation to the plate boundaries are the ones that form the basis of the earth movements that are said to have formed most of the physical features of the world we see today.

12. • Extension boundaries (constructive margins) – volcanic activity, volcanic islands, normal faulting, earthquakes.
- Compression boundaries (destructive margin) – faulting, folding (fold mountains), trenches.

- Transform boundaries (conservative margin) faulting, earthquakes.
13. Not all volcanoes are found along plate boundaries.
 14. They occur beneath areas that are referred to as hot spots. Thus beneath the plates in some areas are pools of very hot active magma which erupt at times.
 15.
 - Tristan da Cunha
 - Iceland
 - Ascension
 16. When the plates move, their sideways movement is not as smooth and swift as we may think. Infact as the plates move, longer sections of the rocks get stuck to each other, when the friction drag of the plate is in play. This dragging builds up some stress which to a certain extent (limit) make the rocks to jerk as they move past each other causing an earthquake.
 17.
 - African and Eurasian plates are compressing (meaning between them is a compression boundary).

Some of the resulting features are: Volcanoes eg. Vesuvius and Etna, earthquakes, folding that has resulted into the Alps and Atlas mountains on the Eurasian and African plates respectively.

 - Indian plate and Eurasian plate are compressing (or collision zones).

Some of the resulting features are folds that have resulted in the formation of the Himalayas.

 - African and South American plates are diverging (meaning between them is constructive boundary).

Some of the resulting features are volcanic eruptions resulting in volcanic islands, the mid Atlantic Ridge, faulting.

 - The North American plate and the Pacific plate are colliding against each other side ways.

Some of the resulting features are; faults (San Andreas fault), Earthquakes (Notable one - San Andreas earthquake).
 18. There are several explanations that back the theory.
 - Similarity of fossils found on both sides of the Atlantic coast especially East Coast of S. America and W. Coast of S. Africa.
 - We would think of the above evidence in terms of the following :
 - floating and swimming organisms would cross the sea but land based animals would not, therefore this shows that the coasts were at one time one because of the presence of similar

land based animals on both coasts.

- some plants grow through dispersion. Their seeds could have been too big to have dispersed across the sea by wind (bearing in mind its vastness) yet they are found on both sides of the Atlantic hence the coasts were one.

- Similarity in the structure and rock type (i.e. of rocks on the Eastern Coast of American continent and those on the Western coast of Africa and Europe. Examples are:

- similar rocks are found at the cape of Good Hope (west coast of S. Africa) and (East coast of Argentina in S. America).

- another example are rocks on the folded Appalachian mountain which have same characteristics as rocks of Ireland and Brittany.

- Coastline fit – the coasts of the continents fit, if the continents are put or joined together. This evidence also backs the first one in that the similar rocks and fossils are found along the areas where the coasts almost exactly fit.

In this evidence, we can imagine a broken china ware plate or saucer. Even if you had not seen it before, you would tell that it was a plate or saucer by simply picking up the pieces and joining them together. If it had decorations eg flowers you can make them up in the process of joining the pieces. This is how we should look at this evidence. The fitting together of the continents just as pieces of a plate or saucer would fit together to form a whole, simply tells us that they were once one mass.

- Formation of coal

- coal is believed to have formed in areas with equatorial climatic characteristics (where there is plenty vegetation). Large coal deposits these days are found in areas which do not have such climatic characteristics e.g. Antarctica, Britain. This shows that such areas (some of which are now covered with ice which means there is not even a trace of Equatorial characteristics) were once covered with vegetation and they drifted to their present positions.

- Study of magnetism in ancient rocks

- this evidence is derived in rocks that contain magnetic particles. During plate movements some rocks assumed a molten state due to the collision or sliding of the plates. The molten rock particles then were free to align themselves in the direction of the earth's magnetic field (just like a compass needle does). On cooling, the alignment became permanent that even if the rocks were moved further the alignment would not change (because the influence of the earth's magnetic field on the rock particles would not work on dried rocks). Therefore rocks that have a different alignment along the boundaries show that they originally were not where they are but they moved.

19. It explains the changing activities in the earth's crust, why these occur and the result of these changes. The theory in principle, explains the origin of the major features of the planet earth e.g. the continents, oceans and ocean basins, mountains from a simple system of gradual movement of molten material underneath.

20. Within areas of the plates themselves, the earth's crust is more stable than where they converge or diverge called the plate boundaries. Plate boundaries are areas of crustal instability where folding, faulting and volcanic activities are common. These places are also associated with earth quakes.
21. • They move as follows
- they diverge i.e. they move apart (split and spread), this is due to tension (or pulling force) ref .to extension boundaries Q 11.
 - they converge (move towards each other and slide), this is due to compression (or pushing force). ref.. to compression boundaries Q 11.
22. • Where the plates diverge (spread apart) the following take place
- block faulting
 - upwelling of magma through cracks that are created
 - breaking up of continents as is happening between South and North America.
- Where the plates converge
- subduction (sinking) and this results in formation of trenches
 - mountain building (i.e.where two plates move against each other , one rides over the other and overlying continental rocks are compressed and folded to form fold mountains.
23. • Earthquakes
- Tremors
 - Depressions²⁷

Mountain building (folding and its associated features)

24. What do you understand by the term orogeny?
25. Mention some of the types of mountains that are formed by orogenesis?
26. What are folds?
27. Explain the causes of folds?

²⁷Sinking or warping of land

28. Where can we easily see folds?
29. How are folds described in general?
30. What are the sides of a fold called?
31. Explain the different types of folds?
32. Give examples of areas where folded rocks are found.
33. What can we learn from folds?
34. Mention the features that are formed due to folding?
35. How are fold mountains formed?
36. What else happens when the plate fractures?
37. Describe some of the characteristic features of fold mountains?
38. What is the difference between old and young fold mountains?
39. Give examples of fold mountain?
40. Explain the importance of folded areas or folded mountains.

Answers

24. It is mountain building i.e. it is the folding or uplifting of rock masses (rock and earth material) to form mountains.
25.
 - Fold mountains
 - Block mountains
 - Volcanic (mountains of accumulation)
26. These are bends or warps in rock bodies.
27. Folds are formed by forces of compression. For example when plates move in opposing directions, they compress a part of the earth's crust resulting in it folding.
28. These can be easily seen from mountain sides, road cuts and in some samples of rocks.
29. When rock layers bend upwards it is referred to as an upfold or anticline and when it's bent downwards, it is referred to as a downfold or syncline. (See fig 21)

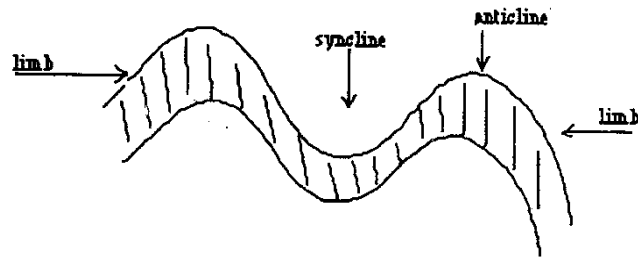
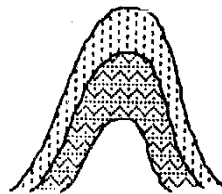


Fig 21: Anticlines and synclines

30. They are called limbs (see fig 21). It should be noted that the anticlines become mountains while the synclines the valleys.

31. They are as follows:

- Simple fold - This is formed when force of compression is equal from both sides. Because of this, the limbs are the same. (see fig. 22a) Though folds i.e anticlines form mountains, simple fold mountains are rarely found.



simple fold

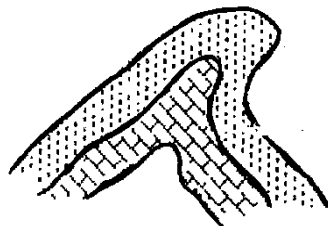
Fig 22a



Asymmetrical fold

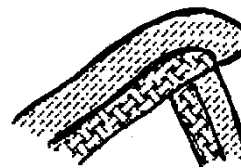
Fig 22b

- Asymmetrical fold - This has one limb which is steeper than the other because the force of compression was stronger on one side i.e. the steeper side. (see fig 22b).



overfold

Fig 22c



overthrust fold

Fig 22d

- Overfold - This is when the force on the steeper side of an asymmetrical fold is even stronger to make one limb overlap the other. (see fig 22c)
- Overthrust fold - formed when pressure continues from the overlapped limb making the overlapping rock to fracture and push forward over the other limb. (see fig. 22d)

- 32 Kigezi (S.W. Uganda) Jura mountain , Swiss Alps, Chimanimani mountain (Zimbabwe).
33. • Learn about the mobile nature of the earth's crust, which lead to the movement of some portions of the earth's crust.
- Learn about the complexity of the folds in relation to the degree of deformation of the rocks (i.e. the complexity of the folds are proportional to the extent of deformation).
- Learn about the nature of rocks that some are capable of bending or folding because they are not hard and brittle as others are.
34. Ridges , escarpments, valleys, fold mountains.
35. They are formed as follows: Heat emitted by radio active material deep below the crust generate convection currents in the semi-molten layer of the earth (asthenosphere). The currents move in a pattern as illustrated in the fig below and this movement make the plate to get pulled down and in the process bending it down in the soft asthenosphere.

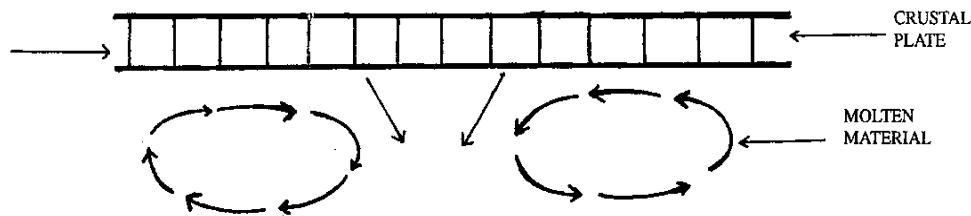


Fig. 23a: Convection currents in the molten material under the crustal plate

- The plate immediately above the point where the currents converge is warped to form a deep trough called a geosyncline (see fig 23b) Such warping of the plate also takes place as a result of plates moving in opposing directions i.e plates compressing each other. (see the arrows in figs 23a, b, c and d).

