BLOCK - III

EXTERNAL PROCESS-I

The Geological processes occurring on the surface of the earth are causing erosion, transportation and deposition of sediments. In this block the geological action of weathering, rivers and ground water are presented

The units included in the block are :

Unit 7 : Rock Weathering

Unit 8 : Rivers

Unit 9 : Ground Water

UNIT-7 ROCK WEATHERING

Contents

7.0 OBJECTIVES

After studying this unit, you should be able to

- explain about the concept of weathering
- describe the physical and chemical weathering processes
- describe the products of weathering and
- define the mass wasting

7.1 INTRODUCTION

The external processes are those which derive their energy from external sources and ultimately from Sun. These processes are also called as exogeneous processes. These processes are mainly caused by geological agents like weathering, groundwater, wind action, running water through rivers, glaciers, lakes, seas, oceans etc. The configurations of the land surface are the outcome of the joint actions of some geological agents having both constructive as well as destructive effects on the existing surficial features. Since these agents originate upon the earth's surface they are known as epigene-geological processes. Already the internal geological processes, also called as hypogene processes were discussed in the earlier units with the topics of volcanoes, mountains and earthquakes.

Weathering may be defined as the total effect of various sub aerial processes that bring about the disintegration and decay of rocks exposed on the surface of the earth. It is the process of alteration of rock materials, during long exposure to air, moisture and organic matter. The prime elements of weather are temperature, pressure and moisture. Warmth and moisture favour chemical action which brings about decomposition of the earlier complex minerals into altered minerals of simple composition, the changes of temperature and pressure due to seasonal variation bring about physical or mechanical disintegration of rocks. Thus weathering is related to the surface of the lithosphere where rocks, air and water come together. Water or moisture soaks into the cracks and joints of rocks, dissolves and alters minerals, expands by freezing and enlarges joints and fractures. This process begins in cracks or fractures and ultimately the entire rock is affected.

The geological work accomplished by weathering is of two kinds.

i) **Physical** or **Mechanical** changes in which the materials are disintegrated by temperature changes, frost reaction and organisms.

ii) **Chemical** changes in which the minerals are decomposed dissolved and loosened by water, oxygen, carbon-dioxide of the atmosphere and by organisms and products of their decay. The physical, chemical and biological agents actively co-operate with one another.

Check Your Progress

Note: a) Space is given below for writing your answer.

b) Compare your answer with the one given at the end of this unit.

1. What is meant by weathering?

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7.2 PHYSICAL OR MECHANICAL WEATHERING

When a rock undergoes mechanical weathering it is broken up into smaller fragments each containing the characteristics of the original matter. This mechanical breaking up of rocks exposes additional fresh surfaces to water and air. Therefore disintegration aids decomposition of the chemical alteration of rock materials. On the other hand some chemical changes are directly responsible for mechanical disruption on a large scale. Normally both phases of weathering go one hand at the same time. In nature four important factors of physical processes lead to fragmentation of rocks, these are frost action, temperature effects, mechanical effects of animals and plants and gravity.

i) Frost action or wedge work of ice : Water entering the cracks and other original planes like joints and bedding planes freezes and thaws. As freezing continues size increases, ice exerts pressure on the surrounding rocks and causes damage. On mountain tops during day time the temperature may reach 120°F degrees or more and the rocks may become distinctly warm or even hot but at night the temperature may drop to below freezing point. Under such circumstances disintegration is most effective. The frost shivered fragments fall to lower levels and accumulate.

ii) **Effects of changing temperatures :** In deserts, semi-arid regions and monsoon lands with a marked dry season the rocks are heated by the scorching sun in the midday to a very high temperature and cooled to a very low temperature during nights. Since the rocks are poor conductors of heat, only the outer layers of the rocks are affected due to alternate heating and cooling and so in course of time they get detached from the main mass of the rocks. These thin outer layers of rocks peel off as curved shells. This separation of successive thin shells during weathering from massive rocks such as granite or basalt is known as **Exfoliation**. This type of weathering is conspicuous only where mechanical disintegration is somewhat aided by chemical decomposition due to the presence of appreciable moisture contact.

The process of exfoliation results the formation of rounded masses of rocks, which is called **Spheroidal Weathering**, and the rounded masses of rocks are called **residual boulders**. The attack starts from the edges and the corners and they have gradually wormed down. Sharp corners and edges are the first to fall away with the development of rounded outlines and as a consequence the hills become more or less dome shaped. On convex slopes successive shells may be seen overlapping like the tiles on a roof, each ready to fall away as soon as it is liberated by the formation of radial cracks. This effect is well observed in the **Inselbergs** (isolated island mounts) of **Mozambique** and other parts of Africa. Another famous example is afforded by **the sugar loaf Hill in Rio Janeiro, Brazil**.

iii) Mechanical work of plants and animals : The growing rootlets of plants and trees exert an almost incredible pressure as they work down into cracks and crevices. Cracks are widened by expansion during growth and wedges of rocks are forcibly rendered apart. Burrowing animals large and small (Earthworms, Rodents) play an important part in preparing material for removal by rain wash and wind. They bring large quantities of partly decayed rock fragments to the surface where they are exposed more effectively to chemical decomposition. It is estimated that worms bringing particles to the surface at the rate of more than 10 tons per acre on average every year.

Plants of all kinds like Fungi and Lichens contribute to chemical weathering since they abstract certain elements from rock materials. Water containing bacteria attack the minerals of rocks and soils very much vigorously and the remains of dead organisms decay in the soil largely as a result of the petrifying action of the soil bacteria and fungi. The chief organic product of this kind of action is a sort of complex of brown jelly like substance collectively called **Humus.** It is the chief characteristic organic constituent of soils and water; it can dissolve small amounts of substances like limonite.

iv) Action of Gravity : Gravity helps in the removal of products of weathering, thereby exposing fresh surfaces of rocks for further weathering. It removes by slow downward movement of the loosened rock-debris. In steep mountain valleys weathered products tend to fall down by gravity and accumulate at the base of the mountain. Such accumulations of the rock fragments dislodged from cliffs by weathering and deposited below are known as Talus. The slope of

Talus is generally about 25 to 30 degrees.

7.3 CHEMICAL WEATHERING

The Chemical Weathering involves the complex processes that alter the internal structures of minerals by removing or adding elements. During this transformation, the original rock decomposes into new substance which is balanced with the surface environments. Consequently, the products of chemical weathering will remain unchanged as long as they remain in their new environment. Water is the most important agent of chemical weathering. The major process by which water decomposes rocks is **solution, oxidation** and **hydrolysis.** They act as carrier of dissolved oxygen and carbon-dioxide together with various acids and organic products derived from the soil. The degree of decay or decomposition depends upon the composition and concentration of solutions so formed, on the temperature, on the pressure of bacteria and on the substances taken into solution from the decomposed products. The chief changes that occur in chemical weathering are **solution, oxidation, hydration** and the **carbonation.** Only a few common minerals resist decomposition, quartz and muscovite being the notable examples, while others like calcite (carbonates) are removed entirely by solution. Most silicate minerals break down into insoluble residues such as clay minerals, with liberation of soluble substances which are removed in solution.

Chief processes of chemical weathering

(i) Solution: Carbon-dioxide (CO_2) dissolved in water forms Carbonic acid (H_2CO_3). Rain water with dissolved Carbon-dioxide percolates into the cracks and crevices of rocks and attacks them in several ways. Limestones are readily attacked, the carbonate being converted into bicarbonate which is readily soluble and can be carried away in solution. For example.

$$CaCO_3 + H_2O + CO_2 * Ca(HCO_3)_2$$

In many limestone regions the effects of solution are more spectacular as evidenced in the **Pennines** particularly around **Ingleborough** where many limestone pavements are found with deeply grooved and furrowed surfaces. When limestones contain impurities such as quartz and clay they remain undissolved and so accumulate to form the mineral basis of soils. The red earth known as **Terra Rossa** of the true **Karst** or the **clay with flints** of Chalk-lands are example of such residual deposits.

(ii) Oxidation: In this process water with dissolved oxygen acts as an agent of decomposition of rocks. Iron minerals in rocks are easily attacked. The iron silicates such as pyroxenes, amphiboles and the ferrous Iron is converted to ferric Iron (as in Heamatite) or to various other hydroxides (Limonite or Geothite etc.), with accompanying colour changes from green black to yellow, red or brown. Hence many soils in warm moist climates are coloured red, yellow or brown.

(iii) Hydration: This process involves chemical addition of water to certain minerals of rock to form new minerals chiefly hydrous oxides and hydrous silicates. Thus orthoclase abundant feldspar in the most widespread continental rock granite is decomposed and converted largely to Kaolin, the principal mineral in the clay.

$$2KAlSi_3O_8 + 2(H_2CO_3) + H_2O * AlSi_2O_5(OH)_4 + 2KHCO_3 + 4SiO_2$$

Potash Feldspar Carbonic Acid Water Kaolin or clay Potassium bi-Carbonate Silica

Plagioclase feldspar is likewise decomposed and most of the alumina is used up in the formation of kaolin. Other hydrous silicates formed by hydration include serpentine, talc, chlorite, zeolite etc

(iv) Carbonation: Another process of decomposition is carbonation by which CO_2 is added to certain bases particularly to oxides of calcium, magnesium, sodium and potassium to form either carbonates or bicarbonates of these metals. All surface water contains dissolved CO_2 derived from the atmosphere. Carbonated water dissolves many substances much more readily than pure water and consequently is an active agent of chemical weathering.

When $A1_2O_3$ and Fe_2O_3 are also present in minerals as biotite, augite, hornblende, clay, chlorite minerals and limonite remain as residual products. In the presence of oxygen limonite is also precipitated from solutions containing $Fe(HCO_3)_2$. For this very reason weathered rock surfaces are commonly stained a rusty brown colour.

Chemical weathering, therefore, either breaks down minerals into soluble compounds which can be removed in solution or so weakens the rocks that they can be attacked more readily by other agents of weathering. It contributes to the disintegration of rocks i) by the general weakening of adhesion between minerals, so that the rocks can readily be attacked by physical agents, b) by the formation of solutions which are washed out by rain so that rock becomes porous and ready to crumple e.g. the liberation of grains of a sandstone by solution of the cementing medium, c) by formation of alteration products with a greater volume than the original material so that the outer shell, as in exfoliation, swells and pulls away from the fresh rock within.