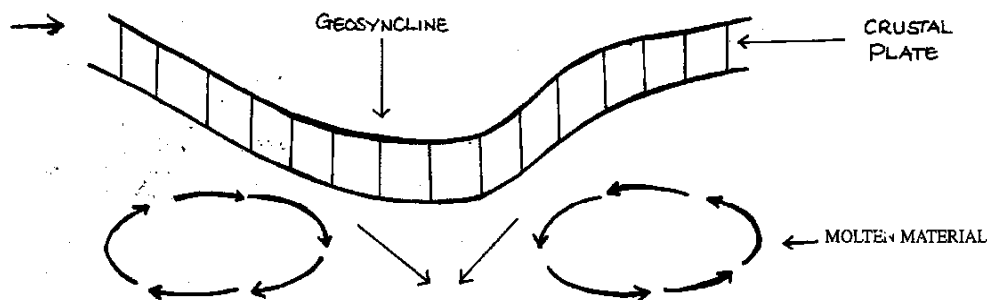


Fig. 23b: Convection currents making the crustal plate to depress and form a geosyncline.

- Large quantities of sediments accumulate with passage of time and their weight help to warp the plate further. The continuous warping of the plate due to the weight and force of compression lead to the fracturing of the plate (see fig 23c)

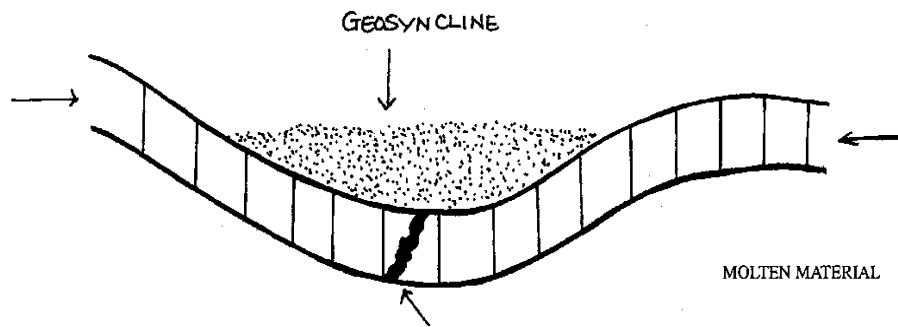


Fig 23c: Fracturing of plate due to compression

- The plates from the fracture slide i.e. one moves (rides) over the other. The plate that moves down is the one that has been too overburdened by the weight of the sediments to remain at the same position and again been subjected to more compression by moving plates. The sliding reduces the area covered by the sediments and in the process they get bent or folded.

The folding, crushing of the sediments leads to the formation of fold mountains. (see fig 23d)

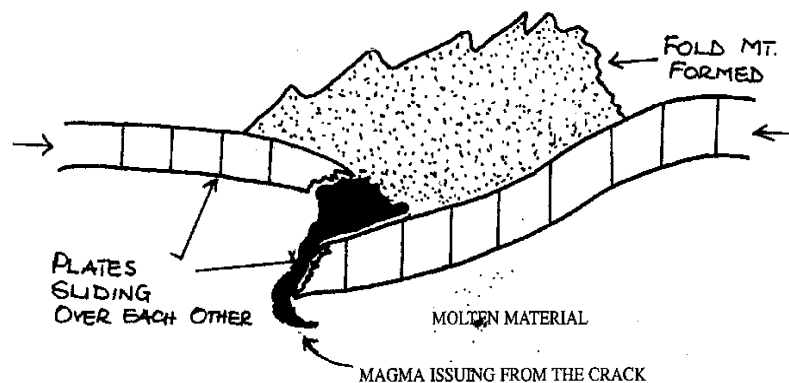


Fig 23d: Sliding of plates due to compression

Source: Young and Lowry: *Course in World Geography* (1979) pg. 22-23

36. • Magma bursts up through the fracture and the upwelling magma leads to the formation of batholiths that act as roots of the fold mountains. The intrusion of magma also lead to the folding of the rocks above it. Sometimes the magma burst into a volcano (see fig. 23d).
37. • They are high
 - Some of them are formed in parallel sets
 - They have igneous rocks (batholiths) that form their 'root'
38. • The former were the first to be formed and the latter formed later.

- Old folded ones are generally lower (in height than young folded ranges because they have been undergoing erosion for a longer period).
 - Old fold mountains comprise material that is more resistant to denudation than young fold mountains.
39. • OLD
- Akwapim hills (Ghana), Urals (Russia), Ben Nevis (Scotland) Cape Ranges (S. Africa), Appalachian (N. America).
- YOUNG
- Altas (Morocco), Alps (Europe), Rockies (N. America), Himalayas (Asia) Andes (S. America).
40. • Ridges in folded areas make good areas for forestry and their valleys make rich agricultural areas.
- Some folded areas are rich in minerals. For example, in the Appalachians of Pennsylvania, anthracite is abundantly found. The folds of this region have also formed important traps for mineral oil.
 - limestone is abundantly found in the Jura mountains in Switzerland which are also folded.
 - coal is also found in folded areas e.g, in the Livingstonia/Kaziwiziwi areas in Malawi.
 - Folding has also helped in transforming some resources into more economically beneficial resources e.g:
 - anthracite found in Pennsylvania resulted from the transformation of bituminous coal by the compression due to folding.
 - the area (Pennsylvania) is also rich in slate which resulted from the transformation of shale by compression again.
 - Most fold mountains attract tourists because of their high altitude e.g, the Himalayas.

Faulting and its associated features

41. Define the term fault?
42. Explain the causes of faulting?
43. Describe what happens where a fault occurs?
44. Explain the major types of fault?

45. Mention some features that are formed due to faulting?
46. With the aid of a diagram, explain how block mountains are formed.
47. Explain the difference between the tilt block and horst (block mountain)?
48. How is a fault scarp formed?
49. What makes a fault scarp to change its form?
50. Give some examples of block mountains.
51. What is the extent of the Great African Rift valley?
52. Which are some of the countries that are covered by the great African rift valley system?
53. Explain how the great rift valley of Africa was formed.
54. How is the formation of a rift valley different from the formation of a horst?
55. Citing examples, mention some of the notable features found in the great rift valley system.
56. Does the rift valley system extend continuously from the Jordan valley to the Zambezi river?
57. There has been movement in rift valleys and still there is. What evidence is there to prove this?
58. Faulting in most areas of the world is associated with volcanic activity yet there are other areas e.g Lake Tanzania and Lake Malawi sections of the rift valley where there are less or no volcanic activity at all. Why is this so?
59. Mention the features formed when a fault scarp formed during rift valley formation is eroded?
60. Give examples of fault scarps?
61. What conclusions can we make from the great African rift valley?
62. If the rift valley system is said to be on a plate boundary (ref. to answers to Q 61), what type of plate boundary could this be?
63. What is the economic and environmental importance of faults?
64. What would have been the situation had the rift system (rift valley system) not been formed?
65. Give specific examples where highlands formed due to faulting have been of economic importance.
66. Which are some of the examples of rift valley lakes.

67. What are some of the characteristics of rift valley lakes ?
68. What are the disadvantages of faults?

Answers

41. Is a crack or break in the brittle²⁸ rocks of the earth's crust
42. • Stresses on the rock mass i.e. Tensional stresses that lead to the stretching of the crust or compressional stresses that tend to squeeze the rock together but instead slide over each other.

Faults occur in rocks that are old and have usually become hard or brittle. Now if they are compressed or pulled apart, they do not bend (as in younger rocks that fold because they are soft) but fracture to relieve the strain or release the energy in the rock.

43. • Rocks slip - The breaking of the rock makes a layer or layers of rock that were at one time continuous to move apart and get separated.
- Displacement along the plane of breakage takes place i.e layers of rocks that were one, differ in their level of occurrence because one is thrown up and another down (see fig 24a).
- Earthquakes or volcanoes (when the cracks allow movement of molten rock material).
44. • Normal fault.

-this has a slanting fracture in which the rocks above the fractured surface (fault plane) have moved down relative to those beneath. (see fig 24a)

-this is the most common type of fault because normally rocks under tension fracture easily.

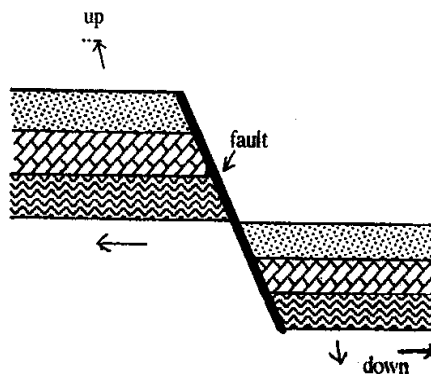


Fig 24a cross section of rock layers after faulting

²⁸These are rocks that are hard but easily break when a force beyond their elastic limit affects them.

- Tear fault (also known as strike slip or transform fault)

- its a fracture that has displacement of the faulted block of rock in a horizontal direction parallel to the fault plane (and not up or down) (see fig 24b)

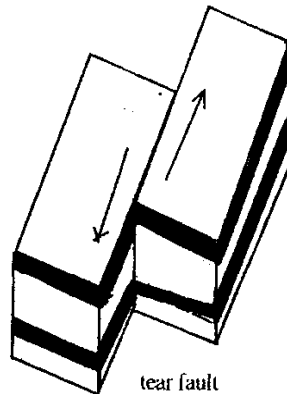


Fig 24b: Tear fault

- the fracture is high - angled

- tear faults result into earthquakes e.g. San Francisco earthquakes resulted from the San Andreas fault²⁹.

- such faults are less common

- they cover very wide areas

- Reverse/Thrust

- this is a result of compression

- In this the rocks above the fractured surface (fault plane) move up over those below the plane (see fig 24c).