Check Your Progress

Note: a) Space is given below[7] for writing your answer.

b) Compare your answer with the one given at the end of this unit.

2. What is exfoliation?

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7.4 INFLUENCE OF CLIMATE ON WEATHERING

Weather is not uniform all over the world, its nature and extent being largely controlled by climatic conditions may be recognized and considered, i) The hot, most moist climate of the equatorial belt, ii) The hot and dry desert climate, iii) The cool and moist climate of the temperate zones and iv) The cool and dry Arctic regions. In each of these climatic regions rock weathering is going on continually but each region presents peculiarities of its own.

In the equatorial regions owing to high temperature and excessive rainfall, chemical weathering is very active and dominant but the thick vegetation hinders transport the product of weathering. Here the organic agencies are much pronounced and chemical reactions are more rapid and vigorous than in cooler latitudes and therefore the decomposition of silicates is almost complete and much of silica is removed in solution. The characteristic end product of chemical weathering is the **Laterite,** which consists largely of red hydrated oxides of Iron and alumina.

In desert regions peculiar conditions prevail, characterized by a dry climate and consequent lack of vegetation and hence the character of weathering differs a great deal from what is found elsewhere. The daily range of temperature is so very great that the effects of alternate expansion and contraction have full play. Rainfall is sparse in deserts and so the solution by downward percolating water is of minor importance. Since the air is very dry and the sun very hot the capillary water is drawn towards the surface where evaporation results in the concentration of salts that are in solution. The warm concentrated solutions react with the constituent of rocks and tend to decompose them. Crystallization of new compounds takes place between the mineral grains and this may cause splitting of solid rocks as much the same manner as the freezing water. Since the waters are constantly rising up towards the surface by capillary action and depositing their dissolved contents, the surface materials become cemented resulting in the formation of **'Hard-Pan'** and irregular concretionary mass in the mantle rock. A very common phenomenon in desert regions is the occurrence of a brown black shiny crust on the rocks known as **"desert varnish"** which consists mainly of oxides of Iron and manganese. In temperate regions the weathering is a sort of combination of all other processes since there are marked seasonal variations. In winter frost action is dominant, whereas in summer water plays a more conspicuous part. In general solution and chemical decomposition are the dominant types of weathering in these temperate lands.

In the Arctic regions where a large part of the surface is covered with snow during most of the year, the underlying rocks are saturated with melt water which is repeatedly frozen and thawed. In such an environment **frost action** and the wedge work of ice are the dominant agents of mechanical weathering. This results in the formation of strikingly sharp ridges and peaks so characteristic of the mountains of high altitudes above the snow line. Under such climatic conditions disintegrations is the dominant process which leads to the accumulation of great masses of fresh rock materials.

7.5 PRODUCTS OF WEATHERING – SOILS

An examination of a freshly cut cliff as in a new highway or quarry wall will often reveal a succession of layers of different earth materials. Starting at the base of the exposure there may be solid rock usually called the **bed rock** which is still in its original place and relatively unchanged. Lying above the bed rock may be a layer of soft mineral mater, the **regolith** which may be formed in place by decomposition and disintegration of the bedrock that lies directly beneath it. Within this regolith individual mineral grains or small groups of mineral particles are easily separated from one another. In some places the regolith has been stripped away exposing the bed rock which then appears at the surface as **Outcrop.**

In many places the soil grades down through subsoil composed of partially weathered material into the original fresh bed rock beneath. Soils are the most useful products of weathering and they are a complex mixture of inorganic mineral matter and decomposed organic residues. They differ greatly from area to area, not only in quantity but in quality as well.

The chief factors in the soil formation are i) parent rock material ii) climate iii) action of living organism's iv) slope of the land surface v) time. Hence the character of the ultimate soil derived from a given rock will to a great extent depend upon other factors of soil formation.

Soil which rests upon the bed rock from which they are derived are called **residual soils.** They show a gradual transition downward in to subsoil and in turn to solid bed rock. Transported soils are those which are derived from mantle rocks that have been carried to their present position from their original places. They owe their present location and position to agents of transportation like wind, running water, moving ice or simply gravity. Since these agents accomplish different degrees of sorting transported soils naturally vary in texture from fine silts to coarse gravel. They also vary in chemical composition.

Types of Soils

The mature soils are grouped into classes or types determined by the prevailing climate and associated vegetation of the concerned areas. They are described in the following.

(i) **Lateritic soils:** These are developed by intense weathering in hot, humid climate regions under the rain forests. The material, high in iron and aluminum oxides and hydroxides is red, yellow or brown in colour and very often is leached of bases and silica. Basalts, Granites and Gneisses generally give rise to lateritic soils under peculiar tropical monsoon climates. This type has little agricultural value because it lacks important salts and humus.

(ii) **Black Soil or "Chernogem":** As the very name indicates it is black in colour and granular in texture. It is a type of clayey soil which is generally formed from the decomposition of basalts and other types of basic rocks. They contain high percentage of oxides of aluminum, calcium and magnesium and rather variable percentage of humus.

The Iron and the humus content determine the black colour of the soil. It swells up when wet and has a high water-retaining capacity. This is a highly fertile soil and so very suitable for cotton cultivation, that is often referred to as the **Black cotton soil**. These are generally formed in temperate, sub-humid climates typically associated with tall grass vegetation.

(iii) Podsol : This type of soil is generally developed in subarctic to cool moist climates under a cover of coniferous forests. The colour of the soil is ash grey, organic matter low, acid often leached and it is almost always underlain by secondary clayey subsoil. It is generally sandy and not very much fertile.

(iv) Loamy soil: This type of soils contains sand and clay materials in roughly equal proportion, they are considered fertile and suitable for agriculture and horticulture or garden cultivation.

Check Your Progress

Note: a) Space is given below for writing your answer.

b) Compare your answer with the one given at the end of this unit.

3. Classify various types of soils

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7.6 MASS WASTING

We shall now turn our attention to two other processes of denudation namely, erosion and transportation. The materials loosened by various processes of weathering are subjected to further influences which remove them from their former positions and deposit them elsewhere. Large pieces fall to the ground where weathering agents continue to break them up as gravity influence them down slope. Surface water forms gullies and washes loose material into large streams. These materials in transport become themselves tools for further destruction. The chief agents to transportation are gravity, wind, running water and moving ice. But in other regions dynamic agents are least active and effective, the products of weathering may be also on the move. In such areas one of the most active forces at work is the gravity with other factors may produce results of marked effect on landscape. Because this is part of the general wasting to which all lands are subjected, the entire process is called **Mass Wasting.** This may be defined as the down slope movement of weathered rock debris.

Although gravity is the controlling force of mass wasting, other factors play an important part in bringing about the down slope movement of material. Water is one of these factors. When the pores in the materials become filled with water, the cohesion between the particles is destroyed allowing them to slide past one another with relative ease. When clay is wetted, it becomes very sticky, an example of the lubricating effect of the water. Water also adds considerable weight to a mass of the material. The added weight in itself may be enough to cause the materials to slide or flow down slope.

Check Your Progress

Note: a) Space is given below[7] for writing your answer.

b) Compare your answer with the one given at the end of this unit.

4. Define the term Mass Wasting.

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7.7 SUMMARY

External processes or exogenous processes are mainly caused by the geological agents like weathering, groundwater, wind, rivers, glaciers, lakes, seas, oceans etc. Weathering may be defined as the total effect of various sub aerial processes that brings about disintegration and decomposition of the rocks. The disintegration occurs with: physical processes and hence called as physical or mechanical weathering. The decomposition of rocks occurs with chemical processes. The factors effecting mechanical weathering are frost action, temperature, plants and animals, gravity etc.

In the process of frost action, water first enters the cracks, joints, fractures of rocks. Due to fall in temperature, water freezes and exerts pressure on the rocks and it left to their disintegration.

In semi arid regions temperature influences the weathering. In this regions due to high temperature during day time and low temperature in the night time rocks are subjected to alternate heating and cooling. With this the outer layers of the rocks detached and this process is known as exfoliation. Exfoliation results in the formation rounded masses of rocks, and such weathering is called spheroidal weathering. Plants with their root system and burrowing animals are also causing disintegration of rocks. Gravity along the hill slopes removes loose sediments and causes weathering.

Chemical weathering involves complex processes that alter the internal structure of minerals by removing or adding elements. Solution, oxidation, hydration and carbonation are the processes in chemical weathering. Chemical weathering breaks down minerals soluble compounds which can be removed in solution or weaken the rock. Weathering is not uniform all over the world. In each of the climatic regions weathering occurs continually and shows peculiarity. The products of weathering are called soils. Soils are classified as lateritic soils, black cotton soils, podsol and loamy soils. Mass wasting is another feature associated with rock weathering.

7.8 CHECK YOUR PROGRESS-MODEL ANSWERS

1. The physical disintegration and chemical decomposition of rocks exposed to climate is called weathering

2. The process by which concentric curved shells or plates are successively stripped from massive rocks is known as Exfoliation.

3. The important types of soils are the lateritic soils, black soils, podsols and loamy soils.

4. Mass wasting also known as slope movement or mass movement, is the geomorphic process by which soil, sand, regolith, and rock move downslope typically as a mass, largely under the force of gravity.

7.9 MODEL EXAMINATIONS QUESTIONS

I Answer the following questions in 30 lines

1. What is weathering? Describe the agents of weathering
2. Describe the geological work of climate on rocks.
3. What are soils? Explain the types.

II Answer the following questions in 10 lines

1. What is chemical weathering?
2. What are the different types of soils?
3. Explain about Mass wasting.

UNIT-8 RIVERS

Contents

8.0 OBJECTIVES

After studying this unit, you should be able to

- explain geological work of rivers
- describe the geological features of rivers
- define drainage systems
- explain types of streams

8.1 INTRODUCTION

Water enters upon the earth surface mainly as rain, sleet, hail and snow. This process is called precipitation. Some of this water is evaporated, some penetrates or percolates into the ground below to become groundwater and some is retained on the surface for longer or shorter periods and is carried off as streams ultimately to find its way into the seas and oceans. It is established that about 22% of the total precipitation on the land area of the earth is carried off by streams and constitutes the run-off by streams which is the chief degrading agent on the land surface and therefore, the most important factor in the process of denudation. The area which receives the rainfall is called the **catchment area** and it has a direct bearing on the rate at which erosion takes place. The distribution of rainfall is influenced by the wind which carries water vapor from places where it is evaporated to regions where the temperature favors its condensation and precipitation.

Of all the geological agents running water may have the greatest impact on the people. We depend upon rivers for energy, travel, irrigation and their fertile flood plains have fostered human progress since the dawn of civilization. It is the prominent agent of landscape alteration and has shaped much of our physical environment.

The work of the running water begins with the **rain drop**. On smooth slopes the running water or run off takes the form of a thick film of water which moves downhill more or less uniformly as **sheet flow**. On uneven slopes the run off sweeps out and flows into the initial depressions and thus collects into **rills**. These rills then modify the original slopes by enlarging their runways into miniature valleys called **Gullies**. Several gullies join to form streams which later unite to form a **river system**. A **stream** can be defined as body of water carrying rock particles and flowing down a slope along a channel which may be a mighty river like the Ganges or the Godavari. In any given part of its course, a stream is a quantity of water flowing down a slope at a certain average velocity. The slope is measured along the stream and is often referred to as the gradient of the stream. The average velocity is often expressed in meters per second or kms /hour. Every stream possesses a definite amount of energy depending up on its volume and velocity. The energy of a stream is partly utilised by friction and partly by the transport of solid rock materials in suspension.

Streams attempt to maintain balance behavior between all the factors which control their flow. An Import control over stream flow is the **base level**. It is the lowest point to which a stream can erode its channel. There are two general types or general base level exits. Sea level is considered the ultimate base level since it represents the lowest level to which stream erosion could lover the land. Temporary or local base levels include lakes, resistant rock and main streams which act as base levels for their tributaries. All have the capacity to limit a stream at a certain level. Any change will cause a corresponding readjustment of stream activities.

The observation that streams adjust their profile for changes in base level led to the concept of a **graded stream**. A Graded Stream has the correct slope and other channel characteristic necessary to maintain just the velocity required to transport the material supplied to it. On the average a graded stream is not eroding or depositing material but is simply transporting it. Once a stream has reached this state of equilibrium it becomes a self- regulating system in which a change in one characteristic causes an adjustment in the others to counter act the effect.

8.2 GEOLOGICAL WORK OF RIVERS

The geological activities of a river can be divided into three processes i) Erosion ii) Transportation and iii) Deposition

8.2.1 Erosion

The erosion work is accomplished by a number of sub-processes which act in co-operation with each other. Erosion of a stream involves **hydraulic action, abrasion, solution** and removal of material. These activities go on simultaneously in all stream channels. They are described here individually.

Hydraulic Action: It is lifting and moving of loose rock particles by the force inherent in the flow of water. It is the quarrying effect of the impact of water itself thrown against loose debris into cavities and crevasses' of cracks, joints etc. The rock materials is churned up and removed or washed away.

Corrosion or Abrasion: It is the mechanical wear of rock, due to the impact and friction of silt, sand, gravel and boulders carried by the streams on the bed and on the sides of the stream channel, rubbing, scraping, bumping and crushing are involved. This is also called **attrition.** In most of the streams bed material and load decreases the average diameter of their size from head to the mouth of the stream. This results partly from abrasion and partly from gradual sorting out and deposition of coarse particles as gradient and other factors gradually change from point to point along the stream.

The corrosive power of river water varies as the square of the velocity of the stream. If the velocity of the current is doubled, it will hurl twice as many sand grains as before in the same period and it will erode the rock surface four times as fast as it was before the velocity was doubled. If the channel is composed of bed rock most of the erosion is accomplished by the abrasive action of water loaded with sediment, a process analogous to sand blasting. Pebbles caught in eddies serve as cutting tools and bore circular holes into the channel floor which are called **pot holes.**

Solution: It occurs as the water of the stream dissolves matter from the minerals that constitute the bed rock in the channel and the rock particles in transport. Only a small proportion of the matter in solution in stream water gets dissolved by the streams themselves. Most of it is contributed by the groundwater beneath the slopes tributary, to the streams and percolated into the streams.

8.2.2 Transportation

The materials carried by a stream are called its **load.** This load is derived from a number of sources. A large part of it is supplied by weathering and removal of rock from the slopes of its tributaries. Streams transport their loads carried mechanically as sediments or carried in solution as dissolved load. They move the loads a) by pushing and dragging, many of the angular pieces on the floor of the channel, b) by rolling the sub angular and rounded pebbles along the floor, c) by carrying in suspension the finer grains of sand, clay and silt d) by dissolving and carrying in solution the more soluble compounds.

Boulders, pebbles and large rock particles slide or roll along the bed, sand gains are lifted above the bed by eddies and jump to new position of rest. This jumping movement of rock particles in a stream of water or air is often referred to as **saltation.** Sliding, rolling and saltation are transitional into the movement of the suspended particles.

8.2.3 Deposition

Whenever a stream's velocity is reduced, its competence is also lowered. Consequently, some of the suspended particles begin to settle out. Materials deposited in this manner gradually are called **Alluvium.** Although some material settles in the channel temporarily, it tries to reach its final destination, viz. the ocean or sea ultimately.

Many streams rise in flood seasonally because of the distribution of rainfall in time over the streams or the river system. During the floods, the stream is able to transport an increased aggregated load. A common flood time occurrence in many streams is nearly tenfold increase in discharge. Part of the increased load that usually accompanies augmented discharge and velocity in a stream is supplied by its tributaries. Another part of it is picked up by the stream from its own channel. Therefore, much of the geological work is accomplished during regular seasonal floods than during intervals of low water.

Check Your Progress

Note: a) Space is given below for writing your answer.

b) Compare your answer with the one given at the end of this unit.

1. Define the term "base level".

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8.3 GEOLOGICAL FEATURES OF RIVERS

The important geological features of rivers are Waterfalls, Ox-bow lakes, Alluvial fans, Deltas etc

8.3.1 Waterfalls

Some streams particularly in mountain head water areas, have steep slopes and channels consisting of bedrock. Turbulence resulting from steep downstream slope sets up frictional forces capable of moving rock particles of very large dimensions. The stream erodes its bed by hydraulic plucking, the lifting out by turbulent water of blocks bounded by joints and other surface of weakness. Under special conditions like a stream falling over a rock hedge of cliff as at waterfalls, the increased velocity of the falling water sets up strong turbulence at the base of the falls where both hydraulic plucking and abrasion deepen the stream bed quite exceptionally. The cliff is gradually undermined and the waterfalls tend to retreat upstream. In arid regions, narrow valleys often have nearly vertical walls, while in humid regions the effect of mass wasting and slope erosion caused by heavy rainfall produce the typical V-shaped valleys. A narrow V-Shaped valley indicates that the primary work of the stream has been down cutting towards base level. On the other hand streams with broad valley floors have been widened by lateral (side to side) erosion. The most prominent features of a narrow valley are **rapids** and **waterfalls**. Both occur where the stream profile drops rapidly a situation which is usually caused by variation in the erodibility of the bed rock into which the stream channel is cutting. Waterfalls are places where the stream profile makes a vertical drop.

Once a stream has cut its channel closer to base-level it begins to reach a graded condition and downward erosion becomes less dominant. At this point, energy is directed from side to side. Due to this lateral erosion the valley of the stream is widened and ultimately a flat valley floor called **flood plain** is produced.

8.3.2 Oxbow lake

The outstanding and striking features of broad valley are the presence of meanders and point bars. **Meanders** are loop like bends in a stream channel. They occur in very small streams as well as in large rivers like the **Mississippi** and **Ganges** or **Godavari**. Meanders can form in a stream whether or not the stream is carrying a load. A meandering pattern appears to represent a condition of stability or near equilibrium. Though load is not necessary for the development of meanders, many meandering streams carry abundant loads and deposit sediments according to a definite pattern. These sediments are generally laid down on the convex bank of the channel building up crescent shaped bars which are known as point **bars.**

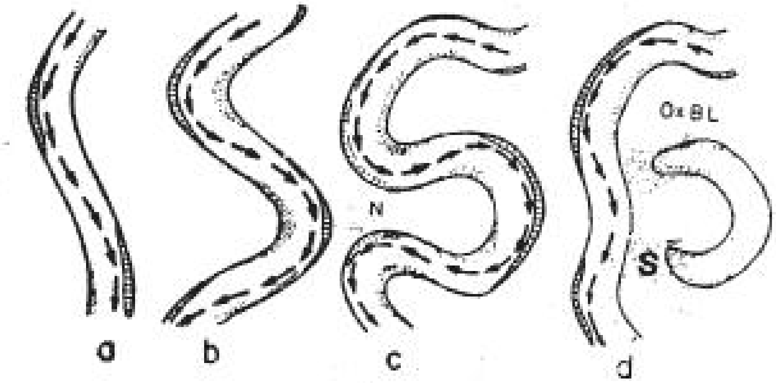

Fig. 8.1 Ox-bow lake

N = Neck Ox BL = Oxbow lake S = Silt of clay

Whether it meanders or not, a stream in a valley floor with alluvium accomplishes much erosion by bank caving. Meanders continually change position by moving sideways and slightly downstream. The sideways movement occurs because the maximum velocity of the stream shifts towards the outside of the bend, causing erosion of the outer bank. At the same time the reduced current inside the meander results in the deposition of coarse sediment, especially gravel sand. Thus by eroding its outer bank and depositing material along its inner bank a stream moves sideways and slightly down stream without changing its channel size. On certain occasions one meander moved down stream faster than another and finally erodes the neck of the land between them. When this happens, the meander is said to be cut-off. This may be defined as the intersection of meander bend by bend next upstream, causing the stream to bypass the loop between the bends. The usual results of such a neck cut off is called an **Ox-bow** lake which is a curved lake occupying a cut off meander loop that becomes blocked with alluvium at both ends.