- the fracture in this has a low angle i.e. the fault/fracture is more slanting.

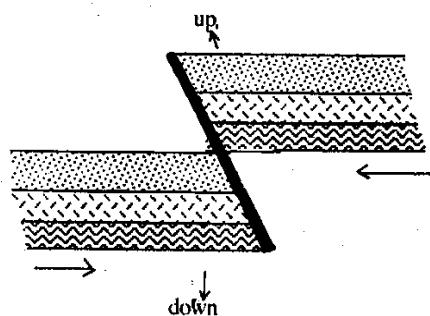


Fig 24c Cross section of a reverse fault

²⁹The San Andreas fault got formed in 1906. It involved horizontal movement as explained under Tear fault. It extends over half of California. This is the one that caused the San Francisco earthquake

45. • Valleys (rift valleys³⁰) or Grabens - they are troughs or low lying areas formed by down faulting (subsiding of a block of land) usually between two parallel faults.
- Lakes (rift valley lakes)
 - Block mountains (horsts) - this is an upstanding or highland formed by up - faulting between two parallel faults.
 - Fault scarps.
46. The earth movements at times result in a stretch of land having fractures (faults) which occur in multiples and parallel to each other. Such a setting leads to blocks between the faults to get displaced i.e others get uplifted and others displaced. (see fig 25)

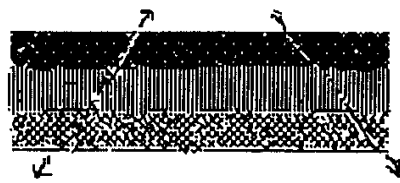


Fig 25a: Parallel faults

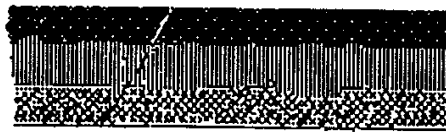


Fig 25b: Single fault

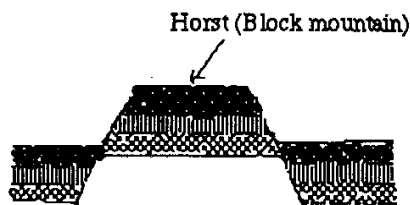


Fig 25c: Horst

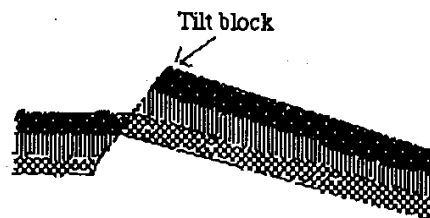


Fig25d: Tilt block

The uplifted blocks assume either of the following positions:

- The block stands at typical horizontal position with a flat top and this forms a horst or block mountain.

³⁰They are known as rift valleys because they were formed from breaking of the rocks or rifts in the rocks not by wearing away of land by rivers.

b. They become tilted because one part was more uplifted than the other and form a tilt block.

It should be noted that the parallel faults that form the horsts are extensive. They cover some tens to hundreds of kilometres. This therefore means the mountains are long.

47. The tilt block usually has only one scarp which is prominent while a horst or block mountain has two prominent scarps.
48. When up/down movement of rocks due to faulting takes place, a scarp forms on the bit that is thrown up. (see fig 26a)

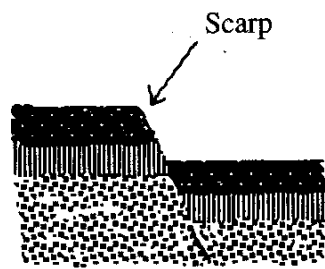


Fig 26a: Scarp

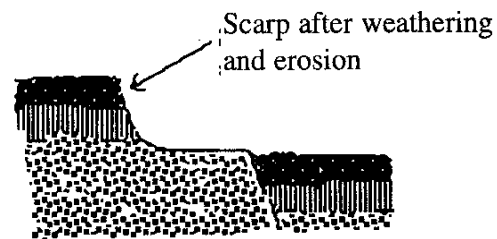


Fig 26b: Scarp retreat

49. The fault scarp just as any other feature formed due to earth movement, is vulnerable to weathering and erosion. When a fault scarp is worn away as in fig 26b the process is referred to as scarp retreat.
50.
 - Ruwenzori (Congo/Uganda border).
 - Ethiopian highlands (Ethiopia)
 - Congo horst (Congo)
 - Khana mountain (Namibia)
51. It extends or stretches from the Jordan valley via the Red sea and East Africa through Malawi to the Zambezi river (see map 1).
52. Syria, Israel, Egypt, Ethiopia, Kenya, Tanzania, Uganda, Malawi, Mozambique, Burundi.
53. A zone of tension or compression in the earth's crust was created as in the diagrams below.

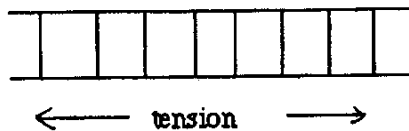


Fig 27a: Tension

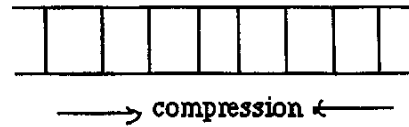


Fig 27b: Compression

- The tension or compression created fractures. These got created because the rocks could not withstand the strain from the tensional and compressional forces. In other words, the rocks were strained beyond limit and because they could not fold as is the case with softer rocks, they cracked.

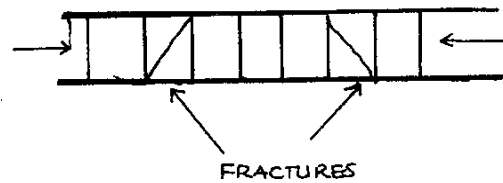
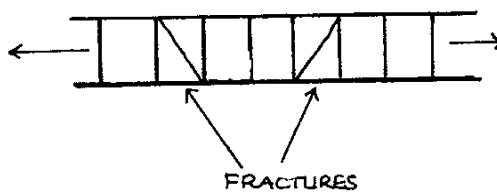


Fig 27c: Faults due to tension

Fig 27d: Faults due to compression

- The fractures then led to the displacement of the blocks of rocks in an upward direction or downward direction depending on the nature of the force.

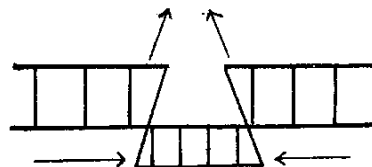
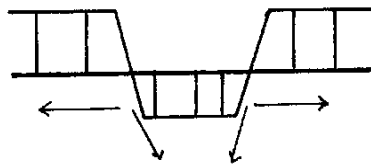
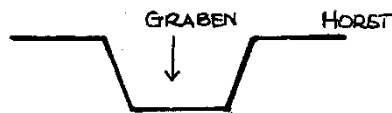


Fig 27e: Graben formed due to tension

Fig 27f: Graben formed due to compression

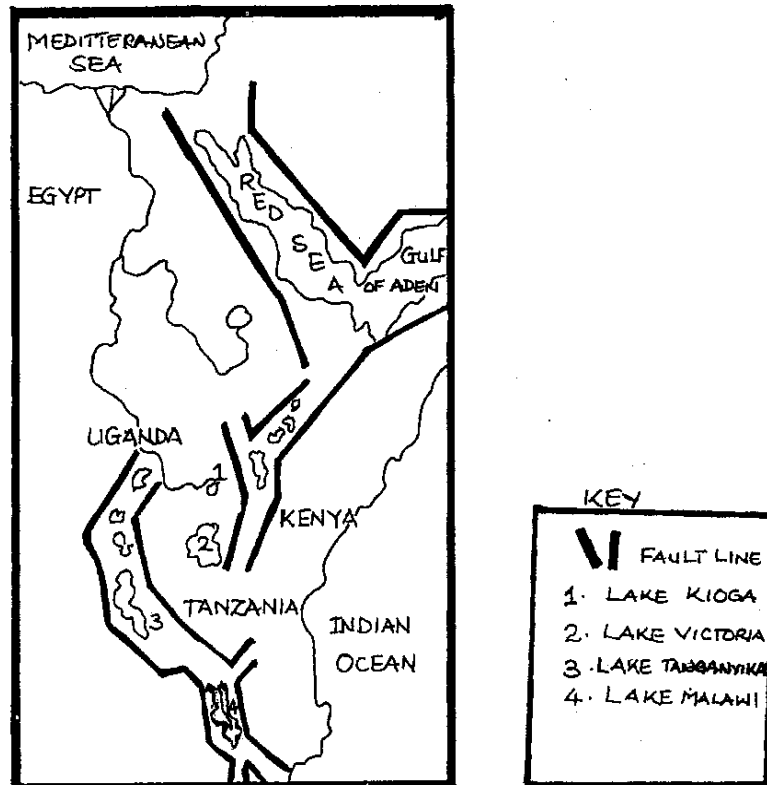
- fault scarps (cliffs) were created. The down placed block became a valley (graben) and the one that went up become a block mountain (horst).



- The fault scarp³¹ with time got eroded thereby erasing original marks of displacement.
54. A rift valley occurs when the rock between two vertical faults slip downwards e.g the Dead sea, Lake Tanganyika, Lake Malawi lie in rift valleys. A horst on the other hand is formed when rocks slip down on opposite sides of two parallel vertical faults. The faulting movement leaves an elevated section of rock between the two faults.
55. • Seas- e.g, Dead sea (Israel), Red sea (Egypt/S. Arabia/Ethiopia border).
- Lakes-(Refer to question 66 in Chapter 2)
 - Block mountains(horsts)- e.g, Ruwenzori(Uganda/Democratic Republic of Congo), Rungwe mountains (Tanzania).
 - Volcanic mountains that are found along the valley e.g, mount Elgon.
 - Hot springs-e.g, Mawira and Chombo in Nkhotakota, and Mawira area at Liwonde.
56. The rift valley system does not stretch continuously, it has some sections that divert from the main valley (see map 1). as follows:
- A The fault line extending eastwards from the Red sea through the Gulf of Aden.
 - B The section extending from Uganda (from L. Mobutu to L. Tanganyika)
 - C A small section westwards that include L. Mweru in Zambia.

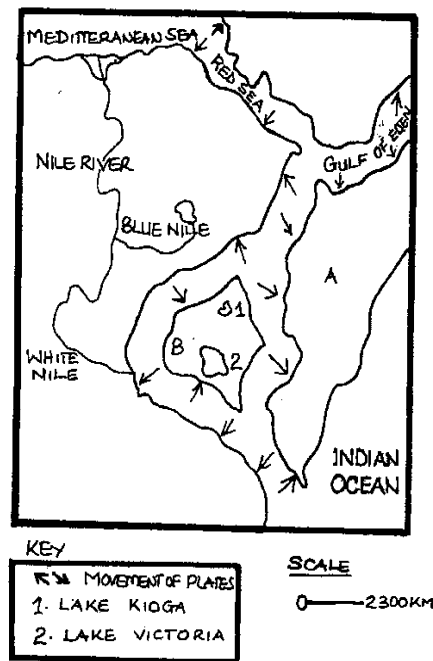
Note: that there are still more minor rift valleys that are on different sides of the main valley.

³¹Scarp means the same as escarpment



Map 1: The Great African Rift Valley

57. Earthquakes and tremors are being felt from time to time in areas near the rift valleys e.g. earth-tremors in Salima (Chitala area) which were more prominent in 1989 and others that have occurred in recent years).
58. Thorough studies by geologists have shown that magma does not move up to the surface along major faults of the rift valley region. This is because the major fault lines are very tight as the blocks move. This therefore means that magma only has the chance to get to the surface where the faults open up and form fissures. The tightness of the major fault lines therefore makes the area to be free from volcanic activity.
59.
 - Spurs
 - River valleys
 - Gorges
 - Cliffs
60. Livingstonia and Thyolo escarpments (Malawi)
61.
 - The area where the rift valley system is found is not a stable one. This is shown by activities e.g earthquakes, tremors, hot springs and this suggests that this area may be on a plate boundary.
 - The faulting that took place could be a signal that the fracturing of the continent would later lead to the drifting of the portions of land that have been separated or demarcated by the fault lines (which resulted from the formation of the great rift valley) see map 2.



Map 2: The possible split of plates along fault lines

The map illustrates the possibility that the African continent would end up splitting into many portions (plates) as explained in the theory of plate tectonics. On map 2, plate A and B are drifting from the main mass of the African continent.

Here however, it should be emphasised that any theory just like this one (of plate tectonics) is subject to limitations and this at times leads to conflicting conclusions. For example the African plate is said to be the most stable because the extension boundaries (to the west and east) pushes it together and in line with this others argue that instead of the African rift valley splitting apart, there is possibility that it would be compressed to form fold mountains.

- It is a complicated process which result in a wide range of features getting formed with different shapes, sizes and heights that range from more than 300m below sea level e.g, the floor of the Dead sea to more than 3,000m above sea level.

- The process is a slow one. If it were a rapid one, we would probably by now have had the continent of Africa split thus taking into account when the rift valley system was formed.

- The processes that led to the formation of this did not take place at the same time and were neither the same all through. The evidence is in the fact that there are numerous features of different ages, structure etc found at different places within the system e.g some places have scarps that are steep meaning they haven't undergone rigorous retreat while in others the scarps are gentle thus a sign of having undergone intensive retreat. This in itself tells us that some scarps are young and others old to mean they were formed at different times.

- The interior of the earth is indeed dynamic. It is not as rigid and dead as we thought in the first place.

62. Since the following: Faulting, volcanic activity in some parts, earthquakes/tremors occur in

the rift valley system and these are normally associated with extension boundaries, we can conclude that the system is lying on an extension boundary. Further more, folding which is due to compression is not a common feature in the system.

63. Ore - forming chemical solutions rise along faults e.g. Oil is usually found in fault traps.
 - Faults make it easy for underground water to rise e.g. In cold or hot springs making water readily available for the human race's use.
 - Grabens in some areas form plains that are agriculturally productive and horsts make good areas for forestry.
 - Valleys so formed have lakes (rift valley lakes) that are useful in many ways e.g. fishing, transport, irrigation e.g, Lake Malawi.
64. • Much of the areas would have been low lying (with low altitudes).
 - Most of the low lying areas e.g. in East Africa as well as Central Africa e.g, Nsanje and Chikwawa are dry with low rainfall of less than 900 mm, comparatively high areas have higher rainfall. This therefore means the rift system has in a way helped to regulate climate in terms of temperature and rainfall due to the formation of the highlands (horst/block mountains). Thus the temperatures are low in the highlands at the same time they receive more rains than the low lands. These areas are agriculturally productive.
 - We would not have had some important/useful features that we have today e.g lakes, rivers. Life would therefore have not been what it is like today without these.
65. Highlands in Kenya (Muguga highlands), Malawi (Shire Highlands) have been used agriculturally and produce cash crops which are important exports of the countries e.g. Tea and coffee which are not grown in low lying areas.
 - They have also attracted tourists who come to view the scenic beauty of the areas of such highlands.
 - The highlands are also used for forestry.
66. Lake Malawi, Lake Kivu, Lake Tanganyika, Lake Rudolf, Lake Turkana, Lake Rukwa, Lake Albert.
67. • Long and elongated
 - Deep (which make them suitable for navigation)
 - Narrow in width
 - Bordered by steep scarps
 - Some parts of the lakes lie below sea level e.g. Sea of Galilee (Lake Tiberius)
68. • They result into earthquakes that bring problems e.g, collapsing of buildings.

- They give passage to magma that result into volcanoes which are also hazardous
- Fault scarps form high topographic barriers across which it becomes difficult to build roads and rail roads.

EXTRACT 2

69. Read the Extract 2 and answer questions that follow

The event was an unforgettable one to the people in the heart of Wodiod town. This was mostly unforgettable to Mr. Vumalam who had his three star hotel torn apart along the long fracture that people discovered during the morning of the 20th of February that year. It was difficult to repair the hotel. "Probably it would require experts from outside the country because one of the torn apart areas had been downwardly displaced." This was a comment from one of the many experts in different fields that were invited to determine what had happened. "That area may as well be declared inhabitable because more strange things may happen." Said another. It remained to be seen as to what would be done to the area after reports from the experts were finalised.

- (a) What do you think had happened in the town?
 - (b) What evidence is there in the passage to back your answer in (i)
 - (c) Why did the other expert think more strange things would happen to the area?
 - (d) Mention any one of the strange things that would happen?
 - (e) What makes you suggest the answer you have given in (iv)?
70. What is the similarity and difference between a fault and a joint?
 71. What causes the cracks (joints) in the rocks?
 72. How do joints occur in sedimentary rocks?
 73. Is there any relationship between joints and drainage?
 74. What are the advantages and disadvantage of joints in rocks?
 75. Explain how volcanic mountains (mountains of accumulation) are formed
 76. Give some examples of volcanic mountains
 77. What are residual mountains?
 78. What are the similarities and differences between mountain building (e.g formation of fold, block mountains) and wearing down of mountain (e.g. formation of residual mountains).

CLUE A

79. How was mountain formed? (Note that you can fill in any mountain in

the blank space).

- To answer this, you should first recall some examples of mountains and how each of them was formed. That is if the mountain falls under examples of block mountains, then you should explain how the blocks came into being due to faulting, if its under fold mountains, then you should explain how movement of plates led to the bending of rock masses.
- Location of the mountain can also help to determine its formation e.g, mountains along zones of plate movements are either Block or Volcanic mountains.
- It is usually difficult for one to explain how a mountain was formed if you do not know what type it is.

Answers

70. • Both are cracks in a rock or earth's crust
- Where a fault occurs, displacement results whereas joints do not lead to displacement.
 - [A joint is a simple crack or fracture along which there hasn't been any displacement].
71. • In general, they are caused by strain that comes about due to any of the following:
- contraction when molten rocks dry up
 - earth movements
 - penetration of tree roots into a rock
 - presence of acids in the rocks weakens their structure resulting in them cracking
 - availability of water in rocks may lead it to react with other chemicals and weaken the rock to a point of cracking
72. They occur 'perpendicular' to bedding planes
73. Joints in many places control the development of courses of streams e.g. the secondary tributaries as is the case, in Trellis pattern of drainage.
74. **Advantage**
- They provide the necessary openings for ground water and for petroleum migration and accumulation in 'reservoir rocks'.³²

³²Reservoir rock stores crude oil when it migrates from where it was formed (source rock)

- They give room to roots of plants to penetrate and help in weathering of the rocks to form soil.
- They act as habitats to some living things e.g insects, micro-organisms etc

Disadvantage

- They can be a burden if a bedrock where a dam has been constructed has joints. The dam would dry up easily as water could be penetrating the joints.
75. They are formed from material that has been forced out of the earth's crust by volcanic eruptions (Refer to how igneous rocks are formed)
 76. Mount. Kenya, Mount. Elgon, Kilimanjaro (Tanzania), Cameroun (Cameroun), Paricutin (Mexico), Drakensburg (S. Africa), Fujiyama (Japan), Mulanje (Malawi).
 77. These are mountains that have formed due to denudation i.e. agents of denudation (weathering and erosion) lower mountains and the resistant (remaining) parts form residual mountains (see fig 28).