Check Your Progress

Note: a) Space is given below for writing your answer.

b) Compare your answer with the one given at the end of this unit.

2. What is a meander?

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Another characteristic feature associated with broad valley of a stream is the **flood plain** which is that part of a stream valley indurate during floods. The channels of many meandering streams are bordered by **natural levees.** These are broad low ridges of fine alluvium along both sides of stream channel. Natural levees are built up and are added to only during floods so that the flood is converted essentially into a lake deep enough to submerge the levees.

Not all streams meander placidly on their flood plains. Those that have more load than their channels can handle tend to become logged, causing the stream to break into many interwinding channels. Because such a stream had a braided appearance it is appropriately called a **braided stream.** A braided stream may be defined as one that flows into three or more inter connected channels around islands of alluvium. Such streams are especially found in dry regions or in those regions where streams emerge from of glacial sources.

8.3.3 Alluvial fans

When a stream flows down through a steep highland valley and comes out suddenly on to a wide and nearly level valley floor, the abrupt decrease of slope reduces the stream energy and also its ability to transport the load. The resulting deposit of alluvium is concentrated at the foot of the steep slope in the form of a **fan.** It may be defined as a fan shaped body of alluvium built at the base of a steep slope. The surface of the fan slopes outward through a wide area form an apex at the mouth of the steep valley. On most fans the stream channel pattern is braided. Unless special circumstances preserve it, a fan will be destroyed piece-meal by continued erosion. A fan therefore is likely to be a temporary deposit representing a stream's quick attainment of near equilibrium at a place where equilibrium on the original slope is impossible.

8.3.4 Deltas

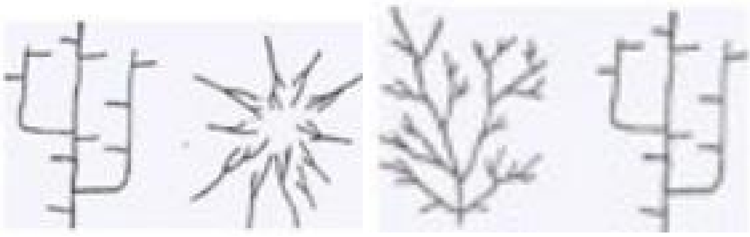
A delta is a body of sediment deposited by a river flowing into standing waters of the sea. The flow of the stream is checked by frictions as the water diffuse into the waters of a lake or sea. The stream loses its energy and deposits its load in the form of a delta. There are several kinds of deltas. A delta defers from a fan in two ways. i) Loss of stream energy is gradual rather than abrupt. The sediments are deposited more slowly and with an orderly arrangement ii*)* The surface level of the lake or sea sets an approximate limit to up building of the deposit, the top of which is flatten than the profile of an alluvial fan.

The particles in the bed load are deposited first in the order of decreasing weight. A layer deposited at any one time is sorted grading from coarse at the mouth of the stream to fine off shore. The deposition of many successive layers creates an embankment that grows outward. This coarse, thick, steeply sloping part of each layer in delta is called **Forest bed**. Traced seaward each bed becomes rapidly thinner and finer, covering the bottom over a wide area.

This gently sloping fine and thin part of each layer in a delta is called **bottom set bed**. The top set beds are deposited above the already deposited forest beds. The stream gradually extends seaward over the growing delta, erodes the top of the forest beds during floods, and at other times deposits part of its bed load in its channel. The channel deposits form the **top set beds,** of the delta which are stream channel sediments that overlie the forest beds. During floods the stream spills out of its channel and forms distributary channels through which the water enters the sea independently multiplying the top set beds. These radiating distributary channels give the delta its somewhat triangular shape resembling the Greek letter from which the deposit derives its name.

8.4 DRAINAGE SYSTEMS

A stream is a small component in a much large river system. Each system consists of a drainage basin, the land area that contributes water to the stream. The drainage basin of one stream is separated from another by an imaginary line called **drainage divide or interfluve**. Such divides range in size from a small ridge separating two small gullies to continental divides which split continents into enormous drainage basins. For example the western ghats in peninsular portion of India, is a large divide that runs North-South, and separates the drainage basins of the East flowing rivers Godavari, Krishna and Kaveri and other rivers that flow West into the Arabian Sea.



a **b** **c**

Fig. 8.2 a = Dendritic Pattern, b = Trellis Pattern c - Radial Pattern

Although divide separate the drainage of two streams, if they are tributaries of the same river, they form both part of the larger drainage system. All drainage systems are made up of interconnected network of streams which form particular patterns depending upon the material over which they flow. In regions where the surface material is relatively uniform, a branching tree like arrangement develops and is referred to as the **dendritic** pattern. Where bands of alternatively resistant and less resistant rocks are exposed at the surface a **Trellis** Pattern forms. Here, the main stream is able to cut across the resistant ridges, while tributaries occupy valleys cut into soft rocks. Where an elevated structure such as a dome or a volcano exists, the drainage takes the forms of **radial** pattern (Fig.8.2)

Check Your Progress

Note: a) Space is given below for writing your answer.

b) Compare your answer with the one given at the end of this unit.

3. What are the different types of drainage patterns?

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8.5 VALLEY DEVELOPMENTS

A major portion of the rain water runs of the surface in thin sheets over smooth sloping land surfaces, on the slightly irregular surfaces running water flows in tiny rills. These rills unit to form gullies and then into streams or river which cut out deep and deeper channels. These streams later join to form a river or a river system.

The deepening of a valley accompanies its growth in length. During each successive down pour the gully acquires more surface water and washed out deeper. Side gullies develop and grow into tributaries. The tributaries also acquire side gullies and the surface water of a large area is directed through the single main channel. It follows that the erosion of the main channel increased for increased volume means increased velocity with its greater eroding power. Streams that flow only during rainy season or during a downpour of rain are called **intermittent streams.** As a valley is deepened the floor of the channel approaches the level of the groundwater table. The pore spaces of rocks are saturated with water, and after the bottom of the valley penetrates this level, its reserve of water sufficiently increased so that it supports the stream even during the dry seasons. Seasons that have their valleys cut to the groundwater table level are known as **permanent streams.**

In regions where the ground slopes are steep the down-cutting by the streams will proceed much more rapidly than, where the slopes are gentle, such that there is approximately a balance between the amount a stream erodes and the amount it aggrades, such a stream is said to be as a **graded stream.** The depth limit of a valley is determined by the level of the body of water into which its river flows. In general the level of the sea or ocean or a lake is approximately the depth limit of the valley. Only the lower end of the valley ever attains this limit, since the stream bed must have a gradient or else the stream will not flow. The lowest possible level of which a stream can erode its drainage basin by mechanical wear is the **base level** of stream erosion.

The widening of a valley or lateral erosion goes on in conjunction with its deepening. In some regions conditions for down cutting are more favourable than for lateral erosion as in the case of Colorado River or certain tributaries of Himalayan rivers whose walls are thousands of meters high and with a few hundred meters wide. Most valleys are much wider than the streams though the character of the rock over which the stream flows may produce local variation in width. A **narrow valley** will be formed where the stream cuts across hard resistant rock.

Valley widening is accomplished in many ways, the most important of which are i) by creeping and slumping ii) by rain wash iii) by the activities of animals and plants iv) by glacial erosion v) by under cutting and vi) by tributaries. The course of a stream is rarely straight and at each curve, it tends to cut more on one bank than on the other. This is due to the fact that the water tends to pile up on the bend and the outside of the curve receives a greater volume of water. In this way the velocity is increased and the bank is undermined and moved back. Thus by this process of meandering the valley is gradually widened.

River development A newly uplifted or elevated land marks the starting point in the history of a drainage system which consists of a main river with its family of tributaries. The topography produced by stream erosion will changes as erosion continues and advances. Changes are determined in part by the altitude of the uplifted areas and the nature of the rocks and the structural features associated with them. By the process of stream erosion, the land is sculptured into a series of hills and valleys.

The first effect of erosion is to roughen the surface of the area by excavating gullies and valleys and by leaving ridges and hills as divides. Ultimately the divides are lowered and the result is a comparatively level surface or a plain. Hence, erosion tends to produce plains. The sequence of forms, essentially hills and valleys through which landmass is thought to evolve from the time it begins to be eroded till it reaches the base level is generally known as the **cycle of erosion.** In the first part of the evolution, the surface is generally irregular and the stream gradients are steep and erosion rapid so that the valley is being actively deepened and makes sharp cuts into the land. Because of the vigorous growth of the valleys a land surface in this state is called **youthful stage** or simply in **youth.** In this stage streams flow rapidly in **V-shaped valleys or canyons or gorges** with steep sides. The slopes are steep because sufficient time has not elapsed for the valleys to be widened. If the area is recently elevated the streams are numerous and have few tributaries. Since they have not had time to erode extensively, they still have rapids and waterfalls along their course. **The Grand Canyon of the Colorado** is a youthful valley.

In the later part of the evolution, the surface has become more stable. As erosion continues the topography changes until the features characteristic of youths are classified into different forms and the sharp straight lines of the landscape give place to valleys with flaring sides and gently rounded upper slopes. The divides are narrowed and the region becomes thoroughly dissected by a complex network of valleys resulting in very rugged topography. The number of tributaries to the main stream is to some extent determined by the amount of rainfall. Tributaries and streams are more numerous in semi-arid regions. As the tributaries are deepened the lakes and swamps are drained or filled and the escarpments that produced waterfalls and rapids are lowered so that the rivers attain gradients which are gentle and the river erodes more slowly. Towards the close of this stage the lower courses of streams become graded. A landscape in this condition is described as **mature**.

In the next stage, the stable mature surface is lowered to the base level with the rate of erosion becoming increasingly slow. A stream with a surface in a late phase of erosion lying close to the base level is believed to have attained **old age.** In this stage, the deep channels are transformed into broad valleys with gentle slopes and low divides. The streams lose their vigour and deposit their load rather than erode. The valleys become shallower owing to deposition and the sluggish streams swings from side to side in long loop plains a land surface thus worn down by streams and mass wasting to very low relief, nearly a plain with very gentle slopes of old age topography is called as **peneplain.** Frequently isolated residual hills of more resistant rock formations rise above the general level of the peneplanation. These features are called **Monadnocks,** named after the Mt. Monmadanock in New Hampshire.