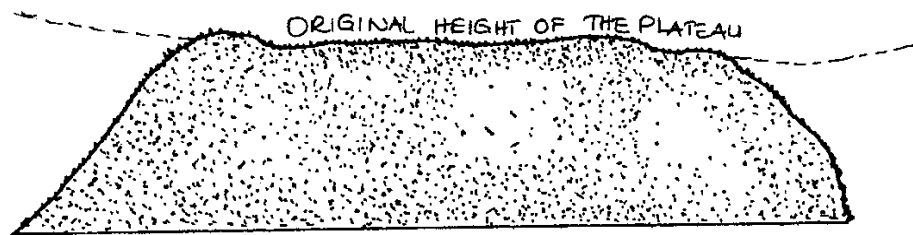


Fig 28a Show an original plateau before denudation

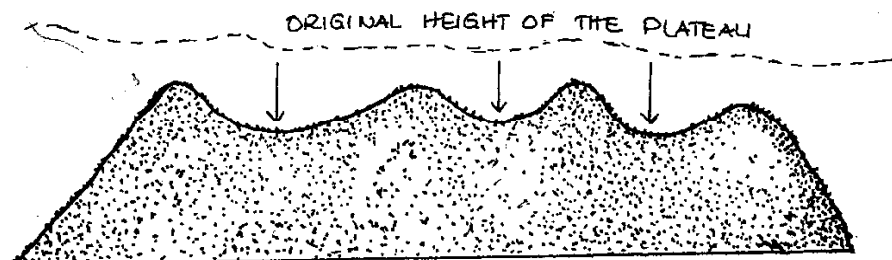


Fig 28b Show the original plateau being eaten up by weathering and erosion

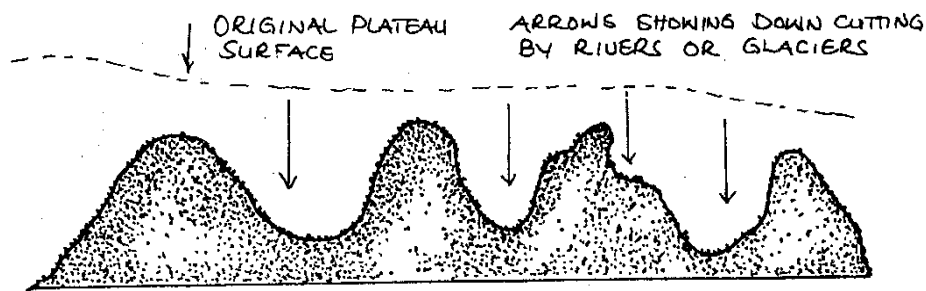


Fig 28c Show the limit of denudation due to resistant rocks
 Source: Leong G.C. Certificate Physical and Human Geography (1983) Pg. 23

For example, plateaus may be subjected to denudation and down cutting by rivers or streams and result into such mountains.

On other mountains e.g. volcanic mountains, the upland rocks get weathered and then eroded down making the highland reduce in height with passage of time until when more resistant rocks are reached.

Examples are: Scandinavian highlands, Scottish highlands, Hora mountain.

78 Similarities

- The process of wearing down of mountains just like the mountain building process is slow.
- Just as there are violent phases in the course of mountain building, there are also violent events in the course of mountain erosion. For example, landslides or rockfalls for mountain erosion and sinking of land (in the case of formation of a geosyncline) and earthquakes for mountain building.
- Both end up in having new features formed.

Differences

- In mountain building the features formed are high (they are raised) while in mountain erosion the features are reduced in height.
- Activities in the interior of the crust cause mountain building while in mountain erosion is caused by activities outside the crust.

CHAPTER 3

Weathering

The primary features of continents undergo some changes through wearing away of some of the material that made them. This makes the features to lower in height or have rugged surface etc. and sometimes new features are formed in the process. Where the wearing away has taken place, some features are formed as the worn out material is transported and where the material has been deposited. This chapter will focus on the processes that take place for the primary features to undergo some change and some of the features that are formed as the above happen.

1. What do you understand by the term weathering?
2. How do rocks break?
3. Explain how physical /mechanical weathering takes place.
4. Explain how chemical weathering takes place.
5. What are the major differences between physical and chemical weathering?
6. What are the products of weathering?
7. Explain the composition of soil.
8. On what does the formation of a type of soil depend?

Answers

1. The breaking up of rocks into small particles
2.
 - By disintegrating mechanically (physical weathering)
 - Chemical action that decompose the rocks and weaken them (chemical weathering.)
3. [It should be noted that in most cases, physical weathering easily occurs where there has been prior weakening of the rocks by chemical action].
 - The following are some of the causes:
 - alternate changes in temperature that leads to expansion and contraction in the rock. Such alternate changes lead to the rock breaking.
 - alternation of wet and dry conditions i.e when rocks absorb water they expand and when they lose the water they shrink.

Both the first and second causes also lead to rock peeling which is referred to as exfoliation.

- penetration of ice in openings/cracks (frost action) acts as a wedge³³ that exerts pressure to the rock and makes the rock fracture further.

- plant roots that penetrate rock openings break the rock as they grow bigger.

- animals also contribute to this e.g. hooves of cattle break rocks.

- activities by human kind e.g. mining, quarrying, farming etc also result in rocks breaking.

4. • The following are some of the ways that cause chemical weathering.

- minerals are dissolved by water (solution and rain action) when it combines with carbon dioxide e.g. Calcium carbonate is dissolved away in rocks forming openings, caves etc. Such openings weaken the rock and in the end they break.

- through oxidation where oxygen in water/air reacts with minerals e.g. iron in a rock thereby forming oxides (iron oxides) that easily disintegrate or get eroded.

- dissolution where water dissolves and erodes away some weak rock surfaces e.g. Rock-salt, Gypsum.

- decomposition of rocks by organic acids produced by either bacteria that live on decaying plants and animals or by microorganisms and flowerless plants e.g. mosses that live on rocks and absorb chemical elements in them (rocks).

It should be noted that the more the rock is cracked the more the chemical action.

5. • Chemical weathering takes a long time while physical takes a short time even in the newest rocks.

- Changes in physical weathering can be easily noticed while chemical they cannot.

- Chemical affects certain constituents of the rock e.g. minerals by dissolving or creating new ones while physical doesn't alter the constituents of a rock. (In other words, physical change is in the physical properties of the rock e.g. shape, hardness, colour etc while in chemical new rocks are formed).

- Mechanical produces fine (small particles) while chemical produces larger particles.

³³Something that penetrates into something and exerts a force. In this case the water acts as a wedge because when it is frozen it expands in the rock resulting in it cracking.

- Chemical weathering is least effective in deserts (because of aridity) and in cold climates where water is frozen most of the times while mechanical is effective almost everywhere.
6.
 - Rocks with modified shapes.
 - Features like: joints, screes.³⁴
 - Soil.
 7.
 - Soil is composed of the following:
 - mineral particles e.g. Silica which is highly resistant to chemical decay, iron, silicates etc. and those that are essential for plants e.g. nitrates, phosphates, potash, magnesium.
 - decayed organic matter i.e. remains of animals and plants that are decomposed by bacteria to form an organic substance called humus.
 - water from precipitation which is absorbed by plants or move salts that affect its (soil) formation.
 - air e.g. oxygen - this is in less amounts when the soil is water logged.
 - living organisms i.e. microbes, earthworms, ants. These also aid in soil formation.
 8.
 - There are many factors that influence a type of soil that is formed. These factors do not necessarily act in isolation, they work together (they are interactive) to form soil. The factors are as follows:
 - The parent material.

The source of the fragments that make up the soil is called the parent material.

 - the nature of loose sediments from the parent material often have a major influence on the characteristics of the soil. For example the chemical composition of the parent material gets reflected in the soils that result e.g. if the parent material is rich or lacking in potassium, the resulting rock would be potassium rich or potassium poor.
 - physically, if the weathering of the parent material resulted in large sediments, the resulting soil will be coarse-textured e.g. sandstone, gravel.

³⁴These are particles of rock produced by physical weathering that collect below a steep slope after falling off from the original mass of rock.

It should be noted that the influence of parent material diminishes with time as other soil forming factors come into play e.g, climatic or biological factors. The other thing is that where the soil characteristics do not relate to the bedrock within the area the soil is, it may mean the sediments that formed it were transported from their original parent rock somewhere.

- Climate- this does it in the following ways:

- it determines weathering of the parent material especially in physical weathering. Physical and chemical processes in the soil are accelerated by climatic factors e.g, high temperature and adequate moisture speed up decaying activities in the soil no wonder soils are usually deep in warm and humid areas. In desert, polar regions and high mountain regions, mechanical weathering may dominate but organic material is usually very minimal hence thin soils not suitable for plant growth.

- Slope or ground surface

- the steepness of the slope or the nature of the ground surface determines the development of the thickness of the soil. Soils are thin on sloping areas because surface erosion is more rapid than the development of the thickness of the soil. Such thin soils are regarded as immaturely developed.

- where the land is flat, soils develop more thickness. This is because there is very little erosion therefore more thickness is developed than the amounts that are scraped by erosion (see fig 29)

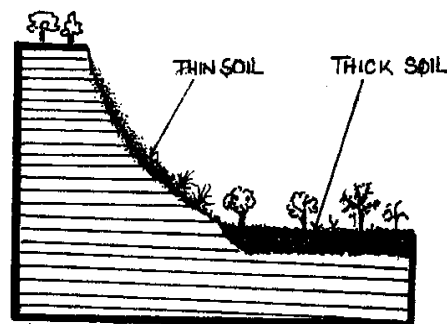


Fig 29: Thickness of soil according to nature of ground surface

- Biological factors

- vegetation help to add fertility into the soil by bringing out from the ground important minerals e.g, potassium, iron through their stems or leaves which release them when they die and decay.

- some organisms e.g, bacteria algae help in absorbing nitrogen from the air and turning it into a chemical form which is useful to plants, a process referred to as nitrogen fixation.

- some insects e.g, ants, termites help in rearranging the texture of the soil by bringing out soil particles from the depth and mixing it with soils on the surface. They also provide pas-

sage ways for water and air to penetrate the soil.

- large animals also contribute through breaking the parent rocks as they walk and through their excreta which fertilise it. Their carcasses also serve the same purpose when they die.

- Time(chronological factor)

- soil formation is a very slow process and depends largely on the above mentioned factors hence a lot of time is required. For example, soils can be more rapidly formed from sediments that are already there than it forming on a bedrock which has not broken yet.