Check Your Progress

Note: a) Space is given below for writing your answer.

b) Compare your answer with the one given at the end of this unit.

4. The end product of river erosion is…

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8.6 RIVER ERROSION

As the drainage basin of a river system passes through the successive stages of normal cycle of erosion, it may be interrupted at any stage by various geological processes.Among the causes of interruption, the following are the most important, namely (1) Glaciation and other interferences by gradational agents (2) Volcanic action and (3) Diastrophism.

A glacier may fill a stream valley with ice or cover its basin with a snow field that protects the surface from weathering and stream erosion. As the glaciers receded enormous amount of glacial debris were deposited irregularly in several forms over the pre-glacial topography with the result that youthful features again were developed and superimposed on large area which had been eroded for beyond the youthful stages.

Due to volcanic action lavas may flow down the slopes of a valley and completely fill its stream channel. In such cases the erosion cycle is interrupted and starts a new cycle of erosion only locally and temporarily or they may cause the streams to start their geological work a new. Changes in the level produced by depression or elevation are generally called diastrophism.

Subsidence or Downing: Depression of the land or rise of sea level hastens the development of old age by bringing the depressed area nearer the base level and by decreasing the material the streams must remove before a featureless plain is produced. When such a rise in sea level occurs along the coast line, the sea occupies the lower ends of the valleys and converts then into **bays** and **estuaries.** The valleys then are **downed.** The tributaries of the main stream after submergence become dismembered and are forced to enter tide water's by separate courses.

Rejuvenation: The most common and significant cause of interruption of the normal cycle of erosion is the rise or uplift of the land in any stage of its erosional history prior to peneplanation, say in maturity or old age. This uplift will result in a notable increase in velocities of the streams. If a peneplainned area is elevated the gradients of the streams is increased and they set to work by cutting gorges and canyons in the bottoms of their old valleys with the result that the region takes new typical characteristics of the youth. Such a region is said to be rejuvenated and the streams infused with new vigour through increased gradients become **rejuvenated** or **revived** streams. They start a new cycle of erosion. The effect is most pronounced on the valley floors of the streams which are graded or nearly so but in time the whole region is distinctly affected by the revival of erosive action.

If the old stream had meandering course before rejuvenation, the revived stream proceeds to cut a youthful valley in the old valley floor without changing course. Such streams which are able to hold their courses notwithstanding the change of level are called **antecedent** i.e., they antedate the diastrophic events that influenced the present topography. Such deeply cut meanders in a rejuvenated region are called **entrenched** or **incised** meanders. The examples of entrenched meanders, the most celebrated **San Juan** River of South eastern Utah in U.S.A. We have the excellent example of **Krishna** River with incised meanders in the rejuvenated region of **Srisailam**. Rejuvenation may be by uniform uplift of an old eroded surface in which case the altitude is increased but the attitude or slope is not very much changed, or the rejuvenation may be by tilting accompanying uplift of an old eroded surface. An excellent example is the south western part of the **Colorado** plateau which is an old peneplainned surface upraised hundreds of meters with a southward slope and deeply trenched by the Colorado River.

Stream terraces are another example of interruption that caused increased erosion. **A Stream terrace** is a bench along the side of a valley, the upper surface of which was formerly the alluvial floor of an old valley. In a stream flowing on a broad valley floor cut from bedrock, sudden increase in the rate of erosion results in the cutting of a new valley within the floor of the older one. The floor of the older valley is left as a pair of stream terraces, which will intern, be entirely destroyed by erosion.

8.7 TYPES OF STREAMS

On the basis of their characteristics and patterns, streams are classified into a number of groups each of which implies something of the origin and history of stream. They are described below.

Consequent Streams: On any newly uplifted land surface the first streams will have their own characters determined by the original slope and natural irregularities of the surface. Such streams are, therefore, **consequent** of the original relief features. They may not only lengthen by head erosion and deepen and widen their valleys but also they may have tributaries developed as a direct consequence of the initial topography. All such streams, whose pattern is determined solely by the direction of the slope of the land or consequent on the initial topography, are called **Consequent streams**. These occur generally in massive and flat-lying rocks and commonly have **dendritic** patterns.

Subsequent Streams: These are streams that occupy a belt of weak rocks and this pattern is determined by the nature of the weak rocks. They originate independently of the original topography and are determined and regulated by erosion proceeding differently upon bed rock according to differences in hardness, structure and resistance to erosion. Since they originate and develop independently and subsequent to the original relief of the land they are appropriately called **Subsequent streams** in contradiction with the streams that are more commonly the tributaries of the main consequent streams. Usually subsequent tributaries develop at nearly right angles to a consequent main stream. This angular pattern of stream courses is known as **trellis patterns**. Streams in which no adjustment of rock structure takes place since they develop in a large area of massive rock formation as granite, never have subsequent tributaries. This is because the adjustment is complete from the beginning. This insequent stream pattern is often tree like and hence designated as **dendritic.**

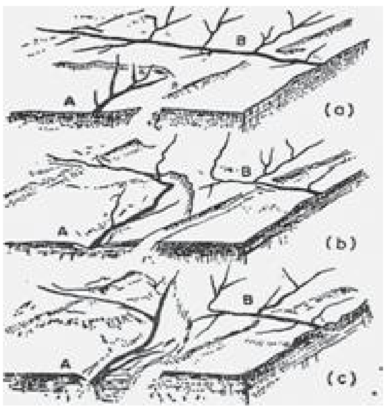
Obsequent Streams: A subsequent stream that develops as a tributary at about right angles to the main consequent stream may, in turn have tributaries which often flow in the opposite direction to the original course of consequent stream and hence called **Obsequent streams**. The Condition favourable for the development of Obsequent streams are to be found in regions of tilted strata where escarpments such as cuestas form the land surface which is worn down by erosion.

Antecedent Streams: These are streams that have maintained their courses across a local uplift of the crust that rose by folding or faulting in their paths. The name antecedent stream arises due to the fact that the stream is antecedent to or older than the uplift.

Super imposed Streams: A Super imposed stream is one that was let down or superposed from overlying strata on to a buried surface underneath them. The stream's path was not controlled in any way by the surface on which it is now flowing. Most superposed streams began as consequents of the surface of the covering rocks.

8.8 RIVER CAPTURE OR PIRICY

During the growth of a drainage system by stream erosion, it often happens that certain streams steal or capture parts (or all) of other streams by a process known as **stream piracy or capture**. When one of two streams flowing in opposite directions from a single divide (a line separating the two drainage systems) has a steeper gradient than the other, it can extend its valley headword shifting the divide against the weaker stream. In this way it reverses the weaker stream little by little and can capture a long tributary by intercutting it at its mouth. This process of stream capture, the diversion of a stream by the headword growth of another stream, is illustrated in Fig 8.3. A stream whose upper water has been captured by another is said to be headed. Through the process of stream capture there is a strong tendency for many streams to leave the harder and more resistant rocks and envelop softer or less resistant rocks. In other words they tend to adjust their courses to the characters and structure of the various rock formations of a region. This is known as **structural adjustment of streams**. Capture of drainage on a still largest scale becomes possible when the major river acquires vigorous subsequent tributaries each working along feebly resistant formations and each pushing back the secondary divide at its head.



Fig, 8.3 Stream Capture or Piracy

Check Your Progress

Note: a) Space is given below for writing your answer.

b) Compare your answer with the one given at the end of this unit.

5. What is River Capture or Piracy?

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8.9 ASSOCIATED LANDSCAPES

The following are the features associated with the geological action of rivers.

Canyons and Gorges: These are special types of valleys and are called gorges like the Godavari gorge at **Papikondalu**, **Gandikota gorge** of the **Pennar River** in Ananthapur district of Andhra Pradesh and they are called **Canyons** like the **grand canyon of Colorado**. The term canyon is generally applied to large gorge. They are among the most spectacular scenic wonders attracting the attention of tourists. The gorges or canyons are due to the rapid down-cutting by streams through resistant rock formations enough to maintain steep slopes or cliffs usually situated in arid regions that are usually more favourable than others because weathering agents cause valley widening. The grand canyon of Colorado River in Arizona State is the greatest of all canyons. Many of the Himalayan rivers like the Sind and Ganges and their tributaries have also cut deep gorges in their courses.

Narrows and Gaps: River narrows and water gaps are only special types of gorges. If a stream cuts across a belt of hard and resistant rocks, the valley carved out by the stream is less wide in hard and resistant rocks than in weaker rocks. Such local contractions of river valleys formed under the conditions just described are called the **narrows** and if they are very short they are called **watergaps**.

A watergap abandoned by its stream becomes **Windgap** because of the tendency for wind to blow with unusual force through them. Windgaps are formed as a result of stream capture or piracy.

River terraces: Along the sides of a river valley there may be benches or nearly that surface with steep fronts facing the river in the valley and too high to be covered by flood waters. Two or more of such bench like terraces may be arranged one above another in a step like form in both sides of the valley. Such benches when formed by the action of the river are called **River Terraces**.

One mode of origin of these river terraces is due to the process of rejuvenation of the rivers which have attained late maturity or early old age. A river on approaching grade in its down-cutting process begins to widen its valley floor notably by meandering back and forth from one side of the valley to the other. A flood-plain of such a river may be covered with more or less stream deposited soil called fluviatile alluvium, uplift of this region at that time causes the river to be revived and make it cut young and steep-sided inner valley (or Gorge) into the old flood plain. The remnants of the old valley with flat bedrock covered with alluvium constitute the rock-terraces.

Rock towers and Pillars: During the process of denudation of the lands by erosion it very commonly happens, that certain local portions are not cut down as fast as other portions of the area and hence are left standing out more prominently above the general level of the country. Among such remnants of erosion are the **Rock towers, Pinnacles or pillars**. These, as their name indicate, consist of harder isolated masses of resistant rocks and are variously shaped.

Ridges: Where erosion proceeds upon a region of highly inclined or folded strata which consists of alternately of hard and soft beds, the hard beds stand out bold in relief in the form of ridges because erosion cuts down the weaker and softer beds much more rapidly developing the valleys in them.

Hog Backs: A Hogback is an erosional ridge with a long, relatively gentle slope on one side and a short and steep slope on the other side. Such a ridge develops where rock formations are moderately tilted with a hard layer lying between two soft layers. The long gentle slope is caused by the removal of the weak rock from the top of the hard layer and the tendency of the weak underlying rock to erode or whether faster than the hard tilted layer just above it.

Cuesta: A Cuesta is a sort of a ridge of resistant rock formation with the slope on one side being very steep forming an escarpment and its dip slope.

Mesas and Buttes: A mesa is a waste land capped by resistant bed and having steep side all around. An excellent example is the Table Mountain behind Cap Town in South Africa produce by long continued wearing back on all sides. A mesa dwindles into an isolated flat - topped hill. Such a hill is called **Butte** a name widely used in America, but in South Africa similar residual landforms which are capped by isolated relics (outliers) of one continuous dolerite sills are called **Kopjes**.

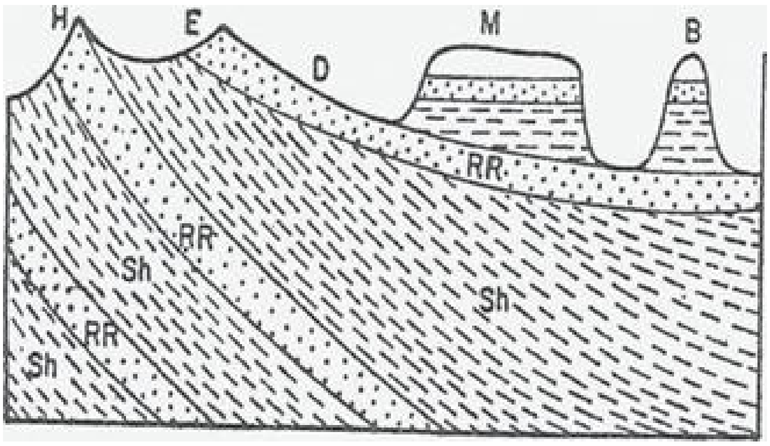

Fig 8.5 Illustrating the relation of various erosional land forms to the structure and dip of the strata Sh-Shale, RR = Resistant Rock, H = Hog back, E = Escarpment,

D = Dipslope, M = Mesa, B = Butte

8.10 SUMMARY

Rivers are acting as geological agents. Water reaches earth with rainfall. After reaching earth some of this water is evaporated, some penetrate or percolates into the earth and the remaining carried as streams and rivers. The work of running water begins with raindrop. On uneven slopes rain drops make rills. These rills then modify and form gullis. Several gullis join to form streams which later unite to form river system. A stream can be defined as a body of water moving down slope. It may carry some rock particles as well. The geological activities of rivers include erosion, transportation and deposition. The process of erosion involves hydraulic action, abrasion, solution and removal of materials. These materials are carried by pushing and rolling on the floor of the river, carried by suspension and solution. Whenever stream velocity reduces the materials are deposited as alluvium.

The geological features of rivers are waterfalls, ox-bow lakes, alluvial fans, deltas etc. Waterfalls are formed along the mountain head water areas where slopes are steep and channels consisting bed rock. Along the broad valleys meanders are common. On certain occasions one meanders moved down stream faster than another and erodes the neck of the land, which results in the formation of ox-bow lakes. When river suddenly enters on to a wide and nearly leveled valley, alluvial fans are formed. Whenever river joins standing waters of seas, deltas are formed. A stream is a small component of a larger river system. Each system consists of drainage system. All drainage systems are made up of interconnected net work of streams. Drainage patterns are grouped as dendritic, trellis and radial patterns. There are three stages in valley development and river system development. The three stages are youth, mature and old age.

On the basis of stream characteristics and patterns, streams are classified as consequent, subsequent, obsequent, antecedent and super imposed streams. River capture or piracy is a process which occurs in youth stage of river. Here, one river reaches the course of another and diverts the course because of greater gradient of first river. The associated landscapes with river system development are the Canyons & Gorges, Narrows & Gaps, River terraces, Rock towers & Pillars, Ridges, Hogbacks, Cuesta, Mesa, Buttes etc.

8.11 CHECK YOUR PROGRESS- MODEL ANSWERS

1. Base level is the level below which a stream cannot erode.
2. The meander is one of the curves of regular freely developing curves, bends, loops turn or windings in the course of a stream. The meander cut off is formed when a stream cuts through a meander neck.
3. The different types of drainage patterns are 1) Dendritic 2) Trellis 3) Radial
4. Peneplain
5. River capture or River piracy is the process that occurs in the youth stage. In this process one river enters into second river and diverts its course.

8.12 MODEL EXAMINATION QUESTIONS

I. Answer the following questions in 30 lines

1. Describe the geological work of rivers.
2. Describe the stages in valley development.
3. Give an account of different drainage patterns.
4. Write briefly about the classification of streams.

II. Answer the following questions in 10 lines

1. What is meant by base level of erosion?
2. What are meanders?
3. How is Ox-bow lakes formed?
4. What is meant by river rejuvenation?

UNIT-9 GROUND WATER

Contents

9.0 OBJECTIVES

After studying this unit, you should be able to

- define groundwater
- describe the vertical distribution of groundwater
- explain the geologic work of groundwater
- describe the uses of groundwater

9.1 INTRODUCTION

The water that is found in pore spaces, cracks and crevices of the unconsolidated or consolidated rocks beneath the ground surface is called subsurface water or underground water or simply **groundwater.** Of the entire world's water, only about 0.6% is found to occupy the voids in the lithosphere. The groundwater is of great importance to mankind since the inhabitants of many regions are entirely dependent upon groundwater as a source for domestic water supply and industrial uses. Groundwater supplies about 15 to 20% of country's freshwater requirements. In addition, it is of great significance as an equalizer of stream flow and as an agent of erosion. The erosional work of groundwater is responsible for the creation of caves and caverns and other related features.

Sources of Groundwater: The chief source of groundwater is the annual rainfall or snowfall or simply the meteoric water from the atmosphere. Of the water that is precipitated nearly half is returned to the atmosphere by evaporation or transpiration. About one fourth of it flows as run off in streams and rivers and is carried into the lakes and seas or oceans. The remaining finds its way into the crustal rocks through pores, cracks, fissures and other openings in bedrock. Some of the factors that favour the descend of water into the earth's crust are humid climate, dense vegetation which interferes with the runoff and a relatively high degree of porosity and permeability and fissuring of the bed rocks.

9.2 DISTRIBUTION

The water that descends into the crustal rocks is known as **groundwater**. Perhaps a large amount of it, returns to the surface through natural seepages and springs, some amount moves to the surface by capillary action in loose rock materials and then evaporates, some amount is drawn up to the leaves by transpiration and eventually evaporated and a considerable amount is removed through wells for domestic consumption and industrial uses while a small amount of water enters into chemical combination with various minerals and rocks to be held there often for ages.

Another source of groundwater is that which occupied the spaces between grains of sand and silt and other materials as the sediments accumulated, on the floors of the lakes or seas ultimately to become sedimentary rocks. Such water trapped in the sediments is called the **connate water** and is commonly found along with oil in many oil fields.

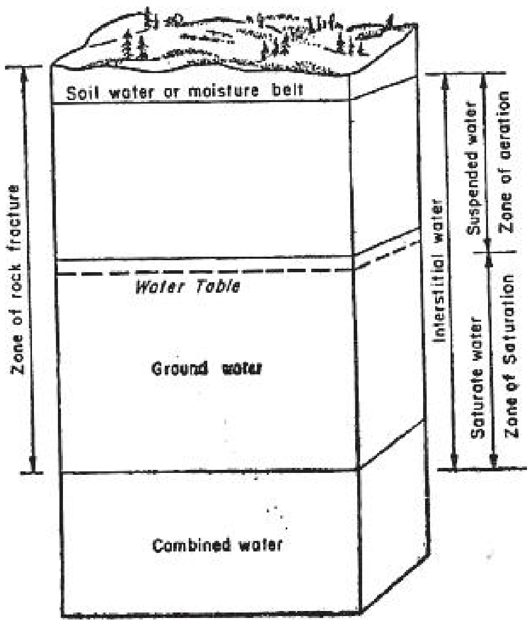

Fig. 9.1 Distribution of Groundwater

Another source of groundwater is that derived from deep-seated magmas. Such **magmatic** or **Juvenile water** is added to the general groundwater wherever large masses of magma thrust below into the crust of the earth. It is probable that water of certain hot springs and geysers are partly of magmatic origin especially in such well known areas as the **yellow stone National Park - USA.** Just beneath the surface there is a **zone of aeration** in which the open spaces in the regolith or bedrock are normally filled mainly with air with little or no water. Next comes the **zone of saturation,** the subsurface zone which all opening are filled with water. The upper surface of this zone of saturation is called the **water table.** The water table is not to be understood as a plane and it is generally undulating. It tends to follow the undulations of the topography of a region but it is more regular. It generally lies at shallow depth in a valley than below a hill top, where it lies deeper below. Ordinarily the water table lies within a few meters of the surface but it may vary sometimes more or less.

Within the zone of aeration there is **Vadose zone** which is a belt of soil moisture from which many plants draw their moisture and from which some moisture is evaporated back to the atmosphere. Between this belt of soil moisture and water table there is an intermediate belt where water is held by molecular attraction and where little movement takes place except during period of rain or melting of snow. A moist fringe is drawn upward a few cms to a few meters above water table by capillary openings and action. Such water is called Capillary water. This rise is called **Capillary Rise.**

WATER TABLE : The Water table is the upper limit of the zone of saturation and is a significant feature of the groundwater system. The level of the water table is important in predicting the behavior of wells, in explaining the changes in the flow of springs and streams and in accounting for fluctuation in the levels of the lakes. Although we cannot directly observe the water table, its position can be mapped and studied in detail in areas where wells are numerous because the water level in wells coincides with the upper boundary of the saturated zone or the water table. Such maps reveal that the water table is rarely level as we might expect a table to be. Instead, its shape is usually a sort of a subdued replica of the surface topography. It reaches its highest elevation beneath hills and then declining in height towards valleys. Where a lake or a swamp is encountered the water table is right at the surface.