Erosion

9. Define the term erosion?
10. Explain some of the causes of soil erosion ?
11. What are the agents of erosion?
12. How does ice/glacier erode and deposit material?
13. Explain the different types of moraine.
14. Describe some features that are formed by glacial erosion
15. What are the values of glaciers and glaciated areas to the human race?
16. What are the disadvantages of ice/glaciers?
17. How does wind erode material?
18. In which areas does wind erosion commonly take place.

Answers

9. The process that loosens and removes/moves rock particles or any other particles to another place on the earth's surface.
10.
 - Cultivating on steep slopes without taking into consideration precautionary measures to prevent runoff.
 - Monocropping renders the soil texture to loosen making it prone to erosion .
 - Overstocking which leads to depletion of pasture leaving the land bare and vulnerable to erosion.
 - Deforestation which denies the soil a mechanism to hold it together.

11. Running water, wind, waves, glaciers/ice and gravity.
12. Beneath a glacier³⁵ melt water gets into joints /fractures and act as a wedge that loosens the blocks of the rock. The material that has been loosened from the rocks stick to the glacier and when it moves, the rocky material scrap the bedrock or earth over which it slides. The weight of the glacier makes the scraping to be more effective such that large quantities of material is eroded. The load that is eroded, transported then deposited is called moraine.
13. • Lateral moraine
 - this is load that is found along the sides of a glacier
 - easily identified by their dark appearance which becomes conspicuously different (see fig 30a and b).

When a tributary glacier enters the main valley and a lateral moraine of a tributary merges with a lateral moraine of the main glacier and gets positioned on the width of the river.(see fig 30 a and b)

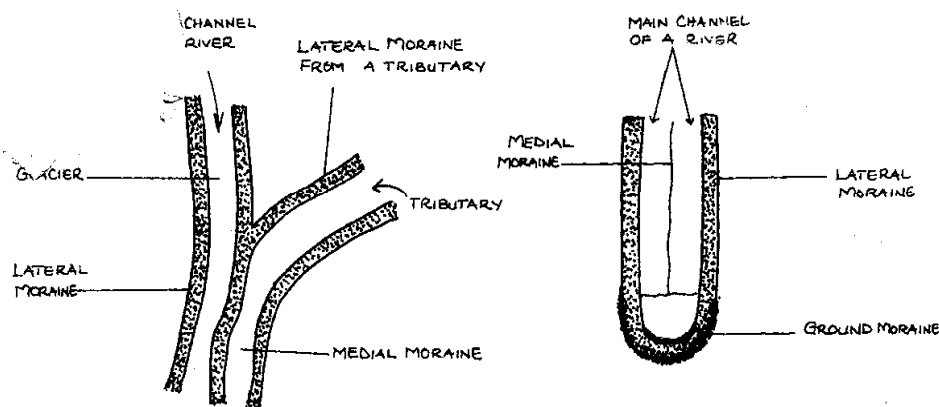


Fig 30a Lateral and medial moraine on a river course.

Fig 30b Cross section diagram showing ground moraine

- Ground moraine
 - these are eroded material (load) found at the bottom of a glacier.(see Fig 30b)
- Terminal moraine
 - this is the load that is deposited at the end point of the glacial movement due to melting and evaporation of the ice.

³⁵A large accumulation of ice.

14. • Cirque (corrie) - a depression on a mountain side or at the upper part of a glacial valley, that has been dug by ice scraping due to weight of the ice and boulders that get gripped to the ice /glacier. (see fig 31)

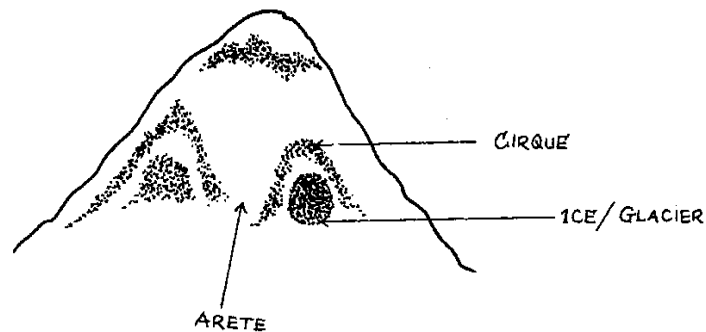


Fig 31: Features formed by glacial erosion

- Arete - when cirques develop on the same mountain slopes adjacent to each other they form a spur - like feature between them and this is called an Arete. (see fig 31)
 - Tarn - a lake so formed when glacier/ice in a cirque has melted.
15. The following are some values of the glaciers and glaciated areas to humanity.
- boulder clay plains that form due to glacial deposition offer fertile agricultural areas at times e.g. North America Dairy belt.
 - some features formed by glaciers result into lakes that are of value to man. e.g. St. Lawrence seaway and the great lakes believed to have been formed during the glacial period.
 - glaciated regions especially mountains attract tourists.
 - some valleys e.g. in the Alps offer some good pasture during summer and accommodate semi-nomadic people who practice transhumance.
16. • Once they have melted they end up into forming marshy areas not ideal for agriculture.
- They bring about too many lakes that in the end become unnecessary for they just eat up land that would have been developed artificially.
 - They lead to depopulation of those areas occupied by them (glaciers).
 - They give a lot of stress to animals and plants. As for animals, they are usually displaced and some even get extinct.
 - Glaciers cause water to cool and freeze and this affects the distribution of marine life
 - Permanent accumulation of ice (permafrost) has the following bad effects.
 - people have problems to build houses on normal foundations.

- transport (both on roads and railways) is difficult.
 - water supply and sewage disposals do not work properly.
 - agricultural development is retarded since soils are not well developed due to inactivity of microorganisms.
17. • Wind erodes material in the following ways:
- deflation - This is the blowing out (lifting) and removing of loose sand and dust particles from the surface of the earth. Such lifting of loose particles end up in the development of depressions (i.e. where the material has been removed).
 - abrasion - In this, small particles of rock are lifted by wind and as they are moved and come into contact with other features made of rocks, they rub or scrap against such features thereby wearing them. This result in the scraped features assuming new looks. e.g. a flat surface of a desert with weak and resistant rocks may be scraped by such (as explained above) and form Zeugens and Pedastals.
18. • In desert areas or arid regions i.e. both western coast desert (those that rarely receive rain-fall due to onshore winds that cross cool currents) and continental deserts (that rarely receive rains due to long distance from sea that make air lose moisture).

- Semi- arid regions

Western coast deserts include the following:

- Atacama - adjacent to which there is the Peruvian cold current
- Kalahari - adjacent to Benguela cold ocean current.
- Mohave desert - adjacent to California cold current.

Continental deserts include the following:

- Sahara (Africa).
- Gobi (Asia).

Drainage

One of the agents of erosion is water. This erodes as its being drained away.

19. Define the term drainage?
20. What is a river system?
21. Explain the different drainage patterns.



22. Mention the two types of erosion that take place in a river course.
23. Mention some features that are formed by vertical erosion in a river and their importance.
24. What are the disadvantages of rapids?
25. Mention some of the features that are formed by lateral erosion in a river.
26. Mention some of the problems that are brought about by erosion.

Answers

19. This is a system by which all the water from different areas is collected and channelled into the sea/ocean.
20. This comprises the main river channel and all its tributaries that drain water into lakes/seas/oceans.
21. • **Dendritic**
 - the main course of the river and the tributaries form a structure like that of a tree with many branches or veins of a leaf. (see fig 32a)

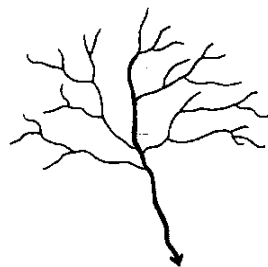


Fig 32a Dendritic pattern

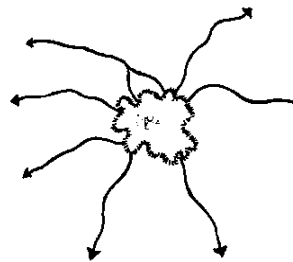


Fig 32b Radial pattern

- such a pattern develops in areas which have rocks that have the same resistance (to erosion) but are subjected to vigorous erosion.
- in between the tributaries, ridges and spurs are found and these form the watershed.
- the tributaries flow in almost the same direction as that of the main course of the river.
- A good example is the Likangala river which has a number of tributaries e.g, Mulunguzi joining it and ending up with one main stream pouring into L. Chirwa.
- **Radial**
 - courses of many rivers originate from the same watershed area.

- such a drainage often originates from conical hills or volcanic domes or cones e.g., mount Elgon which is a volcanic cone.

- the rivers form a pattern like that of spokes of a wheel. (see fig 32b)

- the rivers usually do not have many tributaries because they flow through a steep slope.

- the rivers in this type of drainage are mostly characterised by vertical rather than lateral erosion.

• Trellis

- in this pattern , the river courses flow along non-resistant formations of rocks i.e. the pattern develops where hard and soft formations occur alternately.

- the rivers or streams usually flow in only two orientations which appear regular and well arranged.

- such drainage patterns are common where joints occur.

- the tributaries join the main course of the river at right angle. (see fig 32c)

- the tributaries are normally not too long.

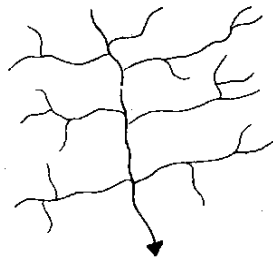


Fig 32c Trellis pattern

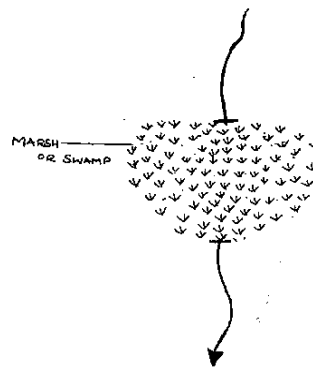


Fig 32d Disappearing pattern

• Disappearing

- a river course ends up in a marsh or swamp then resurfaces again. (see fig 32d)

- this is common in areas where a river passes through a flat but wet area which is adjacent to a gentle slope in the direction of flow of the river.

- in some cases the river does not resurface.

22. Vertical erosion - this usually takes place in the upper course of a river.

- this results into deep, narrow valleys. (See fig 33a)

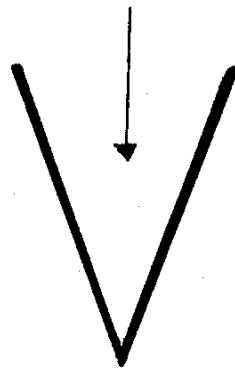


Fig 33a Vertical erosion

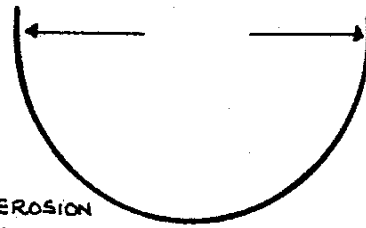


Fig 33b Lateral erosion

ARROW SHOW
DIRECTION OF EROSION
IN THE VALLEY

- Lateral erosion - this usually takes place in the middle and lower course of a river
 - this results into wide valleys. (See 33b)
23. • Gorges (narrow and deep river valley with steep walls).
- Waterfalls (This is where a river plunges down in a sudden fall of some height).
- Such a sudden fall may either be due to presence of a highly resistant rock to erosion or when land has been uplifted e.g. due to volcanic activity.
- **Importance of gorges and falls:**
 - they offer suitable areas for the establishment of Hydro-electric plants since water flows fast over a high area.
 - falls are usually tourist attractions e.g. Victoria falls.
 - gorges offer ideal conditions for the construction of bridges across rivers.
 - they are also ideal sites for the construction of dams.
24. • Rapids (formed due to unequal resistance of rocks to erosion which lead to formation of a wavy river course). see fig 34.
- They hinder navigation . For example, the rapids in the middle part of the Shire.

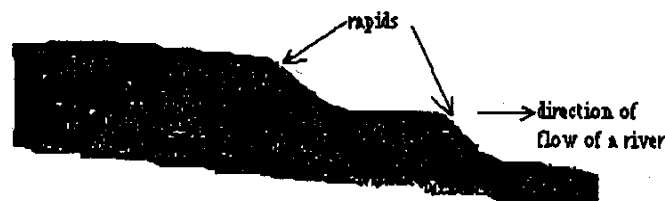


Fig 34 Uneven flow of a river.

25. River cliff - this is when a river side has been eroded to form a steep (concave - like) bank.
- Bluffs - formed when the ends of interlocking spurs³⁶ are eaten up by water leading to the widening of the river valley. The slope so formed is almost perpendicular to the base of the river and usually forms on a curve of a river meander.
26. Fertility of the soil is lost e.g, along hill slopes.
- Unnecessary deformation of the landscape.
 - Eroded soil particles lead to siltation of rivers. e.g., siltation in the Shire which has affected generation of electricity.

Deposition

27. Define the term deposition?
28. When does deposition occur?
29. Where does deposition take place in a river?
30. Mention some features that are formed by river deposition, how they are formed and their importance if any.
31. With the aid of a well labelled diagram, explain how an oxbow lake is formed.
32. What are the factors that affect the formation of a delta?
33. How is a delta formed?
34. What other features are associated with formation of deltas?
35. Describe the different types of deltas and give examples of where each type is found.
36. How are deltas important?
37. Mention some features that are formed by glacier deposition.
38. Explain how some features are formed due to deposition by wind.
40. Draw the cycle of landform :

³⁶Highlands that occur alternately on both sides of a main river and are separated on each side by tributaries (joining the main river)

Answers

27. This is when eroded material is no longer moved by the eroding agent and get stuck on one spot where they accumulate.
28. Takes place when an erosion agent has insufficient energy to carry further the load it was transporting.
29. It takes place at any point or stage of the river depending on circumstances especially the old stage.
30. Flood plains - these are areas that are flat and have been deposited with material (alluvium) that was carried by a river.

Importance of flood plains:

- flood plains are usually covered by fertile alluvial soils that are favourable for farming.
- where rivers flow through desert areas, they are used for settlement since people get access to easy water and fertile land.
- Oxbow lakes - formed from remains of meanders that have been cut off due to deposition. In simple terms it is a cut off meander that holds water.

Note that oxbow lakes in the end dry up by either evaporation or silting. It's only in very rare cases where they have existed for long or permanently. If it is getting flooded by water from the river, the lake may turn into a swamp or marsh.

Importance of an oxbow lake:

- for small scale irrigation e.g. vegetable growing.
- some contain fish.
- some animals e.g. cattle drink water from them.

31.

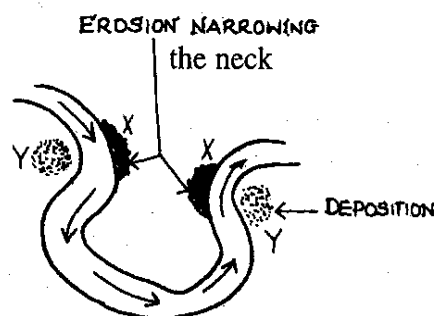


Fig 35a: Showing deposition on outside (Y) of a meander and erosion on the inner side (X)

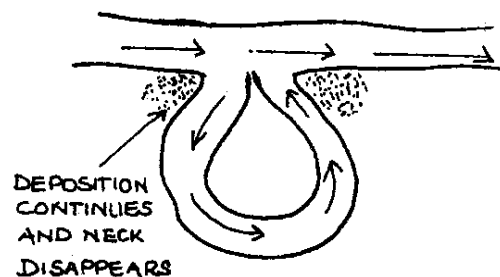


Fig. 35b: Showing continuation of erosion and deposition rendering the neck non existent

- (i) As the water flows, it deposits some of the load at Y while X get eroded thereby narrowing the neck.
- (ii) As erosion continues, the Y neck completely disappears and deposition begin to cut off the meander from the main river. Most of the water flows in the main channel of the river.

Note that the dark arrows denote alot of water while the faint ones denote less water flowing through the meander due to deposition.

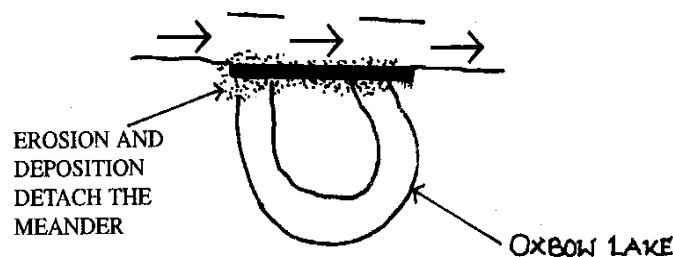


Fig 35c Showing a cut off meander

- (iii) The deposited material later completely cuts off the meander from the main river.

- **Levees:** These are ridge-like banks that are formed due to deposition of eroded material on the river banks.

Importance of levees:

- for settlement especially by semi- nomadic people e.g. along the Zambezi during flooding.
- once they are well developed (high enough) they prevent excessive flooding in the flood-plains.
- **Braids :** - These are divisions of a river into several channels due to the heavy load carried which blocks the movement of water (see fig 36). The process of forming these is referred to as braiding.

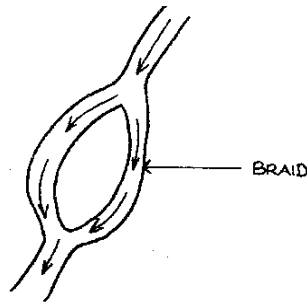


Fig 36 Showing braided part of a river

- Delta - a low lying swampy plain area which gradually gets covered by various types of plants.

32. Formation of a delta depends upon the following:

- rate and amount of sediment supply (load) i.e. large amounts of sediments are required for a delta to be formed - hence vigorous erosion in the upper section of a river is necessary.
- rate of subsidence and removal of sediments by waves and tides e.g. if stream deposition dominates, the delta is extended seaward but if waves dominate then the sediments get deposited along the coast as beaches³⁷ or bars³⁸.
- the sea being joined by the delta should be shallow for sediments to easily accumulate to the surface.

33. Reduction in the velocity (speed of the flow of water) causes the transported material (load) to get deposited.

The deposited material then forms a bar (an accumulation of sediments/sand) on the main channel of the river. (See fig 37a)

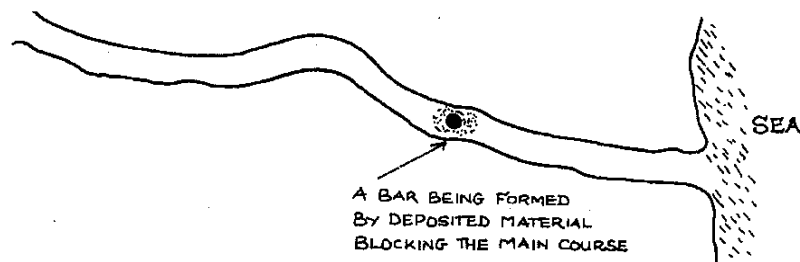


Fig 37a: Formation of a bar in the main course of a river

The bar then diverts the water into two distributary channels. (see fig 37b)

³⁷A coastal or shoreline area composed mainly of sand and formed by the action of waves. It forms a boundary or transition zone between land and water

³⁸This one is a ridge or band usually of sand that is deposited off the shore of a lake or sea. A good example of this is found in the fringes of the north sea in Netherlands. Bars also form along rivers.