A number of factors contribute to the irregular nature of the water table. For example, variations in rainfall and permeability at a place can lead to uneven infiltration and thus to differences in the level of the water table. However, the most important cause is simply that groundwater moves very slowly and at varying rates under different conditions. For instance groundwater that is far from stream valleys at the centre of hills moves much more slowly. The water table on either side of a stream or river usually slopes towards the stream. Contrary to common belief that groundwater supplies are replenished by the streams, the reverse is more often true.

Usually in humid regions, the flow of streams is maintained by steady supplies of groundwater. Such streams are called **Effluent**. However, in arid regions where the water table is far below the surface, this kind of supply is not possible. The local conditions are such that the zone of saturation lies below the river and the streams actually lose water into the earth. Such a river is known as **Influent** stream.

Perched water table: sometimes a body of water in porous or pervious material may be perched or suspended within the Vadose above the main water table. These bodies of water are generally above an irregularly shaped mass of impermeable rock above basin shaped beds of clay.

Check Your Progress

Note: a) Space is given below for writing your answer.

b) Compare your answer with the one given at the end of this unit.

1. What is groundwater?

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9.3 POROSITY AND PERMEABILITY

The **Porosity** of a rock is determined by the percentage of the total volume of pore space available in the total volume of the water bearing rock. Apart from mineral particles, rock contains interstices, pores or voids and since water moves through these openings or interstices, their nature and volume become important in the movement of underground water. Porosity varies with the nature of the material. Weathered or stratified rocks are usually more favourable for containing of water than massive igneous rocks. The range of porosity in earth materials is extremely great.

Sediments are usually quite porous and open spaces may occupy from 10 to 60 percent of the volume. The amount of pore space depends upon the size and shape of the grains as well as packing, degree of sorting etc. Clay, for example, has a high porosity of nearly 50% while in many sands and gravels voids make up only up to 20 percent. Most igneous and metamorphic rocks are composed of tightly interlocking crystals. The amount of open space between the grains may be negligible. Therefore, if these rocks are to have greater porosity, fissures and joints must provide significant proportions of the open space. Porosity alone is not a satisfactory measure of a materials ability or capacity to yield groundwater. Although clay has a high percentage of porosity and can hold water in a large quantity, its pore spaces are so small in size that water is unable to move. Such rocks or materials are called impervious. The rock or sediment may be porous and still do not allow water to move through it.

The **permeability** of a material is the capacity or ability to transmit a fluid. It is a measure of the velocity of percolation and may be said to be the rate at which the rock formation will allow water to flow through it under a given amount of pressure. Groundwater moves, through small openings. Coarse grained sands and gravels without fine grained particles in the spaces between grains are more permeable and allow water to move readily through them.

Although, a rock may possess high porosity, it is not necessarily to be permeable. For example clay has high porosity than sand but since the particles that make up clay are minute flakes, the interstices between them are small and, therefore, water will not pass easily through the clay because fine grained material gets swollen closing the interstices and also because of the molecular attraction. In contrast, water is free to move through sand because the passage ways are relatively large.

9.4 TYPES OF AQUIFERS

A lithological unit that is capable of containing and transmitting water through it is called an **Aquifer** (water-carrier). Bodies of gravel and coarse sand are very good aquifers. Many standstones are good aquifers. Some limestones are also aquifers since due to solution the fractures and bedding planes in limestones are enlarged into open passage ways. Igneous and metamorphic rocks and some shales which have extremely small spaces between their grains should be normally impermeable and therefore not aquifers. But they may be rendered permeable by the presence of cracks, fissures, spaces between layers and other openings that are too large to be controlled by molecular attraction.

On the other hand, impermeable layers composed of materials such as clay that hinder or prevent water movement are called **Aquicludes.** The smaller the pore spaces, the slower the water moves. If the spaces between the particles are very small the films of water clinging to the particles will come into contact or overlap. As a result, the force of molecular attraction which binds the water to the particles extends across the opening and the water is held firmly in place. Clay is an eminent example of such an Aquicludes. **Aquifuge** is a type of formation which neither holds nor transmits water. **Aquitard** is a type of formation that holds water but transmits water with jointing or cracks.

The depth to which the surface water penetrates varies with the character of the rocks in that area. In some places they reach a depth of several thousand meters whereas in other places very little water is collected at more than a few hundred meters.

Check Your Progress

Note: a) Space is given below for writing your answer.

b) Compare your answer with the one given at the end of this unit.

2. What is an aquifer?

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9.5 SPRINGS AND WELLS

A spring is defined as a natural outlet on the ground surface which flows underground water. Groundwater moves down either to the first impervious layer or to the water table. If the groundwater comes out of the ground surface and flow either continually or intermittently, it is called a **spring.**

Springs usually issue upon a hill side or in a valley. An ordinary hill side spring is formed where aquifer formations like gravels and sandstones rest upon impervious strata where the water comes out to the surface along an escarpment, it comes out in the form several small seepage springs.

An aquifer spring issues out on the hill side or in a valley when an aquiferous formation interbedded with impervious strata is exposed on the surface.

The most common device used by man for tapping underground water is the well, an opening dug or drilled into the zone of saturation. Well serves as a reservoir into which groundwater moves and stored from which water can be drawn from the surface. Discharging water from the wells lowers the water level and so creates a cone of depression. Large scale withdrawal of water may cause cone of depression more wide and deep resulting in the lowering of the water table in the vicinity.

Most of the wells are simply dug down in loose rock material to a few meters below the water table. The depth seldom exceeds 15 meters in humid-regions. Wells are bored in loose materials with large augers, rotated by power developing machine to a depth of 100 feet or more. In hard rock formations wells are drilled by rigs using rotary methods. Drilling deep wells for irrigation and industrial purposes is quite helpful and also helps in gaining knowledge of the underground rocks.

Artesian springs and wells: A certain arrangement and disposition of inclined rock formations makes it possible for special pattern of circulation of groundwater. In a series of inclined rock layers which include permeable layer like sandstone and an impermeable layer like shale or clay above and below, groundwater can percolate through the sandstone which is an aquifer. In the shale the water is held immobile. In the area of water intake where the standstone is cut by the surface of the ground, Meteoric waters enter the aquifer and percolate down. Percolation is confined within the aquifer because it is confined in between impervious formations. The aquifer acts like a broad, flat sandfilled conduit holding the groundwater under hydrostatic pressure of the column of water extending up to the water table at its upper end. Wells piercing the root layer and penetrating the aquifer releases water which rises in each well to the level of the water table. Such wells are known **as artesian wells,** which may be defined as wells whose waters rise above the aquifer. The name artesian is derived from the French province of Artois in which near Calais, the first well of this kind in Europe was bored.

In India the well-known Cuddalore sandstones in South Arcot district of Tamilnadu form an excellent artesian system and are very good sources of groundwater supply. Artesian to semi-artesian conditions exist in the Rajahmundry sandstones in east and west Godavari districts of Andhra Pradesh and places such as Sattupally in Telangana state.

Artesian conditions are not confined to wells. They operate also where the confined water has a natural outlet usually through a fissure of fault plane in the rocks. The result is a natural artesian spring. Hot or thermal springs bring warm or hot water to the surface and they are called hot water springs. Usually an excess of 15 to 20°F over mean temperature is regarded as characterizing of a thermal spring. Most of the thermal springs derive their heat from masses of magma that is pushed into the crust nearly to the surface and are now cooling. The water may pass through masses of volcanic rocks of recent geological age which have not yet cooled to the normal temperatures of the earth's crust. Yellow stone National Park in the U.S.A, contains thousands of such hot water springs (many of them boiling) where in recent times successive out pouring of lava covered a wide area. Another source of heat of thermal springs is the special conditions of the groundwater circulation that carry it in to a depth sufficient to warm it by the nominal increase in the earth's crust and then rise to the surface under hydrostatic pressure. It is known that the temperature of the earth's interior rises downward at 1°F for every 50 to 75 feet. Water emerging from depth of a few hundreds of meters would naturally be very warm. Such springs are usually not very hot and they emerge usually along prominent fractures of faults which extend to great depths.

Geysers: Geyser is a special type of thermal spring which intermittently ejects large quantities of hot water with considerable force. The word Geyser comes from the name of a spring of this nature Geyser in Iceland. Geysers are found only in a few of the recent volcanic regions of the world.

Mineral springs: The underground water in its circulation causes the solution of some minerals in it. The amount of mineral matter dissolved depends upon several conditions such as the distance the water travels, the kind of rock traversed, the pressure and temperature and gas contents. Such groundwater with dissolved minerals emerging on the earth's surface is known as mineral springs. They yield hard water which may be hot or cold and contain much calcite, dolomite, gypsum and certain gases like H_2S, CO_2 and other gases. Mineral springs are more or less useful for the medical effect of waters. Such springs have attracted attention of mankind throughout history. Even to this day special medical and therapeutic values are assigned to spring waters. They are often referred to as spas. In the early days of human civilization, they were regarded with superstitions and sometimes temples are built around them as in the case of Mahanandi Temple near Nandyal in Kurnool distrit of Andhra Pradesh.

Many natural geyser and hot spring areas around the world are potential sites for tapping geothermal energy, that is, natural steam used for electric power generation. In Newzeland, Italy, Mexico, Russia and USA underground supplies of superheated steam are now being used to provide power for generating electricity. In U.S.A the first commercial geothermal power plant was built around 1960 at the "Geysers", north of San Fransisco.

9.6 GEOLOGICAL WORK OF GROUNDWATER

The primary erosional work carried by groundwater is that of dissolving soluble rock materials. Soluble rocks, especially limestones, and silica cover several million square kilometers of the earth's surface, and so groundwater carries on it rather unique and important role as an agent of erosion. Although, limestone is highly insoluble in pure water, it is quite easily dissolved by water containing small quantities of Carbonic acid. Most natural water contains this acid because rain water readily dissolves CO_2 from the air and from the decaying plants. Therefore, when groundwater comes into contact with limestone, the carbonic acid reacts with the calcite that composes the limestone and forms calcium bicarbonate which is readily soluble and it is carried away in solution by groundwater.