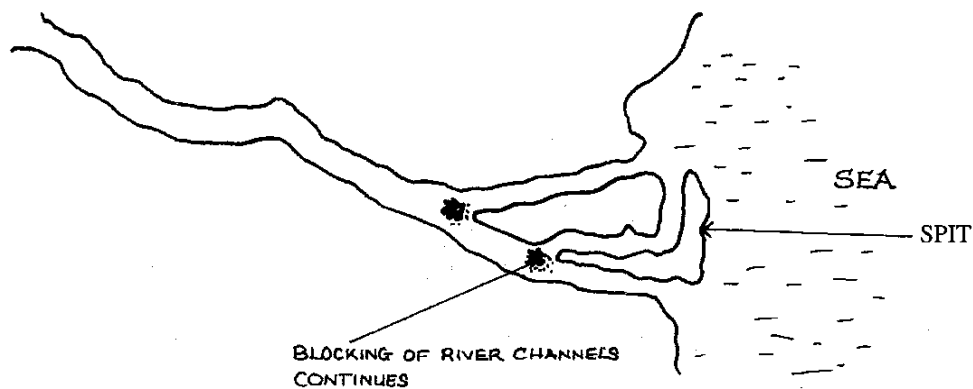


Fig 37b: Channels formed due to presence of bars

The same process (as above) happens in the newly formed channels where bars are formed and further distributaries created. Some features like spits, lagoons form and more distributaries are created. (see fig 37c)

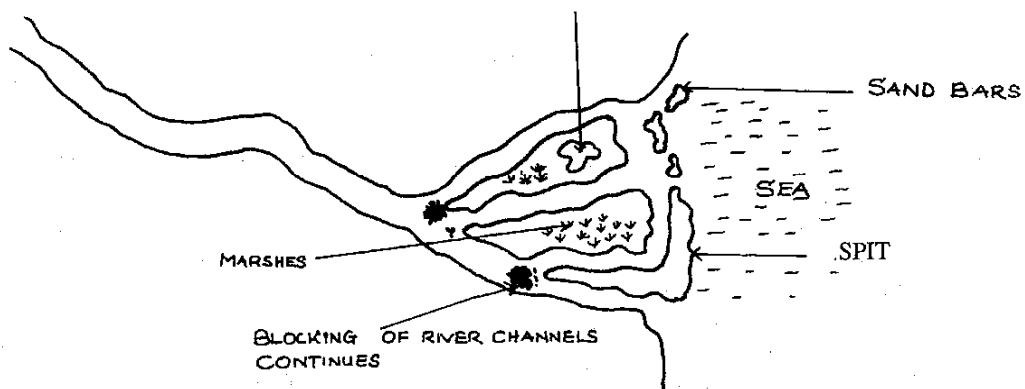


Fig 37c: Features associated with delta formation

Because of rich alluvial sediments that accumulate and moisture that is always available, different types of vegetation e.g, marshes, reeds grow and these help in ensuring more deposition for the deltas' expansion.

34. **Levees** - These are ridge - like structures that form along the distributaries due to deposition. (see question 29 under deposition)
- Spits - Along narrow tongue of alluvium/sand that is connected to land at one end with other end protruding into the sea across a mouth of a river, estuary etc.(see fig 37). Such features are also evident in the Nkhotakota area along Lake Malawi.
35. **Birds foot delta (Digitate)**
 - this occurs where the processes of river deposition dominate and discharges a huge load

annually i.e. occurs along seas that are wave and tide free to disturb the sediments.

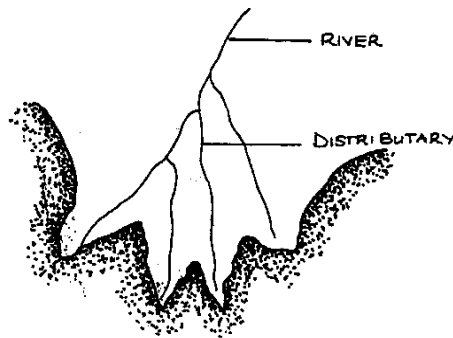


Fig 38a Birds' foot delta (digitate)

- it has a few distributaries because the velocity does not get seriously weak to form many bars in the channels.
- the few distributaries maintain their clearly defined channels across the delta
- fine silts dominate such deltas.
- levees are found and these form as the load gets deposited during floods.

Example: Mississippi delta (U.S.A).

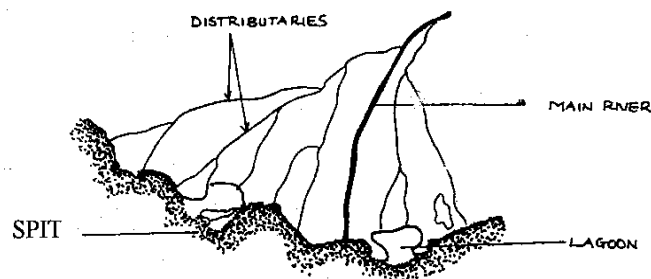


Fig 38b Arcuate delta

• Arcuate delta

- its triangular in shape with an almost straight edge along the shore or coast.
- the main channel is split up into a series of distributaries by accumulations of the load that block the channel.
- alluvial soils, sand and gravel usually dominate, no wonder commercial as well as subsistence agriculture takes place in most of such deltas.
- bars, lagoons, spits are formed in such deltas.

Examples: Nile, Mekong, Niger, Indus, Irrawaddy.

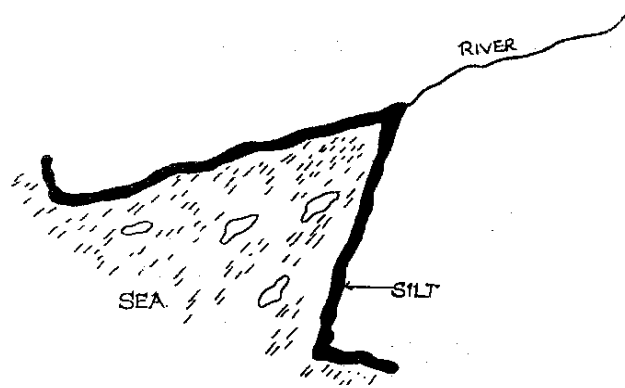


Fig 38c Estuarine delta

- **Estuarine delta.**

- its funnel shaped and forms at the mouth of a submerged river.
- waves and tides dominate where this forms leading to sediments being pushed back and getting submerged.
- it takes the shape of an estuary and has bluffs on the sides.

Examples: Elbe (Germany), Vistula (Poland), Zambezi (Mozambique).

- **Cuspate delta**

- has a tooth like shape (its pointed like a tooth).
- occurs where deposition is vigorous and waves counter the deposition.
- the action of waves make the sediments form a pointed feature that extend into the sea.
- this maintains the main channel which leads the load further into the sea/ocean (forming land extending into the sea). Examples, Tiber delta (Italy), Ebro (Spain).

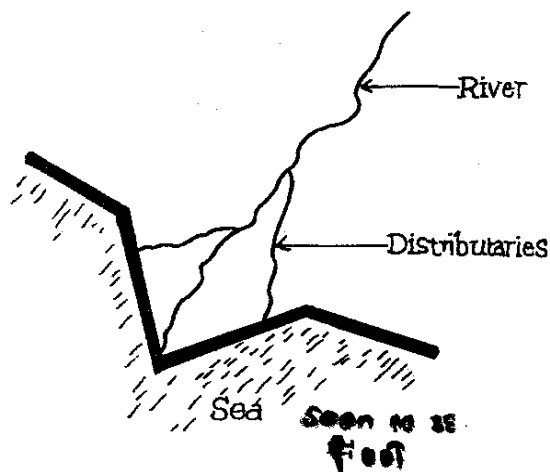


Fig 38d Cuspate delta

36. • They are fertile and offer very productive agricultural land.

- The distributaries, lagoons formed within them make better grounds for fishing.
- Some deltas e.g. Niger delta have fresh - water swamp forests with species that are used to make brooms , baskets ,mats etc.
- Some channels in deltas are used for transport.
- Some deltas have valuable minerals e.g. petroleum as in the Niger delta.

37. • Boulder clay deposits

this is clay that contains angular rock particles that are carried by glaciers.

- Drumlins - When the boulder clays are thick (i.e. several hundreds of metres thick) they form rounded hills across a surface. The rounded hills so formed are Drumlins.
- they are elongated in the direction of movement of the glaciers.
- Lakes (moraine damned lakes) - These are formed when moraine blocks a river.

38. • Dunes - These are low mounds of sand that accumulate due to:

- a blockage (e.g. a rock or some small vegetative matter).
- the velocity of the wind dying down

some have crescent shapes and others are elongated and are in form of ridges.

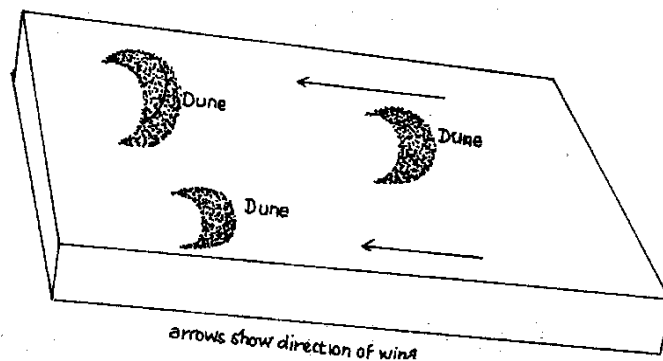


Fig 39 Sand dunes formed by wind erosion

- Loess - This is an accumulation of unconsolidated silts and dust that has been transported by wind.

This accumulates over an extensive area and forms a blanket cover.

EXTRACT 3

39. Read extract 3 and answer the questions that follow

"It was a terrible experience that I didn't expect when we were setting off. We took with us a lot of food and water alright but the journey itself was a nasty experience"

"What happened ?" Ambootal asked.

"There was heavy wind which brought with it a lot of silts and sand. One of our colleagues got buried. We could actually see him getting interred by the sand but could not save him. We would not even think of getting him out of the mound that had him inside".

"Before you started off didn't you know that this is the situation in such sandy areas?" "I didn't -----"

- What do you think was the major problem they faced on the journey?
- Across which area were they moving?
- Give some evidence of your answer in (ii)
- What do you think was the mound that buried him?
- If you were the traveller, what precautions would you take before starting off on such a journey.

40. The following points summarise the process of mountain building:

Weathering and erosion.

Transportation.

Deposition.

Tectonic activity