Caves and Caverns: Among the most spectacular results of the erosion work of groundwater is the creation of limestone caverns and caves. Although most of these are small, some attain spectacular dimensions. In the USA, Carlsbad Caves in South Eastern New Maxico and Mammoth caves of Kentucky are famous examples. One chamber in Carlsbad cavern has an area equivalent to fourteen football fields and enough height to accommodate the USA capital buildings. Most caverns are believed to be created at or below the zone of saturation, near the water table. Here the groundwater follows lines of weakness such as joints and bedding planes. As time passes, the dissolving process slowly creates cavities and gradually enlarges them into caves. The material that is dissolved by the groundwater is carried away and discharged into streams.

The features that arose the curiosity of visitors to these caves are the stone formation that often exhibit quite bizarre patterns and given some caverns, a wonderland appearance. These features are created by the seemingly endless dripping of water from the ceiling of the caves of great spans of time. The calcite that is left behind produces kind of limestone we call **travertine.** These cave deposits are broadly called **Drip-Stones,** an obvious reference to their mode of origin.

Although cavern formation takes place in the zone of saturation the deposition of dripstone is not possible until caverns are above the water table in the zone of aeration. This commonly occurs as nearly by streams cut their valleys deeper causing the water table to drop as the elevation of the river drops. As soon as the cave chamber is filled with air, the stage is set for the decoration phase of caves building to begin.

The various dripstone features found in caverns are collectively called **speleothems,** no two of which appear alike. Perhaps the most familiar speleothems are **Stalactites.** These ices like pendants hang from the ceiling of the cavern and form where the water seeps through the cracks above. When the water reaches the air in the cave, a little amount of evaporation takes place. Thus some of the CO_2 in solution escapes and a residue of calcium carbonate are deposited. Deposition occurs as a ring around the edge of the water drop. As drop after drop follows, each leaves traces of calcite, behind, and a hallow limestone tube is created, and water then, moves through the tube, remains suspended momentarily at the end, contributes a tiny ring of calcite, and falls to the cavern floor. The stalactite just described is appropriately called a soda straw. Often the hollow tube of soda straw becomes plugged or its supply of water increases. In either case, the water is forced to flow, and hence to deposit along the outside of the tube. As deposition continues, the stalactite takes on the more common conical shape.

Speleothems that form on the floor of the cave and reach upward to the ceiling are called **Stalagmites.** The water supplying the calcite for stalagmite growth from the ceiling spreads over the surface. As a result, stalagmites do not have a central tube and are usually more massive in appearance and rounded on their upper ends. When the downward growing, stalactites and upward growing stalagmites join, they form pillar like structures.

Check Your Progress

Note: a) Space is given below for writing your answer.

b) Compare your answer with the one given at the end of this unit.

3. The vertical hanging of CaCO, from roofs of caves is known............................ as the mass formed on the floor of the cave is ....

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In the State of Andhra Pradesh there are several caves in the limestone country of which mention may be made of the Borra Caves near Anantagiri of Visakhapatnam district and Kona Rameswaram near Rayalacheruvu of Anantapur district. In Borra caves stalactites and stalagmites are seen in the process of formation.

Sinkholes: The solution of those rocks is so rapid that caves and cavern usually collapse from the weight of the overlying' strata before erosion can open them to the surface. Such an opening that connects a cave with the surface is called a **Sink hole.** It may be formed by the solvent action of the surface water which finds its way into the cave.

A natural bridge may be formed by the collapse of all but one portion of the roof of a cave. A famous example is natural bridge off Virginia State in the U.S.A. Natural bridges are also formed by other ways. For examples the natural bridge that forms during the process of erosion of a region when a stream perforates the neck of one of this rather deeply in trenched meanders as in the case of Rainbow Bridge. Noah (U.S.A.). One natural bridge can be found on **Tirumala** hills.

Karst topography: Many areas of the world that have been landscaped have been shaped to a large extent by the dissolving power of groundwater. Such areas are known to exhibit Karst-topography. The term is derived from a plateau region located along the north eastern shore of the Adroiatic Sea in the border area between Yugoslavia and Italy where such topography is strikingly developed. Generally arid and semi-arid areas do not develop karst topography. When solution features exist in such regions, they are more likely to be remnants of a time, when more humid conditions prevailed.

Karst areas characteristically exhibit an irregular terrain punctured with many depressions. These depressions are called sinkholes or sinks, about which mention has been made already. In the limestone areas of Kentucky and Southern India there are literally tens of thousands of these depressions varying in depth from a few meters to a maximum of 30 mtrs. Karst regions show a striking lack of surface drainage. Following a rainfall the runoff is generally funneled below ground through caverns until it finally reaches the water table. When small streams do occur at the surface, their paths are usually short.

Deposition by Groundwater: The chief ingredients carried in solution by groundwater are the bicarbonates of calcium, magnesium and iron and colloidal silica. The iron and silica are derived as the water passes through the soils down of the water table. Some of the bicarbonates of calcium are acquired in the soil zone and more may be added as it passes through limestones and dolomites. These materials are available for deposition in the zone of saturation between grains which are cemented firmly together. Calcite, silica and iron compounds are the chief cementing media. The loose sediments are thus cemented to form compact rocks.

Replacement and substitution may also take place during the percolation of groundwater. Replacement is the process by which groundwater dissolves such matter as already present and at the same time deposits from solution an equal volume of a different substance. Such replacement is well exemplified by parts of certain limestone formations in which calcite have been replaced by dolomite or even silica. The change often takes place, particle by particle so that the original structure is perfectly retained. Calcareous fossil shells may thus be transformed to any of the materials mentioned. Petrified wood is a common example. The famous petrified forests of Arizona in USA owe their origin to this process of replacement. Equally best examples of such petrified wood are found near Sattanur in Tamilnadu.

Another kind of groundwater deposition consists of **nodules** and **concretions** common in certain sedimentary rocks. Under certain circumstances chemical precipitation takes place around some nucleus such as a small leaf or animal remain or even a small pebble. Deposition, once started, seems to lead to further precipitation on the same surface and concentric layers of mineral matter are deposited. Rounded irregular bodies called concretions are formed in this manner. Many coal seams contain concretionary masses of iron sulphide in the form of **marcasite.** Other concretions are made up of calcite, gypsum, barytes, quartz and calcium phosphate.

Cavities in rocks may become lined with crystals formed by precipitation from groundwater. Those which are round or egg-shaped are called **geodes.** In semi-arid regions capillary action draws lime bearing waters to the surface where by evaporation a lime rich deposit called **Kankar** is formed. **Flint Nodules** in chalk deposits and **cherts** in limestones are some of the wellknown examples of concretions.

When underground water highly charged with mineral matter reaches the surface in the form of a spring there is a deposition of part or whole of the mineral content it carried. Reduction of pressure, lowering of temperature and escape of CO_2 are among the principal factors which cause deposition by springs. Deposits of calcium carbonate are not uncommonly found around springs of even relatively cool waters. **Travertine** is the general name given to spring deposits of calcium carbonate. Porous mass of calcium carbonate deposited by spring is often referred to as **Calcareous Tuff**. Large hot springs yield extensive deposits in their immediate vicinities, like the great quantities of travertine deposited around mammoth hot springs of Yellow Stone National Park. In the same region from many of the hot springs and geysers, alkaline waters carry silica in solution which is similarly deposited around the basin as siliceous **sinter** or simply **geyserite.**

9.7 USES OF GROUNDWATER

In most of the countries majority of the population depends upon the groundwater for their domestic consumption. For several cities and towns much water is drawn from the groundwater sources either for public supply or for industry. In certain areas electricity is generating from Geysers. Much of the groundwater in rural areas is used up for irrigation. In refreshing contrast to the non-replenishable natural resources like petroleum, coal, iron and manganese, groundwater formally is a renewable natural resource. There is constant recharging of the underground water reservoirs as water seeps in or percolates into the ground from the surface.

Recognizing the need for increased supply of groundwater, government agencies in several countries including our own, have undertaken numerous studies of subsurface geology in certain critical areas like dry and perched tracts far removed from any known perennial source of water like rivers and lakes. The location of a new aquifer or a successful tube well is mostly based upon a detailed examination of the geological conditions, porosity and permeability of rocks, and other features like joints, fissures and other openings. Every state government now has a department of Hydrogeology for the purpose of locating sites for new sources of groundwater.

Check Your Progress

Note: a) Space is given below for writing your answer.

b) Compare your answer with the one given at the end of this unit.

4. Write any two uses of groundwater?

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9.8 SUMMARY

The water that is found in the pore spaces of rocks below the ground surface called groundwater. The ultimate source of groundwater is rainfall. Surface water, infiltration, becomes a part of the groundwater. The groundwater occupies the safe zone; above it is the zone of aeration. The upper surface of the zone of saturation is called as water table. The level of water table is important in predicting the behavior of wells.

A body of permeable sediment or rock through which groundwater moves is called an aquifer. Impermeable layers of rocks or sediment are called Aquicludes. A spring may be the natural outlet on the surface through which groundwater flows. A geyser is a special type of thermal spring which intermittently ejects large quantities of hot water with considerable force.

The primary erosional work carried on by groundwater is that of dissolving soluble rock materials, especially lime stones, .which results in the creation of caverns and caves. Stalactites and stalagmites are the depositional features of groundwater in lime stones. Karst topography is another feature of groundwater. Karst areas exhibit an irregular terrain punctuated with many depressions, which are called sinkholes. The depositional features of groundwater are the geods, kankar, travertine etc. The groundwater is useful for domestic, industrial and agricultural purposes.

9.9 CHECK YOUR PROGRESS-MODEL ANSWERS

1. The water that is found in the pore spaces of rocks below the ground surface is called groundwater.
2. A body of permeable sediment or rock through which groundwater moves freely or stored is an aquifer.
3. Stalactites and stalagmites
4. The uses of groundwater are domestic, industrial and agricultural

9.10 MODEL EXAMINATIONS QUESTIONS

I Answer the following questions in 30 lines

1. Describe the distribution of groundwater.
2. Describe the geological work of groundwater?
3. What is an aquifer? Explain the various types.

II Answer the following questions in 10 lines

1. What are the sources of groundwater?
2. Distinguish between porosity and permeability.
3. What are the uses of groundwater?